A Comparison of Stump- versus Regularly Planted Conifer Seedling Growth and Performance

Year-4 Summary

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Prepared for:
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Introduction

A variety of tree planting methods have been employed operationally in British Columbia in recent years to improve upon reforestation success. With the implementation of Ministry of Forests planting standards under the Forest Practises Code in February 1997, much discussion ensued regarding the effectiveness of these artificial regeneration methods on different sites (Krasowski and Elder, 2000). Planting into undisturbed forest floor materials is one such technique that has attracted the attention of silviculture foresters.

With a decline in mechanical site preparation in the province due to rising treatment expenses, greater numbers of machine-free zones on the land base and increased harvesting on steep slopes, interest in forest floor planting has increased (Heineman, 1998). Forest floor planting, or duff planting, encourages planting with at least a portion of the root plug in undisturbed forest floor materials (Heineman, 1998). Little information exists, however, to assist silviculturists with the decision as to when to employ this method. Microsite planting, however, has been appreciated and employed more often following research results that suggest positive growth and performance in certain circumstances (Minore and Weatherly, 1990; Spittlehouse and Stathers, 1990; Fries, 1993; Sutton, 1993; Macadam and Bedford, 1998; Simard at al., 2003).

Riverside Forest Products Ltd. (now Tolko Industries Ltd.) developed a planting methodology called "stump planting" in the 1990s that is a variation of duff planting. The premise of this method is that elevated microsites close to stumps provide enhanced growing conditions for planted conifer stock. Stumps are also obstacles that can help prevent trampling by cattle and offset snow creep or press (Heineman, 1998). Stump-planted seedlings are also duff planted, as forest floor materials are expected to provide greater seedling nutrition.

Although the company observed apparent success with stump planting on a variety of sites, the practise had not been experimentally tested prior to 2000. In that year, a project was established to compare the growth and performance of stump planted trees with those that were regularly planted to operational standards of the day. Lodgepole pine (*Pinus contorta* var. *latifolia*) and interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca*), were planted on a dry Sub-Boreal Spruce (SBS) site, at the University of British Columbia Alex Fraser Research Forest (AFRF) in the interior of British Columbia. This report summarizes results following the fourth growing season.

Materials and Methods

Study Area

The project was established on the Gavin Lake Block of the UBC Alex Fraser Research Forest in opening 93A042-379 (UTM 10 584297 5814761 at 1120 m elevation and

UTM 10 584318 5814715 at 1010 m elevation). The 15.2 hecatare block is located in the SBSdw1 (transitional to ICHmk3) and was clearcut harvested in 1999. A uniform reserve of seven windfirm overstory Douglas-fir trees per hectare was left on site. The block was slashed in spring 2000 and planted in May 2000. The planting stratum is located on a uniform rocky, well drained, south facing slope (03 site series) with similar growing conditions in the stump- and regularly planted areas for each species (Trethewey, 2000). Non-crop vegetation was similar at all plots.

Experimental Design and Treatments

Two plots each for lodgepole pine and Douglas-fir were established with stump planting being the treatment and regular planting being the control (total 4 plots). Plot centres and treatment locations were randomly assigned within a pre-chosen uniform stratum with suitable ecological site conditions for each species. Plot centres were marked with a 1.3 m PVC stake, painted blue at the top. The four circular plots (approx. 15 m radius) were divided into four sectors marked with four, 1 m orange PVC stakes at the plot perimeter at cardinal directions. The outer plot boundaries were flagged in orange. Sample trees were marked with yellow plastic number tags, attached to six-inch wire pigtails inserted into the ground as deeply as possible.

One hundred sample trees of each species per treatment were planted and tagged (total 400). The same seedlots were used in both treatment plots for each species (Fdi 1-0 PSB 412A and Pli 1-0 PSB 412A). The regularly planted trees were planted 13 days after the stump-planted trees due to an unexpected delay in the contract. All sample trees, however, were thawed and cached in the same manner for the same period of time prior to planting and had not broken bud at the time of the post-planting measurement (year 0) (Trethewey, 2000). Planting began at the center stake and progressed in a circular pattern outward until all of the 100 trees were planted. Numbering in each plot began near the plot centre in the NE sector and advanced in a zig-zag manner towards the outside perimeter, then advanced to the SE sector and zig-zagged back towards the centre and so on until all the sample trees were marked.

