Morphological Grades of Lodgepole Pine Seedlings Compared After 13 Growing Seasons

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Abstract

The effect of morphological specifications within one stock type of container lodgepole pine grown under conditions that promote secondary foliage was examined. Seedlings were graded into three classes based on height and the tallest stock was further sorted by primary or secondary needles. Root collar diameter was similar among all seedlings except the short treatment group, which had a significantly smaller average diameter. Initial height differences resulted in seedling sturdiness that decreased when height increased. Seedling survival after 13 growing seasons was relatively high for all groups, although that of the mid-height treatment was less at 84 percent because of initial damage from pests, a factor that is unrelated to seedling morphology. After 13 growing seasons, no differences existed in height, diameter at breast height, or stem volume among treatments, suggesting that initial seedling size and needle morphology are not major factors in determining lodgepole pine reforestation success on this type of site in the central interior of British Columbia with low vegetation competition.

Introduction

A number of attributes can be measured to quantify seedling morphology (Grossnickle and others 1991), with the most common being height and root collar diameter (RCD). Indirectly, seedling height provides a measure of photosynthetic (Iverson 1984) and transpirational (Ritchie 1984) area. RCD is a measure of general seedling durability (Cleary and others 1978) and has been regarded as the best single predictor of field survival and growth (Thompson 1984). Along with height and RCD, the height-to-diameter ratio (HTDR) or sturdiness ratio is thought to be an important stock characteristic that influences early plantation performance (Burdett 1983).

These size attributes are the basis for the various stock type sizes currently available for production of reforestation seedlings. Currently in British Columbia (B.C.), reforestation stock is available in a multitude of Styroblock™ (Beaver Plastics, Edmonton, Alberta) containers and grown outdoors, in greenhouses, or a combination of both (Anonymous 1998). For each particular stock type (e.g., species, container size, age), stock is often further graded by assigning specific morphological specifications in the growing contract. For example, container stock grown in B.C. typically has minimum and maximum height and RCD specifications that it must meet, or it is culled (van Steenis 1994). Seedlings that are more than the maximum height are not culled if they meet or exceed a specific target RCD. Reforestation specialists typically prefer a specific seedling size within each stock type. The primary objective of this trial was to determine what effect the seedlings' initial height, within a specific stock type, has on subsequent field performance of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) seedlings. Specifically, how do seedlings of a target height perform relative to shorter or taller seedlings of the same stock type.

Pine seedlings for reforestation may also be ordered with primary or secondary (i.e., fascicle) foliage (Montville and others 2002). Secondary needle growth can be induced by using nursery cultural techniques such as the use of supplemental lighting, although the physiological basis for converting to secondary needles is still poorly understood (Mustard and others 1998). In addition to fascicle needles, secondary-needle pine has a whorl of buds at the apex instead of the single terminal bud usually found in primary needle pine (Montville and others 2002). In some cases, pine has been culled on the basis of its needle type, although this requirement has varied over the years. The second objective of this trial was to determine if the field performance of primary-needle pine differed from that of similar-sized, secondary-needle pine from a crop grown under extended photoperiods, which induced secondary needles in most of the crop.

Methods

Seedling Size and Needle Classes

The seeds of the lodgepole pine seedlings used in this trial were sourced from a local, wild-stand collection (seedlot 39409) near the planting site. The seedlings for this trial were selected during a lift of a large order of seedlings operationally grown for L&M Lumber Ltd. (Vanderhoof, B.C.) at the PRT Red Rock forest nursery (Prince George, B.C.). These seedlings were grown in CopperBlock™ Styroblocks™ (Beaver Plastics model number 313B/4, 30 mm [1.17 in] diameter with 126 mm [4.97 in] depth) under standard commercial growing regimes similar to those described in Wenny and Dumroese (1991) and Landis and others (1989). This regime entailed sowing the seeds into a double-poly greenhouse in mid-March and growing them under cover until mid-June at which time the poly was removed and the seedlings were exposed to full sunlight. The greenhouse poly was replaced in mid-August and the seedlings remained covered until early November when they were lifted and placed in frozen storage (-2 °C [28.4 °F]) until they were planted the next spring.

