# The Influence of Containerized Stock Type on the Growth and Survival of Douglas-fir Seedlings

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## Abstract

Selecting an appropriate stock type is an important reforestation decision affecting the success and cost of reforestation projects. This study was designed to quantify the effect of three containerized stock types on Douglas-fir seedling survival and growth at two sites in the Central Coastal Range during the initial 8 years of establishment. The stock types tested included styro-8 (S-8), styro-15 (S-15), and styro-60 (S-60). Initial size differences at the time of planting disappeared after 8 years of growth such that tree sizes were similar across stock types. The mortality rate of the S-60 stock type was 15 percent greater than the S-8 and S-15 stock types at both sites. Site conditions affected the growth of seedlings, and, after eight seasons, the more mesic conditions on one of the sites enabled trees to be, on average, 0.6 m taller, with diameters at breast height 0.8 cm larger compared with those growing on the drier site.

## Introduction

The survival and growth of planted conifer seedlings is dependent on several factors, including site quality, weather conditions during the establishment period, silvicultural prescriptions (e.g., weed control), and the stock type of the seedlings being planted. Of these factors, stock type selection is one of the first decisions a forest manager can make that will impact establishment efforts.

The Target Plant Concept offers a flexible framework for forest and nursery managers to integrate and improve the link between nursery cultural practices and seedling survival and growth on the outplanting site (Dumroese et al. 2016). One of the pillars of the Target Plant Concept is the idea of "fitness for purpose," which defines seedling quality by outplanting performance rather than nursery performance. Fitness for purpose requires managers to have accurate information on how different stock types produced in the nursery perform under specific field conditions. This information is particularly important considering that seedlings of different stock types also represent different financial investments.

Several studies have examined the impact of stock type selection on Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) growth, however many of these studies are relatively short term, and results are often conflicting. Van den Driessche (1992) tested the survival and growth of six different Douglas-fir stock types during a 6-year period on a site in south central Vancouver Island. Results demonstrated that smaller seedlings had greater mean relative growth rates compared with larger seedlings. Due to this greater growth rate, differences in the average stem volume of the stock types were no longer observed after six growing seasons despite large initial size differences.

In contrast to van den Driessche (1992), Rose et al. (1997) and Haase et al. (2006) reported that larger planted Douglas-fir seedlings outperformed smaller seedlings. Growing 2-year-old bareroot seedlings operationally and separating the seedlings into small, medium, and large size classes based on root volume produced the different seedling size classes in Rose et al. (1997). This methodology, therefore, did not directly test seedlings of different stock types but rather seedlings of different root volume within a single stock type. Haase et al. (2006) found that seedlings grown in large containers (styro-20) were bigger than seedlings grown in small- or medium-sized containers (styro-8 and styro-15) after 3 years. Seedling growth rates, however, did not differ among the stock types after three seasons of growth. The limited duration of this study may have been too short to detect long-term differences in the growth of different stock types. These contrasting results make it difficult to determine general trends of stock type impacts on Douglas-fir seedling outplanting performance.

To expand the information about long-term responses of Douglas-fir stock types, the Vegetation Management Research Cooperative at Oregon State University installed two field trials in 2009 to compare the long-term growth and survival of Douglas-fir seedlings grown in three containerized stock types. The specific objectives of this study were to (1) quantify the influence of container size on initial seedling morphology, (2) compare seedling growth and survival among the three stock types, and (3) compare performance of seedlings from different stock types on sites with varying climatic and soil conditions. This report will provide a summary of the results through the eighth growing season.