Stump-planted trees were planted by a contractor experienced with the Riverside standards on May 3, 2000. Using this method, trees are planted only around stumps. The number of trees planted per stump depends upon the number and density of stumps. To allow for maximum use of stump microsites, no minimum intertree distance is specified. Where there are fewer, larger stumps, up to three or four trees can be planted around a single stump. In areas with a high density of stumps, there may only be one seedling planted per stump. Where there are no stumps, seedlings are planted in the best available spots, usually next to logs or any large, stable woody debris or slash. Good quality planting around stumps is the primary goal and planting substrate and spacing are secondary to this (Trethewey, 2000).

As stump planting incorporates duff planting, no site preparation or boot screefing is necessary. The planting hole includes intact forest floor layers (fermentation layer and humus) and it is acceptable for the upper portion of seedling plugs to be placed within it. Duff planting requires pulling the soil back, placing the seedling plug inside and letting the hole "close itself" when the soil falls back (Trethewey, 2000). The soil around the hole may be lightly pressed by hand but no boot tamping or shovel back-cuts are permitted so that the integrity of the forest floor materials is not damaged by the planting process (Heineman, 1998).

Regularly planted trees were planted and supervised to AFRF standards. The trees in the regular plots were planted on May 16 and 17, 2000 at the same time as the rest of the block. Trees were planted at a target density of 1400 stems per hectare, with no special consideration given to stumps. The actual final density for the block was 1350 stems per ha. Some seedlings in the regular plant treatment happened to be planted close to stumps and are growing on microsites similar to the stump-planted seedlings. These trees were planted to different substrate and quality standards, however, and are not considered part of the stump planting treatment. All seedlings within the regularly planted treatment that were within 40 centimetres of a stump were noted. Table 1 compares the two planting treatments.

Table 1: Comparison of planting treatments (Trethewey, 2000)

Feature:	Stump Planting	Regular Planting
Microsite	- stumps only	- variable
Planting Medium	- includes FH layers	- mostly mineral, some H accepted
Screefing	- none	- required
Planting Hole	- looser plant, low disturbance and no compaction	- firmer plant – may require tamping and back cuts
Inter-tree Distance Latitude	- wide tolerance	- lower tolerance

Measurement of Variables

The seedlings were measured for growth and performance at year 0 (May 2000 before budburst) and after the growing season at year 1 (late July 2000 after budset), year 2 (September 2001), and year 4 (August 2003). Tree height (vertical point above germination), length (along stem if bent in such a way as to make the height and length different), and root collar diameter were measured. Tree condition was assessed as good, fair, poor, moribund or dead and was supported by damage code data and comments.

Statistical Analysis

Statistical tests and interpretations of results are based on three assumptions:

1) Trees planted around the same stump are independent of each other. This assumption can be made at early stages of growth when trees are not yet affecting each other and when the variation in microsite conditions around individual stumps is as high as it is between stumps.

2) For each species, the stump and regular-planted plots are located on uniform sites with similar growing conditions.
3) Tree heights, height increments, diameters, and diameter increments are normally distributed.

In years 1, 2 and 4, all statistical tests were carried out at $\alpha = 0.05$. Mean height and mean diameter of the stump-planted treatment were compared with means of normally planted trees to test for significant differences in growth associated with the planting treatments. Because the error variability associated with these responses varied with species, each species was analyzed separately. A one-way ANOVA model was used in Year-0 and Year-1, and a two-tailed t-test for Year-2 and Year-4 (SAS Release 8.02). As only two means at a time were being compared the results from each method are comparable between years. Height to diameter ratios were determined in Year-4 for lodgepole pine and compared using a two-tailed t-test.

Sample trees that were dead, missing, or mechanically damaged by trampling were removed from the sample for growth assessments. These trees were included in the summary of seedling condition, however.

Due to resource limitations at the beginning of the study, the paired plots were not replicated. Therefore inferences from this study are limited to these seedlots and this experimental unit. Within-site and between-site variability cannot be determined without replication in a randomized complete block design using additional blocks with similar ecological conditions.

Results

Trethewey (2000, 2002) summarizes tree growth and performance following the first and second growing seasons. The following summary is for Year-4 results.