The nursery grew the crop to have fascicle foliage, also known as secondary needles (2°), by extending the day length (23 hr) during the first 10 weeks, although some of the taller seedlings produced only primary (1°) needles. The target height and RCD specifications for the stock at time of lifting were 12 cm (4.7 in) and 2.8 mm (0.11 in), respectively. The minimum height and RCD specifications were 5 cm (2.0 in) and 2.2 mm (0.09 in), respectively. The maximum allowed seedling height was 25 cm (9.8 in), unless the seedling had target RCD or greater. At the time of seedling harvest in November, four treatments were selected off the lift line (Short, Mid, Tall with 2° needles, and Tall with 1° needles). All stock used in the trial fell within the specified parameters and thus would have been planted. The average height and RCD (± standard error of the means) of the treatments are presented in table 1.

Outplanting Site

The field site was established approximately 100 km (60 mi) southwest of Vanderhoof, B.C. (Cutting permit 100; block 670, at km 75 off the Kluskus Forest Service Road). The site is in the 04 site series (Sxw Huckleberry-Soopolallie) of the SBSmc3 (Kluskus variant of the moist cold Sub-Boreal Spruce) biogeoclimatic subzone as per DeLong and others (1993). The trial area is relatively flat, at an elevation of 1,115 m (3,658 ft). The soil was classified as a sandy loam containing 15 to 20 percent coarse fragments, with a 14 cm (5.5 in) mor humus (Sinclair and Wilder 1997). The soil moisture regime was classified as submesic (3) and the soil nutrient regime as medium (C). The harvesting method was conventional roadside, and the silviculture system was clear-cut. The site was disk trenched. During the first growing season (1999), there was 23 cm (9.1 in) of precipitation at the trial site. A data logger, buried 5 cm (2.0 in) deep on a favorable planting spot on the berm of a trench, recorded soil temperature every 30 minutes from May 11 to October 18, 1999. Soil temperature was quite low at the time of planting (May 11, 1999), reaching a maximum in the first season of only 16 °C (60.8 °F), and dropping quite quickly towards the end of September (figure 1). At the time of planting, no competing herbaceous vegetation was present. At the end of the seventh growing season (October 2005), minimal to no herbaceous, woody shrub, or broadleaf competition existed (figure 2). The site was manually brushed of aspen (*Populus tremuloides* Michx.) saplings that summer.

Table 1. Mean height and RCD measurements for lodgepole pine seedlings in each treatment at the time of planting. Means followed by the same letter are not significantly different from one another (Tukey HSD multiple comparisons p > 0.05).

Variable	Short 2°	Mid 2°	Tall 2°	Tall 1°	F-ratio	P
Height (cm/in)	7.3/2.9a	13.1/5.2b	21.4/8.4c	23.6/9.3d	800.02	0.00
RCD (mm/in)	2.9/0.11a	3.2/0.13b	3.2/0.13b	3.3/0.13b	27.878	0.00

RCD = root collar diameter. 2° = primary needles. 1° = secondary needles.

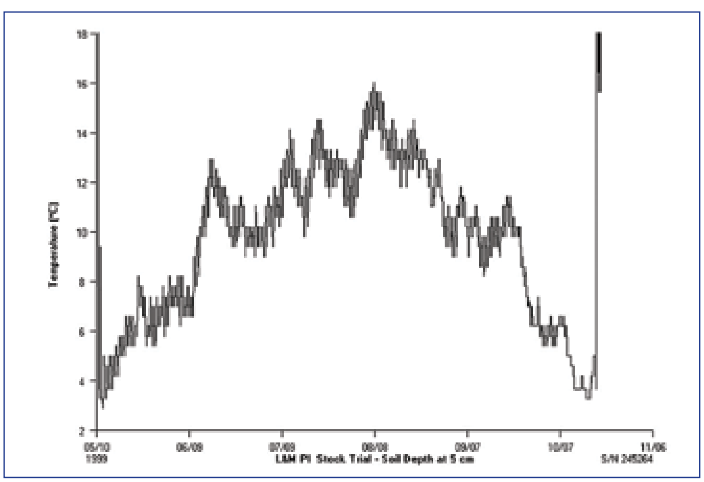

Figure 1. Soil temperature at 5 cm (2.0 in) depth on a favorable planting spot in the berm on a trench from May 11 to October 18, 1999.

