The effects of forest gap size on Douglas-fir seedling establishment in the southern interior of British Columbia

Matt Zustovic

Dr. Suzanne Simard, Forest Sciences – UBC Faculty of Forestry (Primary Supervisor)
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abstract. This study focuses on seedling germination and survival of Douglas-fir (Pseudotsuga menziesii var. glauca [Beissn.] Franco) seedlings in an Interior Douglas-fir (IDF) biogeoclimatic zone forest. Plots were established in the centers of naturally occurring forest gaps of varying sizes (large, medium, and small) and Douglas-fir seedlings were planted with or without the ability to associate with ectomycorrhizal (EM) networks. As seedlings cannot make EM associations until one or sometimes two seasons of after germination, this paper does not report data on EM effects, but refers to literature on the influence of EM networks. A three factorial design was used to assess the effect of gap size and mycorrhizal influence with 9 replications on seedling germination and survival. Data was collected on 3 separate days during the 2011 growing season and included germination counts as well as volumetric soil moisture content data using a ML2 theta probe®. Results for germination were not normally distributed therefore rejecting parametric statistics; however, it was detected that large gaps had lower seedling survivability even though results are not significant. Moisture content data showed that soil moisture could have played a role in tree survivorship but more data is necessary.

Keywords: Douglas-fir, seedling survival, interior British Columbia, soil moisture content, ectomycorrhiza.

Introduction

Interior Douglas-fir (Pseudotsuga menziesii var. glauca [Beissn.] Franco) is one of the most economically viable species in the southern-interior of British Columbia representing 73% of volume harvest in the interior and 90% of the planted seedlings (Nigh et al. 2004). This has resulted in large harvesting efforts in recent years. The reestablishment of these disturbed sites is therefore of utmost importance, as natural regeneration in this area has very low survivability of
new recruits, and low productivity (Meidinger and Pojar 1991). This coupled with the fact that climate models predict decreases in mean annual precipitation for the area (Coops et al. 2010, Chen et al. 2011) natural and artificial seed establishment and growth of Douglas-fir must improve.

Seedling survivorship relies on many factors, both abiotic and biotic (Karst et al. 2011). In their study, Karst et al. (2011) found that watering regime was the most influential factor effecting seedling survival and productivity, followed by soil pH levels. Cooler temperatures, high humidity, and cloud cover can all cause a decrease in growth rate in Douglas-fir (Littell and Peterson 2005). Biotic factors such as seed predation, ectomycorrhizal fungi associations, and disease have variable effects on seed survivability but are considered less influential when compared to abiotic factors (Karst et al. 2011).

Forest gaps naturally occur at multiple scales due to disturbance or seedling establishment barriers such as topography (Koide et al. 2011). As anthropogenic disturbance increases, effort must be put into re-establishing these disturbed sites. As water is a limiting factor in this area, ectomycorrhizal networks become increasingly important as their ability to store and redistribute water is more apparent with drought stress (Bingham and Simard 2011, Lehto and Zwiazek 2011).

This study looks at the effects of natural forest gap size on Douglas-fir seedling survivorship. I hypothesise that (1) germination will be higher in small forest gaps, (2) seedling survival will be higher in small forest gaps, and (3) volumetric soil moisture content will be higher in small gaps.
Methods

Study Site

The study took place North of Kamloops BC, East of the North Thompson River (Figure 1). The site is in the Interior Douglas-fir Biogeoclimatic (BEC) zone spanning 50°52.253’N, 120°18.774’W to 50°52.750’N, 120°19.975’W. Site elevation ranges from 350 – 1250 m with a dominantly south-eastern aspect. The IDF has a continental climate where summers are warm and dry, reaching temperatures of 25°C and winters are cool with minimum temperatures reaching -5°C. Average annual precipitation for the IDF ranges from 300 – 750mm (Meiginger and Pojar 1991).

Dominant tree species of the study site include interior Douglas-fir (Pseudotsuga menziesii var. glauca [Beissn.] Franco), lodgepole pine (Pinus contorta Dougl. Ex Loud.) and Rocky mountain juniper (Juniperus scopulorum Sarg.). At lower elevations, ponderosa pine (Pinus ponderosa Dougl. Ex C. Laws) becomes common and trembling aspen (Populus tremuloides) is common in wetter areas. The site gaps were dominated by grasses such as bluebunch wheatgrass (Pseudoroegneria spicata [pursh] A.Love), pinegrass (calamagrostis rubescens Buckley), and cheatgrass (Bromus tectorum L.): an invasive species.

Soils are brunisolic throughout the site and regosolic at peak elevations. There was relatively high clay content in the soil profile as well as large stones and cobbles. The land is currently leased for cattle grazing and has suffered minimal damage from fire and wind throw in recent years.
Figure 1: Study Site located on O’connar Lake Rd. in Kamloops, BC. The white dots represent individual treatments that were established during the summer of 2011 (90).