Tree Survival and Condition

Figure 1 compares conditions for stump- and regularly planted lodgepole pine and Douglas-fir. Pine survival and condition continued to be better than that of Douglas-fir. 76-90% of the pine ranked as good or fair, while only 59-64% of the Douglas-fir fell into those categories. Within the Douglas-fir plots, the regularly planted Douglas-fir demonstrated better condition and survival than the stump-planted trees, having 64% ranking good or fair versus 59%, and fewer poor, moribund, or dead/missing (36% vs. 41%). The pine plots varied more markedly with 15% more of the stump-planted pine receiving “good” rankings than the regularly planted samples. Lodgepole pine continued to have less mortality as compared to Douglas-fir (3-5% vs. 15-28% respectively). These mortality figures for Douglas-fir have increased from 11-16% after the 2001 growing season (Trethewey 2002) while those for pine have stayed similar. The extreme drought during the summer of 2003 might have contributed to these figures as weather-induced mortality in plantations was reported frequently that year (Day, pers. comm, 2005).

Tree Height Growth

Relative mean height increment over time for both treatments and species is shown in Figure 2. The Douglas-fir treatment and control sample trees show very similar growth while the stump-planted pine has consistently shown greater height increment over the regularly planted control following each growing season. Mean heights for stump-planted pine were statistically greater after the first and second growing seasons. The differences between the Year-4 mean heights for the stump- (97.21 cm) and regularly (87.89 cm) planted pine were also highly statistically significant ($p = 0.006$) (Figure 3). No statistical differences were detected between mean heights for stump- (43.70 cm) and regularly (45.94 cm) planted Douglas-fir (Figure 3).

Figure 1: Year-4 condition of lodgepole pine and Douglas-fir on regularly and stump-planted microsites