Figure 2. The trial site during fall measurement, October 17, 2005. The 2 m (6.6 ft) height pole is leaning against a lodgepole pine tree with an 83 cm (32.7 in) leader. (Photo source: Steven B. Kiiskila).

At the final measurement (October 2011), no vegetation competition existed, although site occupancy was high, with high amounts of naturally regenerated pine ingress.

Study Design

The trial's experimental design was a randomized block design, with four replications (i.e., blocks) established adjacent to each other. Site conditions were relatively homogenous within and among blocks. Each of the four blocks contained four rows of 25 seedlings, one for each treatment, randomly assigned within each block. Cedar posts, placed at the front of each row 2.5 m (8.2 ft) apart and at the end of end of each row, allowed for average spacing of 2.5 m (8.2 ft) within the rows. Two professional planters working in the area planted the seedlings using operational planting practices at the time which involved planting the seedlings on the berm of the trench, approximately one finger deep (distance of container plug beneath the soil surface). Planters were instructed to choose the best seedling microsite, rather than predetermined planting spots. Each seedling was marked by ribboned wire pig tails with a uniquely numbered aluminum tag.

Data Collection and Analyses

Each seedlings was measured for height and stem diameter on the day of planting, and in the fall at the end of the 1st, 2nd, 3rd, 5th, 7th, and 13th growing seasons (October 18, 1999, September 29, 2000, October 18, 2001, October 3, 2003, October 17, 2005, and October 5, 2011). At the end of the second and third growing seasons, vigor was rated with a subjective visual assessment: 1 = poor, 2 = fair, and 3 = good. At the end of the 7th and 13th growing seasons, trees were subjectively rated for vigor using a four-point system: 1 = moribund, 2 = poor, 3 = fair, and 4 = good. Stem volume (cm^3) after the 7th and 13th growing seasons was calculated as a cone: (⅓ by p by [ground level diameter/2]^2 by height).

SYSTAT 10.2 was used to perform the analysis of variance, and Tukey's post hoc multiple range test was performed if treatment differences were found to be significant. The trial was established as a randomized block design, with block as the replication (rep) and rep x treatment as the error term. The level of significance was maintained at $p = 0.05$. A small number of trees (i.e., 10 out of 400) damaged by disease, pests, and other biotic or abiotic factors were removed from the 2011 data set before the height, diameter, and volume were analyzed.

Results

Survival

Shortly after planting, some of the stock sustained frost damage. At the end of the first growing season, however, survival was 100 percent for the Mid 2° treatment and 99 percent for the other treatments. At the end of the third growing season, the survival rate remained at 100 percent and 99 percent for the Mid 2° and Short 2° treatments, respectively, and at 98 percent for both Tall treatments. Four seasons later, the survival rate was at 96 percent or greater for all treatments except the Mid 2° treatment, which was at 89 percent, with most of mortality attributed to Warren's root collar weevil (*Hylobius warren* Wood). At the end of 12 years, survival was still relatively unchanged at 95, 93, 92, and 84 percent for the Tall 1°, Tall 2°, Short 2°, and Mid 2° treatments, respectively. Mortality occurring after the seventh year measurement was primarily the result of Comandra blister rust (*Cronartium comandrae* Pk.) and western gall rust (*Endocronartium harknessii* [J.P.Moore]Y. Hiratsuka).

Vigor

Overall seedling vigor at the end of the second growing season was 2.6, 2.3, 2.1, and 1.9 for the Short 2º, Mid 2º, Tall 2º, and Tall 1º treatments respectively (figure 3). At the end of the third season, treatment ranking remained the same, but visual assessment of all treatments increased from the previous fall to 2.8, 2.7, 2.5, and 2.3 for the Short 2º, Mid 2º, Tall 2º, and Tall 1º treatments, respectively. After seven growing seasons (fall 2005), overall vigor was rated high at 3.7, 3.6, 3.6, and 3.4 for the respective Tall 2°, Tall 1°, Short 2°, and Mid 2° stock. During the fall 2011 measurement, the vigor rating was nearly identical for all four treatments, ranging from 3.6 to 3.7.