## Methods

Two sites were selected for this study that represent subtle variations in climate and soils common to the Coast Range near Summit, OR. The first site, known as Blackies Corral (BC), is more mesic and is in the central Coast Range. The Hard Rock (HR) site is 16 km (10 mi) east of the BC site on the fringe of the Willamette Valley and is more xeric. BC has soils defined as an Apt-McDuff complex, which is a well-drained, silty-clay loam with an available water storage of 174 mm (6.9 in) in the top 1 m (3.3 ft) of soil (O'Geen et al. 2017). The annual precipitation of this site is 1,869 mm (73.6 in), with an average summertime (June, July, August) precipitation of 107 mm (4.2 in) (Wang et al. 2012). The HR site has soils defined as a Bellpine-Jory complex, which is a well-drained, silty-clay loam with an available water storage of 153 mm (6.0 in) in the top 1 m (3.3 ft) of soil (O'Geen et al. 2017). The annual precipitation of this site is 1,678 mm (66.1 in), with an average summertime (June, July, August) precipitation of 78 mm (3.1 in) (Wang et al. 2012).

A randomized complete design was used for the study that employed 4 replications of the 3 stock types, creating 12 experimental units on each site. Three containerized styroblock™ stock types (Beaver Plastics, Ltd., Alberta, Canada) were included in the study: styro-8 (S-8), styro-15 (S-15), and styro-60 (S-60) with cavity volumes of 130, 250, and 1,000 ml, respectively (figure 1; table 1). Transplanting 1-year-old S-8 seedling for a second season of growth in styro-60 containers produced the S-60 stock type (figure 2). As a result, the S-60 seedlings were 2 years old at the time of planting, whereas the S-8 and S-15 seedlings were 1 year old. All seedlings were grown at the Washington Department of Natural Resources Webster Forest Nursery using a low-elevation improved seed source. The production of S-60 seedlings occurs on a limited basis in forest nurseries, and operational costs for this stock type were five times greater than the cost of growing S-8 seedlings.

**Figure 1.** Seedlings for the study were grown in styro-8 (left), styro-15 (middle), and styro-60 (right) containers. The styro-8 and styro-15 seedlings are 1 year old and the styro-60 seedling is 2 years old. For reference, a 1 m ruler is shown on the right. (Photo by Eric Dinger, 2009)

**Table 1.** Dimensions of cavities in the styro-8, styro-15, and styro-60 containers used to produce the seedlings for this study.

| Container type | Cavity top diameter | | Cavity depth | | Cavity volume | |
|---|---|---|---|---|---|---|
| | (in) | (cm) | (in) | (cm) | (in) | (cm) |
| Styro-8 | 1.5 | 3.8 | 6 | 15.2 | 7.9 | 130 |
| Styro-15 | 2 | 5.1 | 6 | 15.2 | 15.3 | 250 |
| Styro-60 | 4 | 10.2 | 6 | 15.2 | 61 | 1000 |

**Figure 2.** Styro-60 Douglas-fir seedlings growing in the nursery. Each block contains 15 cavities with a volume of 1,000 ml. (Photo by Eric Dinger, 2008)

Seedlings were planted at both sites in February 2009 at a spacing of 3 by 3 m (10 by 10 ft). Treatment plots were 18 by 18 m (60 by 60 ft) and consisted of 36 measurement trees planted on a grid. All seedlings were protected from ungulate browse with vexar tubing. Chemical vegetation control treatments consisted of a fall site preparation broadcast herbicide application prior to seedling planting (tank mix of 9.5 L/ha [4 qts/ac] glyphosate, 0.3 L/ha [4 oz/ac] Oust Extra, and 0.3 L/ha [4 oz/ac] Induce [surfactant]) and a spring release broadcast herbicide application during the first growing season (tank-mix of atrazine at 9.5 L/ha [4 qts/ac] and clopyralid [Transline®] at 0.6 L/ha [8 oz/ac] used at BC; atrazine at 9.5 L/ha [4 qts/ac] and 2-4D [Hardball®] at 1.8 L/ha [24 oz/ac] used at HR).

Measurements of seedling height, ground-line diameter and, when achieved, diameter at breast height (DBH; 1.4 m [4.5 ft]) were taken during the fall of years 1, 2, 3, 4, 5, and 8 when the trees were not actively growing. Additionally, vegetation assessments were conducted during July of growing seasons 1, 2, 3, 4, and 5 on three 1-m (3.3-ft) radius subplots per experimental unit. Vegetation surveys included visual estimates of competing plant cover percentage by species. Each species was assigned one of the following growth habits: forb, fern, graminoid, shrub, vine/shrub, or tree. The vine/shrub growth habit included all Rubus species. Total cover was calculated as the summed cover of all species within a subplot and therefore could exceed 100 percent.