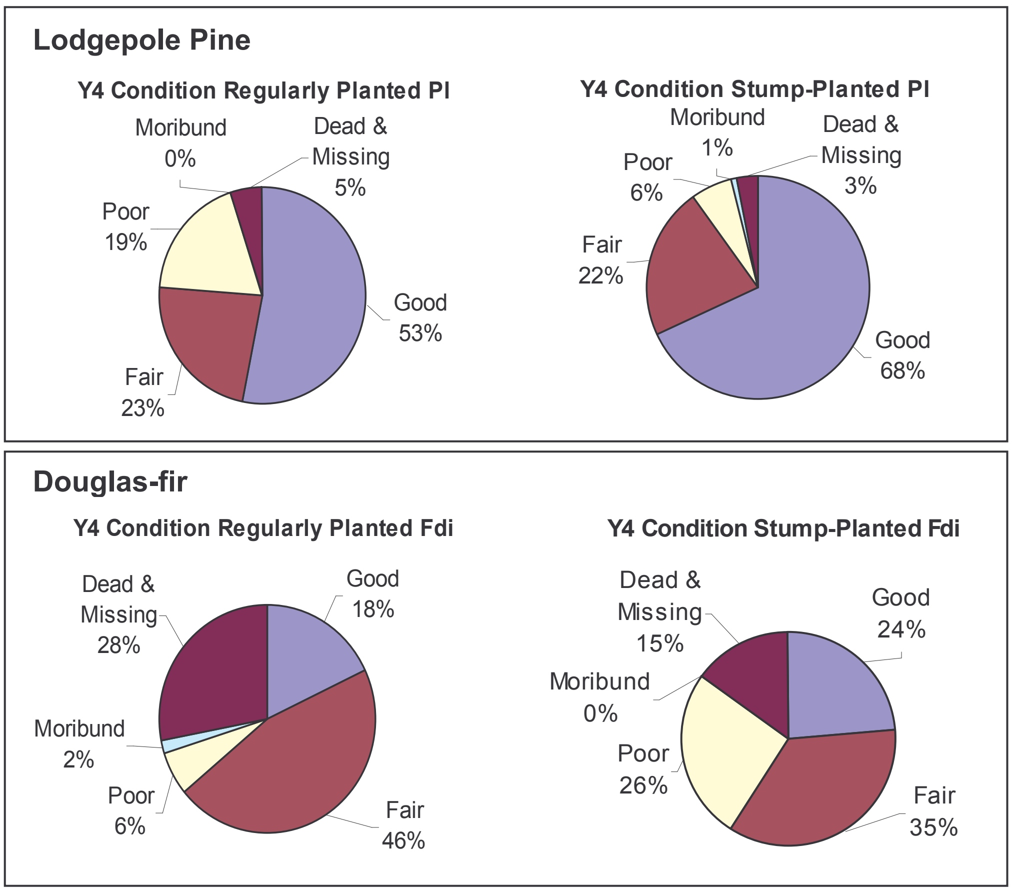
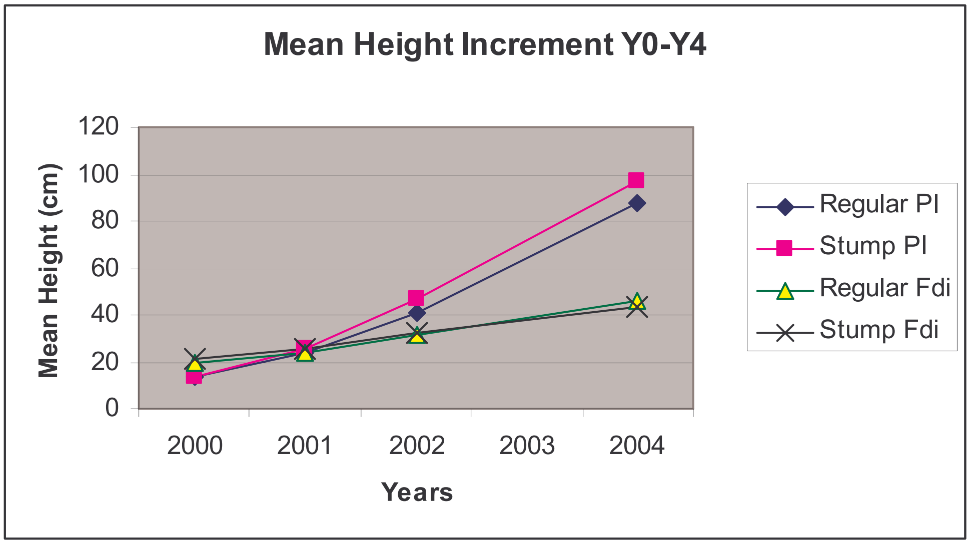
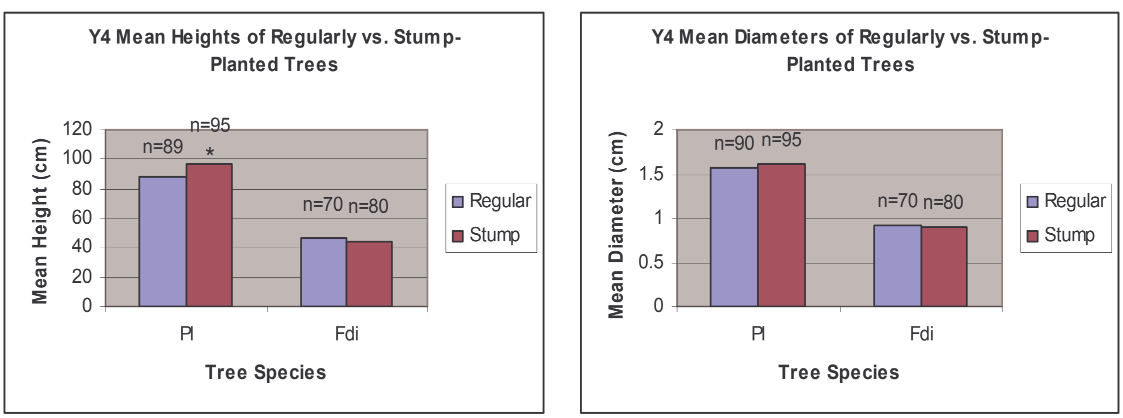


Figure 2: Mean height increment for regularly and stump-planted lodgepole pine and Douglas-fir from Year-0 through Year-4



Tree Diameter Growth
No statistical differences in mean root collar diameter were detected (α = 0.05) (Figure 3). Regularly and stump-planted pine diameters averaged 1.58 cm and 1.61cm respectively while those for the regularly and stump-planted Douglas-fir were 0.92 cm and 0.90 cm. Following Year-2, the mean diameter of the control Douglas-fir was slightly statistically greater than that for the stump-planted samples, however, the difference is no longer significant at Year-4.