Morphology

At the time of planting, statistically significant height differences existed between all four treatments (table 1). As intended, the relative height differences between the Short, Mid, and Tall treatments were substantial, while only a 2 cm (0.8 in) difference in height existed between the Tall 2° and Tall 1° seedlings. At the end of the first and second growing seasons, height rankings among treatments remained the same as the rankings at planting, except that the absolute heights of the Tall 2º and Tall 1º seedlings were no longer significantly different from one another. By the end of the third growing season, absolute height growth had evened out somewhat, with only the Short 2º seedlings being statistically smaller

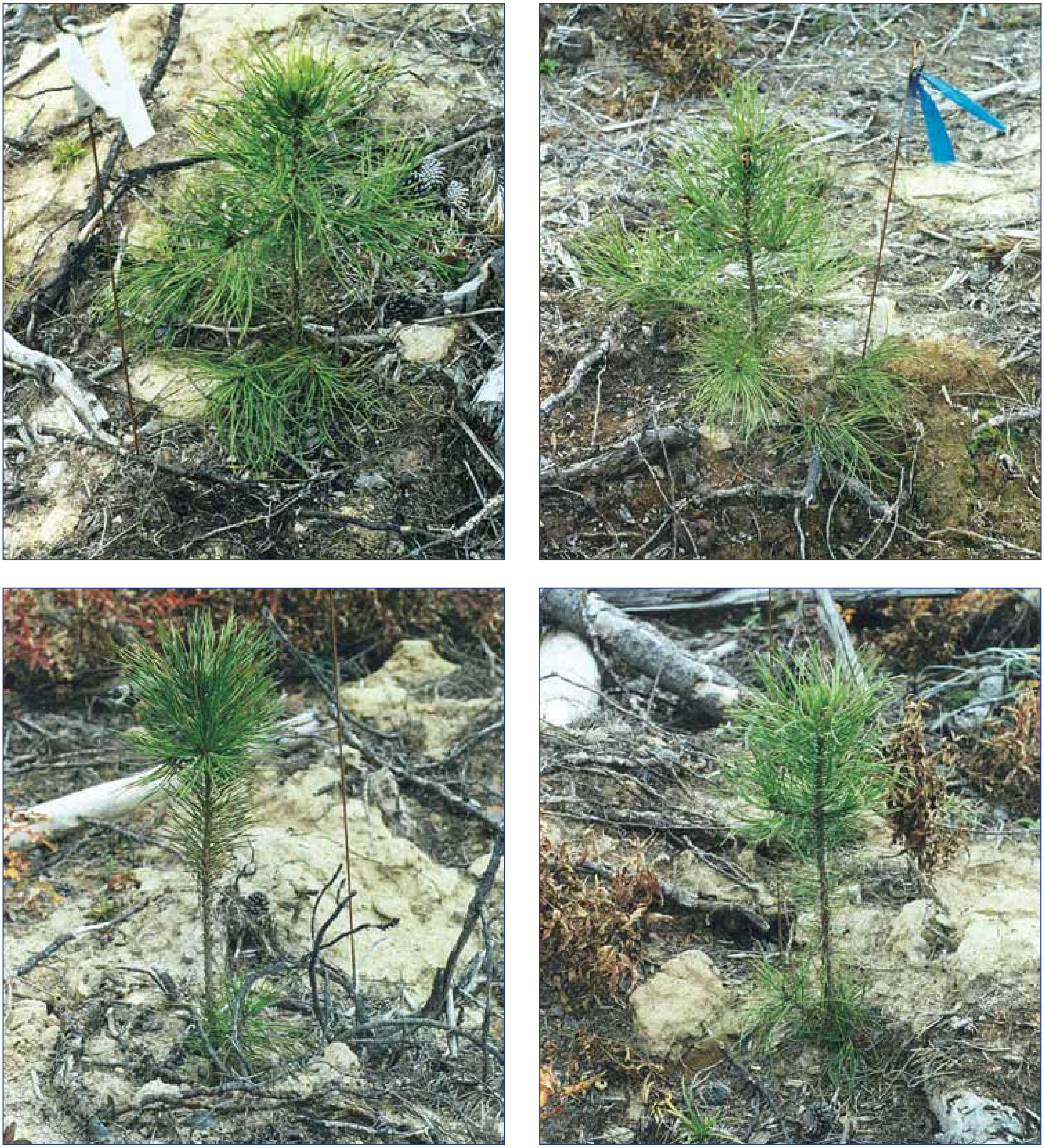

Figure 3. Example of seedlings from each treatment, September 19, 2000. Clockwise from top left: Short 2°, Mid 2°, Tall 2°, and Tall 1°. (Photos source: Steven B. Kiiskila).

than the Tall 2º seedlings. This height difference occurred because height increment during the first three growing seasons ranked among treatments as follows: Short 2º > Mid 2º > Tall 2º > Tall 1º (figure 4). At the end of the 7th and 13th growing seasons, tree height was no longer significantly different among treatments.

At time of planting, RCD of the Short 2º seedlings was significantly less than that of seedlings in the other three treatments (table 1). By the end of the sixth growing season, seedling diameter was similar among all treatments. In the fall of 2011, diameter at breast height (DBH) was measured and was also not significantly different among treatments. Similarly, no statistically significant ($p = 0.05$) treatment differences existed in stem volume calculated after 7 and 13 growing seasons (figure 5).