Plot Establishment

Candidate gaps were scouted and assessed to meet criteria for the study in May 2011. From this pool, 81 gaps were selected. Each gap had its longest and shortest diameter measured and was classified into 3 gap sizes: Small gaps (S), with a minimum diameter between 5 – 10m; medium gaps (M), a minimum diameter between 11 – 20m; and large gaps (L), a diameter greater than 30m.

Seedling establishment took place between May 26 and June 2. In each gap, a 1 x 1m plot in the center of the gap was cleared of all floras. A 30 cm deep hole with a circumference of 20
cm was dug in the center of each plot. Each plot was randomly assigned a treatment type: seedlings with access to mycorrhizal networks, planted in nylon bags with a 35-µm mesh; seedlings with restricted access to mycorrhizal networks, planted in bags with 0.5-µm mesh; and control treatments where seeds were planted in the hole without a mesh bag. Associations with mycorrhizal networks usually take place between the first and second seasons of growth (Teste and Simard 2008). The seedling data discussed in this paper was not affected by mycorrhizal associations at the time of data collection and therefore treatment type will not be analysed as the effects on moisture and nutrient availability due to the nylon bag is minimal (Teste and Simard 2008, Teste et al. 2009).

In order to reduce predation by deer mice and ants, the seedlings were covered with a mesh wire screen. On July 19, the first day of data collection, the mesh was removed. This was to not let the mesh interfere with the seedlings growth. Soil moisture data was collected using the ML2 ThetaProbe®. Readings were taken on August 1 and 19. Three measurements were taken randomly within the 1 x 1 m plot and averaged for volumetric soil moisture content (m³/m³).

For this study a 3 factorial design was used but for the purpose of this paper, we will look only look at gap size and replication (3 x gap size, 9 x replication). ANOVA was used where assumptions for parametric statistics were met. All statistical analysis was performed using minitab® statistical software.
Results

Seedling Survival

Figure 2 below shows the germination and survival rates for Douglas-fir seedlings in small (5 – 10m diameter), medium (11 – 20m diameter), and large gaps (>20m) over the 3 sampling dates within the growing season: July 6th, August 1st, and August 19 of 2011. As seedling germination data was not normally distributed (p < 0.005), parametric statistics could not be used.

![Graph showing germination and survival rates](image)

Figure 2: Germination and survival rates of Douglas-fir seedlings in 62 plots within the O'Connar Lake area in 2011. Each line represents either a large (n = 19), medium (n = 21), or small (n = 22) gap size.

It was observed that Seedling germination in small gaps was lowest on the first collection date as compared to both medium and small gap seedlings; however, seedlings from small gaps continued to germinate during the second collection date while both large and medium gap seedlings showed declines in survivorship. Large gap seedlings showed extreme mortality.
between the first and second collection dates and zero survivorship was detected by August 19. This is very different than the medium and small gaps which showed a final average of approximately one germinant per plot. Medium sized gaps had the highest seedling germination and survivorship throughout the duration of the study.

Soil Moisture Content

Data for average soil moisture content outside of the nylon mesh bag for both August 1st and August 19th had normal distributions (p = 0.549 and p = 0.264) respectively using the Anderson-Darling test. Equal variance was detected (p = 0.625, p = 0.458) using Bartlett’s test allowing the use of a general linear model. The results for both days are shown below in Tables 1 and 2.

Table 1: General linear model for average soil moisture content ($m^3/m^3$) on August 1st of small, medium, and large gaps in the O’Connor Lake study area. (large n = 19, medium n = 21, small n = 22, p = 0.56, $r^2 = 1.86$, DF = 2).

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<th>Adj SS</th>
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<td>0.02</td>
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</tbody>
</table>

S = 0.0214867  R-Sq = 1.86%  R-Sq(adj) = 0.00%

Tables 1 and 2 show that soil moisture is not dependant on gap size and that the differences seen between the gap sizes soil moisture content was not significant (p = 0.56, p = 0.54). This suggests that the variation in Douglas-fir seedling survival was not due to the soil moisture availability of the soil.
Table 2: General linear model for average soil moisture content ($m^3/m^3$) on August 1st of small, medium, and large gaps in the O’Connar Lake study area. (large n = 19, medium n = 21, small n = 22, p = 0.54, $r^2 = 2.05\%$, DF = 2).

<table>
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<tr>
<td>Total</td>
<td>61</td>
<td>0.02</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

$S = 0.0158714 \quad R-Sq = 2.05\% \quad R-Sq(adj) = 0.00\%$

When graphed (Figure 3), it is seen that there was a dramatic loss in soil moisture content from one collection day to the other. The soil moisture content on August 1st is more than twice as high as August 19th.