Figure 3: Year-4 mean total height and root collar diameter of Douglas-fir and lodgepole pine growing on regularly and stump-planted microsites *(* = significantly greater within species, α = 0.05)*



Height to Diameter Ratio for Lodgepole Pine
The height to diameter ratios for the stump-planted pine were significantly different than those for the regularly planted pine (61.58 vs. 55.66 respectively with p= 0.0002).

Discussion

After the fourth growing season, both the treated and control Douglas-fir continue to demonstrate poorer condition than the lodgpole pine in this experimental unit. The plot pair for Douglas-fir has also experienced similar levels of increased mortality since the previous measurements in 2001. The continued occurance of stem and leader damage, chlorosis and necrosis indicates the the Douglas-fir are stressed and likely being influenced and confounded by factors other than the treatments alone.

After the 2001 growing season, the regulaly planted pine had a higher incidence of stem scars, form defects, and stunted growth than the pine planted next to stumps (Trethewey, 2002). Trethewey (2002) suggested that this might partially be explained by the fact that they were planted in more exposed locations and were thus more susceptible to environmental stresses and trampling by cattle and wildlife. The continued good condition and performance of the stump-planted pine might additionally be influenced positively by the planting microsite of the stump environment.

Stumps provide elevated microsite positions to seedlings planted adjacent to them. Similar to mounds created through site preparation, these naturally raised sites can provide improved growing conditions to seedlings in certain circumstances. Fries (1993) in northern Sweden and Macadam and Sutton (2001) in the moist cold subzone of the Sub-Boreal Spruce Zone (SBSmc) in British Columbia both observed greater height growth among lodgepole pine planted on mounds as compared to untreated sites. Macadam and Bedford (1998) observed the same for hybrid white spruce (*Picea glauca x P. engelmannii*) in the SBSmc.

Elevated microsites provide a warmer microclimate than the adjacent terrain (Stathers and Spittlehouse, 1990; Sutton, 1993; Krasowski and Elder, 2000) and are frequently snow-free and warmer earlier than those in depressions or flats (Brett and Klinka, 1998). Soil temperature is a major factor affecting seedling growth (Stathers and Spittlehouse, 1990). Low soil temperatures reduce photosynthetic rate, water absorption by roots, nutrient uptake, and root and shoot growth in conifers (Lupushinsky and Kaufmann, 1984; Simard *et al*, 2003). Stathers and Spittlehouse (1990) state that optimal growth rates occur in the 15 – 25 degree C range, and that increased soil temperatures in elevated microsites can improve seedling growth, especially early in the growing season (Krasowski and Elder, 2000). As mineral soil heats up faster and holds onto heat longer through the night than organic materials, natural mounds are likely to be less warm than the mineral surface of a mechanically prepared mound (Heineman, 1998).

Raised microsites can also provide some protection from summer frosts in areas prone to cold air ponding in late spring and summer (Sutton, 1993). Frost damage occurs when ice crystals form in seedling tissues at -2 degrees C or less (Christersson and von Fircks, 1988). Seedlings planted above the level where cold air pools are at lower risk of frost injury and have greater exposure to direct sunlight (Krasowski and Elder, 2000). van den Driessche (1987) found that new root growth of Douglas-fir seedlings was proportional to light intensity. Mounding is also thought to initially provide planting environments with less light competition and to reduce shading from competing vegetation (Sutton, 1993; Wagner, 2000).

Stumps are known to store and radiate heat back towards seedlings at night, also contributing to the reduction of frost hazard (Stathers and Spittlehouse, 1990). Additionally they can provide shelter to seedlings from the wind, drought and heat during the growing season and from freeze dessication in the winter and early spring (Shaw *et al*., 1987; Krasowski and Elder, 2000). Heineman (1998) also reports that stumps serve as obstacles to cattle trampling, snow press and snow creep.