A subset of 40 randomly selected seedlings per stock type were collected at the time of planting and brought to laboratory facilities at Oregon State University for morphologic measurements, including initial seedling height, root-collar diameter (RCD), shoot volume, and root volume. Volume measurements were made using the water displacement method (Harrington et al. 1994).

Analysis of variance, or ANOVA, was used to test for stock type effects on Douglas-fir growth and survival and to compare vegetation community dynamics between sites. Analysis of covariance was used to test the effects of stock type on Douglas-fir growth using initial seedling size as the covariate. All statistical analyses were performed using SAS version 9.4 (SAS Institute, Inc., Cary, NC).

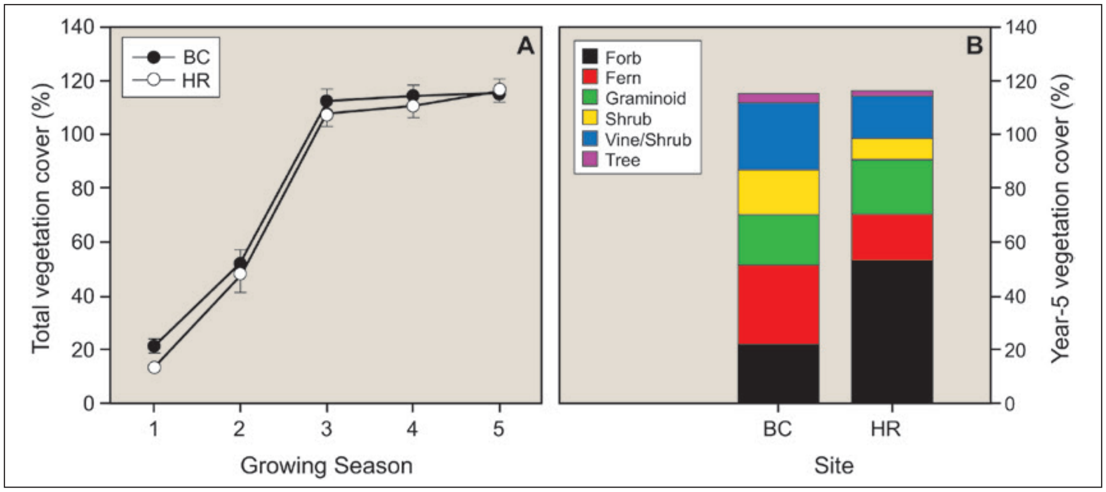


**Figure 3.** (a) Development of total summed competing vegetation cover and (b) mean competing vegetation cover by lifeform during the fifth growing season at the Blackies Corral (BC) and Hard Rock (HR) sites. Standard errors were calculated by stock type over replication.

**Table 2.** Initial seedling height (HT), root-collar-diameter (RCD), height to diameter ratio (H:D), shoot volume, root volume, and shoot-to-root volume ratio (Shoot:Root) of styro-8 (S-8), styro-15 (S-15), and styro-60 (S-60) seedlings. Morphologic measurements that share a letter within a column are not significantly different.

| Stock | HT (cm) | RCD (mm) | H:D | Shoot volume ($cm^3$) | Root volume ($cm^3$) | Shoot:Root |
|---|---|---|---|---|---|---|
| S-8 | 27.8 a | 3.5 a | 80.3 a | 12.3 a | 8.3 a | 1.6 b |
| S-15 | 33.5 b | 4.6 b | 76.3 a | 22.9 b | 12.0 a | 2.0 c |
| S-60 | 57.6 c | 7.5 c | 77.1 a | 51.1 c | 48.1 b | 1.2 a |

## Results

Average competing vegetation cover did not differ between sites and had grown to more than 100 percent by the third growing season (figure 3). There were, however, differences in the composition of the vegetation community. By the fifth growing season, the BC site had significantly higher fern, shrub, and blackberry (vine/shrub) cover when compared with the HR site ($P < 0.047$). The HR site, on the other hand, had 31 percent greater forb cover when compared with the BC site ($P < 0.001$; figure 3).