Figure 3: Average Soil Moisture Content outside of the nylon mesh bag for each Douglas-fir seedling in the O’Connar Lake study area. Data is present for large (n = 19), medium (n = 21), and small (n = 22) gaps for both the August 1st and August 19th collection dates. Error bars indicate standard error.
Discussion

Seedling Germination and Survival

It was observed that seedlings in the small gaps had a lower average germination rate than seedlings in the medium and large gaps. This could be explained by higher levels of shading in the small gaps. Shade can sometimes reduce the amount of solar radiation reaching the seedling and therefore slow down the accumulation of heat sum and delay seedling emergence (Bloomberg 1978). As it was found that heat sum-emergence does not vary largely within seed lot, it is expected that the differences observed were due to environmental factors (Bloomberg 1978). This could explain why germination took longer in the small gaps and why the seedlings in the small gaps were still germinating by the second collection date.

The small gap seedlings were the only group to continue germinating by the second collection date (August 1st). This data could be confounded however, as it is possible that seed mortality increased due to desiccation or predation. Since we did not tally the amount of seeds present on each collection date, more seedlings may have germinated than accounted for in this data.

Both medium and large gap seedlings detected declines in survival by the second collection date. This could be due to lack of shading during the hotter periods and suffering desiccation (Ferrell and Woodard 1966). Interior Douglas-fir show increased drought resistance when compared to coastal varieties but it is unsure whether this is due to drought hardiness or drought avoidance (Marshall 1986). This could also explain why the seedlings of the larger gaps declined so rapidly, as most seedlings had virtually no shading from intense solar radiation.
Desiccation from lack of shade would explain the extremely low survival of the large gap seedlings, but desiccation is due to lack of moisture and as volumetric soil moisture content was not significantly different (figure 2), there may be other variables at play. There are many variables that may have confounded the data for this analysis, the most important being that plot specific conditions are certainly not homogenous throughout the site. This means that small differences in soil structure, nutrient availability and soil pH could have influenced results (Littell and Peterson 2005).

Soil Moisture Content

As the plots were equally spread over the elevation gradient it was expected that soil moisture would be even along the three gap sizes. This is also because the soils of all plots were relatively similar. As water availability is seen as a limiting factor in the area (Karst et al. 2011), it makes seedling associations with mycorrhizal networks that much more important as EM networks can facilitate the uptake of water, especially in drought situations (Bingham and Simard 2011, Lehto and Zwiazek 2011).

EM networks have been shown to increase survivability of Douglas-fir seedlings up to 48% in some areas (Beiler et al. 2009). Nara (2006) found that after disturbance, primary succession can be greatly improved with healthy EM communities. Improving the soil moisture regime is the most important aspect in seedling establishment, EM networks are an extremely important asset in seedling reestablishment (Teste 2010, Koide and Fernandez 2011).

Seed predation

Seed predation by small mammals has been considered a key variable to seedling survival in Southern and central British Columbia. Deer mice (Peromyscus maniculatus) are the
most influential seed predator of dry forests, sometime causing 99% mortality (Huggard and Arsenault 2009, Zolak et al. 2010). Many plots had zero germination and seed predation could be a part of this. During data collection for germination counts there was no tally conducted of how many seeds remained present. This means that it is possible that seeds may have been removed by small rodents or mice.

It is suggested by Reed et al. (2006) that ground cover can effectively reduce seed predation. By surrounding seeds with slash or small sticks it makes it very difficult for the deer mice to detect and forage for seed. Methods like these were implemented but rates of success are unknown due to lack of data.

Other factors

pH was not monitored during this study but pH could play a role in seedling survivability (Karst et al. 2011). As the surrounding forests are primarily coniferous, there was a very thick litter layer of Douglas-fir and pine needles. It is expected that the soils had high acidity which could have effected seedling survival. Future studies of seedling survival should include a complete soil analysis of each plot for posterity and to compare plot specific soil conditions such as soil structure and profiling.

Another large variable to this study was the presence of a black bear (Ursus americanus) and two cubs. Bears are very curious and ripped out many mesh bags and seedling treatments. This resulted in the loss of over 20 treatments during the field season. Slash was used to hide the plots (Reed 2006) but showed no consistency in effectiveness. Effort will have to be made to reduce the losses to bear attacks in order to get complete data.
Understanding natural patterns of regeneration is important to our future practices as forest stewards. Identifying the limitations to growth and establishment allow us strategies to improve reforestation techniques and harvest turnover. It is suggested that forest clear cuts should be made smaller to allow for periodic shading from surrounding trees. It is also strongly suggested to retain hub trees in order to facilitate mycorrhizal associations with seedlings and improve access to limited water and nutrients.

**Literature Cited**