The signifcantly increased height increment of the stump-planted pine over the regularly planted pine in this study is consistent with Shaw *et al.* (1987) who also combined forest floor planting next to stumps. Sitka spruce (*Picea sitchensis*) in clearcuts in southeast Alaska were planted into exposed mineral soil, undisturbed duff and undisturbed duff next to stumps. As a percentage of their initial height, the stump-planted trees showed a mean height increase after 3 growing seasons of 121% as compared to duff only (99%) and mineral soil (89%). Stump-planted spruce were planted on the lee-side of stumps to protect them from prevailing winds. Survival was also thought to be better among the seedlings planted into forest floor materials than mineral soil.

The height to diameter ratios for the stump-planted pine were also significantly higher than those for the regularly planted pine A higher ratio often suggests that trees are putting on height in order to get more light (Waterhouse, pers. comm., 2005). As seedling heights were similar to stump heights at planting, shading might have affected growth in the first one or two growing seasons. Since then, tree height has generally exceeded stump height and height increment has been steady, suggesting that shading by stumps is likely no longer affecting growth. Planting aspect in relation to stump location was not tracked in this study so direct correlations cannot be determined. Brush competition, however, has been fairly high on this site (Koot, pers. obs.), but is similar across treatments.

Forest floor materials are nutrient rich and are associated with increased numbers of ectomycorrhizal fungi, as well as microorganisms that convert nutrients into forms available for plant uptake (Harvey *et al*.,1981; Potts, 1985; Heineman, 1998; Simard *et al*.,2003). Having low bulk density, they are well aerated and provide a good medium for root growth (Heineman, 1998). Kimmins and Hawkes (1978) found the forest floor was the major source of several macronutrients for vegetation on a site near Prince George. Simard *et al*.(2003) determined that mechanical treatments that scalped the forest floor significantly reduced soil N and C concentrations, and reported that N is considered the most limiting nutrient to the growth of trees in interior British Columbia (Hope, 1991). While Sidle and Shaw (1987) did not find that foliar concentrations of N and C to be significantly different among Sitka spruce seedlings grown on undisturbed forest floor materials and exposed mineral soil, they did detect increased amounts of foliar P, Mn and Zn in the duff-planted trees.

Mycorrhyzae are known to augment seedling ability to absorb nutrients, particularly P, and water from the soil (Heineman, 1998). Colonization of the roots of seedings is enhanced when they are planted into undisturbed forest floor materials (Sidle and Shaw, 1987; Heineman, 1998). The gentle duff planting technique employed in this study might have enabled efficient mycorrhzal colonation of the roots of the stump-planted pine while at the same time maintaining a source for nutrients.

Forest floor materials, however, generally tend to have less water storage capacity than most mineral soils (Heineman, 1998). The F-horizon has large pores between particles that can contain much moisture in saturated conditions, but dry out quickly. The H-horizon has smaller pore size so drains less rapidly than the F-layer, but more rapidly than mineral soil (Potts, 1985; Heineman, 1998). As survival and early growth of planted seedlings is largely affected by the availability of water, Krasowski and Elder (2000) recommend forest floor planting in moderately warm sites without soil drainage or drought problems. This study location was on a well drained, south-facing slope that can become dry later in the growing season. In addition, 2003 was also a drought year. The lower drought tolerance of Douglas-fir than lodgepole pine (Klinka *et al.*, 2000) might have contributed to the poorer condition and survival of those samples in this study.

Conclusions

Lodgepole pine planted adjacent to stumps and into forest floor materials is demonstrating continued increased height growth over regularly planted pine on this site at the UBC Alex Fraser Research Forest. There is support in the literature for the concepts that elevated microsites and undisturbed forest floor materials provide suitable or enhanced growing conditions for conifer growth in certain circumstances. It is unknown, however, whether this improved height increment and survival will be sustained to have effects on yield or age of rotation. Height to diameter ratios should continue to be monitored to determine whether or not ratios even out in time as trees exceed brush height.

The lack of significant differences between the mean height and root collar diameter of stump- and regularly planted Douglas-fir suggests that stump planting has had a neutral effect on Douglas-fir growth at this site. Monitoring of soil moisture content and growing-season frost occurrances would assist with condition alalysis for this species. The relatively low cost of planting using the stump planting method warrants further experimentation of this technique in additional replicate blocks to this study in order to make additional observations and provide greater statistical power to the results.

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