Initial morphology differed significantly among stock types. The S-60 seedlings had the largest height, RCD, and shoot volume followed by the S-15 and S-8 seedlings (table 2). The root volume of the S-8 seedlings did not differ from the S-15 seedlings; however, the S-60 stock type had significantly larger root volume than the other stock types. No differences were evident in the height-to-diameter ratio among stock types.

Height did not differ significantly ($P > 0.138$) among stock types at either site by the third growing season (figure 4). In addition, no differences were observed in the average DBH among stock types at the BC site during the third growing season ($P = 0.213$) and in subsequent years (table 3). At the HR site, the average DBH of the S-60s was larger than the S-8s and S-15s during the third and fourth growing seasons ($P < 0.03$), but by the fifth growing season, differences no longer existed ($P = 0.219$). Covariance analysis indicated that initial seedling stem volume did not significantly affect tree height ($P > 0.531$) or DBH ($P > 0.627$) at year 8 at either site. Tree growth varied by site, and after eight growing seasons, trees at the BC site were 0.6 m (2 ft) taller and had DBHs averaging 0.8 cm (0.3 in) larger than trees at the HR site. No significant site by stock type interactions for mean height ($P = 0.101$) or mean DBH ($P = 0.128$) were present.

Mortality was highest during the first 2 years of stand establishment, creating significant differences among stock types in the number of surviving trees (figure 4). At both sites, the S-60 seedling survival averaged 80 percent and was significantly lower than the survival of the S-8 and S-15 stock types. The only exception was at the end of year 8 when survival of the S-15 and S-60 stock types did not statistically differ at the HR site despite S-15 averaging 163 more trees per hectare (74 trees per acre) than S-60 (figure 4). Additionally, seedling survival differed significantly by site ($P = 0.055$), with BC averaging 6 percent higher survival than HR. Survival was not significantly affected by an interaction between site and stock type ($P=0.261$).

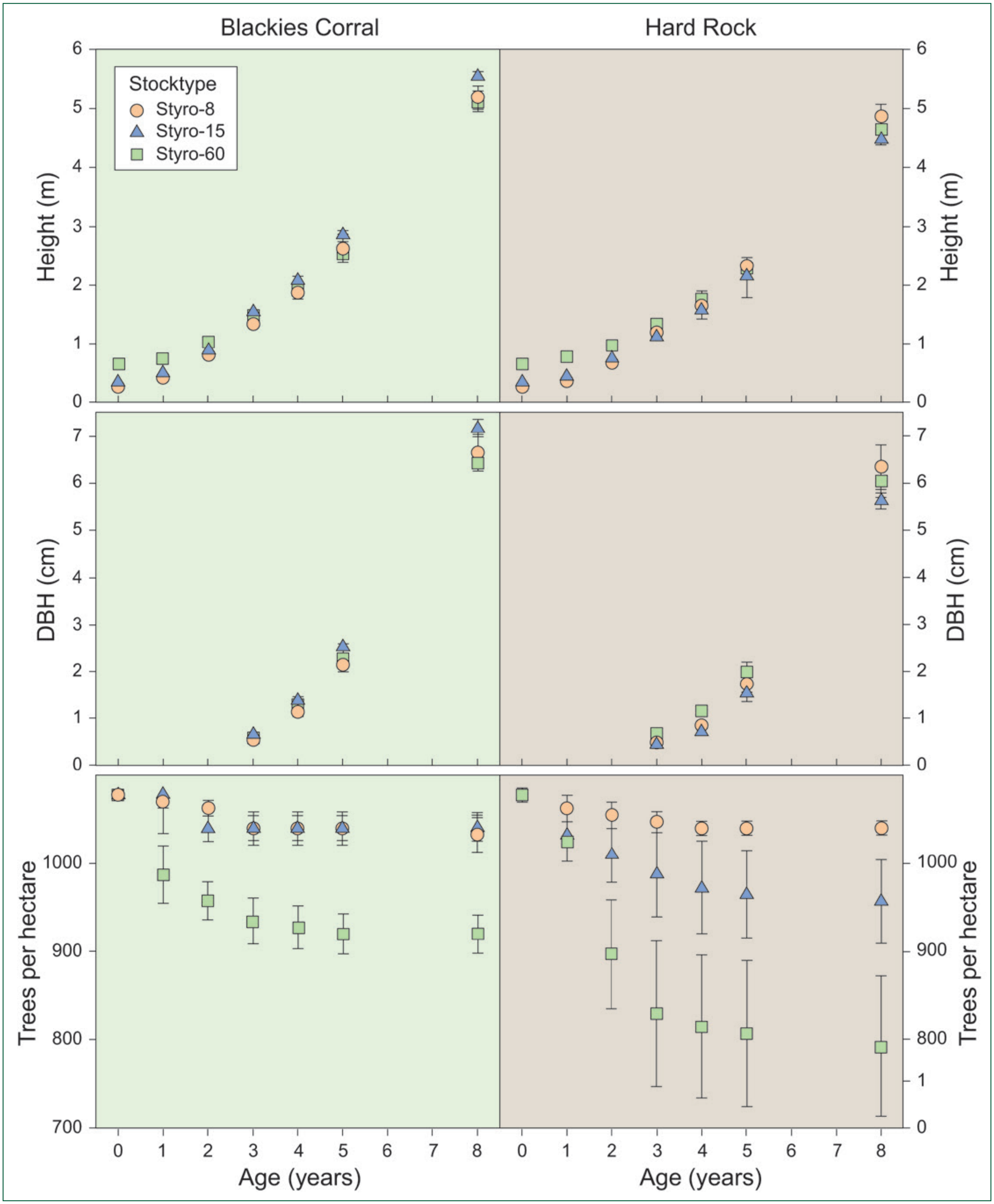


**Figure 4.** Time series of mean height, diameter at breast height (DBH), and trees per hectare for styro-8 (S-8), styro-15 (S-15), and styro-60 (S-60) Douglas-fir stock types growing at the Blackies Corral (left panel) and Hard Rock (right panel) sites. Standard errors were calculated by stock type over replication.

**Table 3.** Mean height, diameter at breast height (DBH, cm), and survival (trees hectare$^{-1}$ [TPH]) of styro-8 (S-8), styro-15 (S-15), and styro-60 (S-60) Douglas-fir seedlings 8 years after planting at the Blackies Corral and Hard Rock sites. Variables that share a letter within a column are not significantly different.

| Stock | Blackies Corral | | | Hard Rock | | |
|---|---|---|---|---|---|---|
| | Height (m) | DBH (cm) | TPH (Trees hectare$^{-1}$) | Height (m) | DBH (cm) | TPH (Trees hectare$^{-1}$) |
| S-8 | 5.2 a | 6.7 a | 1033 a | 4.9 a | 6.3 a | 1040 a |
| S-15 | 5.6 a | 7.2 a | 1040 a | 4.5 a | 5.6 a | 956 ab |
| S-60 | 5.1 a | 6.5 a | 919 b | 4.6 a | 6.1 a | 793 b |

## Discussion

The results of this study suggest that seedling stock type does not have a long-term effect on Douglas-fir tree size. The convergence of tree sizes over time can be observed in the height data shown in figure 4 and is similar to the pattern reported by van den Driessche (1992) for different stock types of Douglas-fir growing in Washington State. This result contradicts the findings of other studies that have reported better outplanting performance of larger stock types than smaller stock types for several conifer species throughout the world, such as longleaf pine (*Pinus palustris* Mill.) in the Southeastern United States (Haywood et al. 2012), Norway spruce (*Picea abies* (L.) H. Karst.) and Scots pine (*Pinus sylvestris* L.) in Sweden (Johansson et al. 2015), and western white pine (*Pinus monticola* Douglas ex D. Don) in Idaho (Regan et al. 2015).

The contrasting results of this study and conifer stock type trials in other parts of the world is likely due to differences in the species tested, silvicultural treatments applied, duration of measurement, and study site soil and climate conditions. Tuttle et al. (1987) found that the survival and growth of loblolly pine (*Pinus taeda* L.) seedlings were negatively correlated with initial seedling height on adverse (droughty) sites, while the opposite was true for nonadverse sites. Similarly, Pinto et al. (2011) found that smaller seedlings had higher growth rates on a xeric site that did not receive a site preparation herbicide treatment, although the same was not true for a mesic site that received a site preparation herbicide treatment. The results of these studies demonstrate that the performance of different stock types can be site specific, and that smaller seedlings may have better early performance on harsher sites. Both of these studies, however, analyzed data after two growing seasons, which may not be sufficient to determine long-term trends. In the current study, the smaller stock types had faster early growth, and initial size differences disappeared after 3 to 5 years. After this point, however, the growth of all stock types was similar, and no differences in tree size were present after 8 years.

Although no effects of stock type on tree size were evident at year 8, an effect of site was present, such that the trees at BC were larger than those planted at HR. This effect is likely due to differences in the climate and vegetation community composition of the sites. HR is a drier site compared with BC, and soil water resources have been shown to impact early Douglas-fir seedling growth (Dinger and Rose 2009, 2010). In addition, although total vegetation cover did not differ between the sites, HR had higher forb cover and lower fern cover than BC. Forbs have been shown to be more competitive than ferns during stand establishment (Balandier et al. 2006), suggesting that competition could have been more intense at the HR site.

The largest stock type tested (S-60) had the lowest survival at both study sites. This lower survival could be related to the larger leaf area of the S-60 seedlings, and thus, increased evaporative demand during stand establishment. At the time of planting, the S-60 stock type had more than twice the shoot volume of the other stock types tested, and leaf area has been shown to be well correlated with water loss (Lambers et al. 2008). Larger evaporative demand may have increased water stress during the summer months when precipitation is often less than 100 mm on these sites.

The cultural practices used to produce the S-60s could be altered to improve survival and early growth of this stock type. The S-60 seedlings were grown as S-8s for 1 year before the transplant process. After this initial year, roots had reached the bottom of the S-8 cavity and air pruned. The second season in the

S-60 cavity (which has the same depth as the S-8 cavity) meant that any additional root growth occurred from branching of lateral roots, as growth deeper into the container was not possible. Although roots of the S-60 had indeed filled the cavity, a large number of air-pruned roots were at the base of the plug, which may have limited the S-60s' ability to access deeper soil moisture reserves on these study sites, contributing to the lower survival that was observed. It is possible that growing a smaller stock type (e.g., S-4) for transplant into the S-60 container may improve outplanting performance. With a shorter initial length, the roots from a smaller stock type could then fill the larger S-60 cavity without 2 years of air pruning, thereby ensuring better root egress beyond the plug when the seedling is planted. In addition, if the seed sowing, early growth, and transplanting process are well timed, it may be possible to produce the S-60 seedling in a single season and reduce their cost.

The results of this study bring into question the significant monetary investment in the larger stock types tested. After eight growing seasons, initial size differences among the stock types disappeared at both study sites, even with operational weed control (fall site preparation followed by 1 year of spring release). Additionally, the largest stock type (S-60) had the lowest survival at both sites. The S-60 seedlings may also create logistical issues due to the large amount of space required to store and transport these seedlings (figure 5). Further research may be needed to better assess how nursery practices, site conditions, and silvicultural treatments interact to influence seedling outplanting performance. This information is critical for understanding the "fitness for purpose" of different stock types and properly applying the Target Plant Concept to reforestation projects.

**Figure 5.** Comparison of the space required for 500 packaged styro-60 seedlings (left of ladder) versus 500 packaged styro-8 seedlings (right of ladder). (Photo by Eric Dinger, 2008)

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