At the time of planting, seedling height of the various specification classes increased as expected from the Short 2º treatment up to the two Tall treatments. Diameter of the taller specification classes did not follow the same trend, however, which resulted in varied sturdiness or HTDR among treatments. During the first, second, and third growing seasons, the HTDR of the Short 2º and Mid 2º seedlings stabilized at approximately 40 (table 2). The initially high HTDR of the Tall stock also stabilized at 40, but not until the fifth growing season. The HTDR, although similar among treatments, increased substantially by the end of the 13th growing season.

Discussion

The results of this trial show that although specific sizes of reforestation seedlings may look more aesthetically pleasing, that does not necessarily equate to greater field performance. According to the operational contract specifications, the Mid 2° treatment was the desired or target size seedling for this stock type. The presence of smaller stock, such as the Short 2° treatment, often causes concern among silvicultural practitioners (L. Cosman 1999, personal communication), even if the seedlings are well balanced in regard to height and RCD. Under favorable site conditions, large seedlings generally grow better than smaller seedlings (Iverson 1984, Ritchie 1984, Racey and others 1989, Burdett 1990). More specifically, greater initial seedling height is more often advantageous on sites where vegetation competition is a potential problem (Cleary and others 1978, Newton and others 1993). On this site, later competition existed from aspen, but none from herbaceous

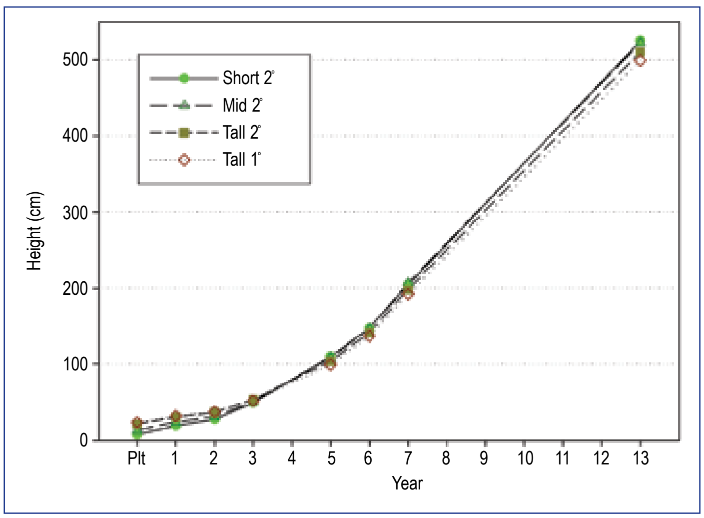

Figure 4. Average height (cm) of seedlings in the four lodgepole pine seedling size/needle morphology treatments from planting (plt = May 1999) through 13 growing seasons (October 2011).

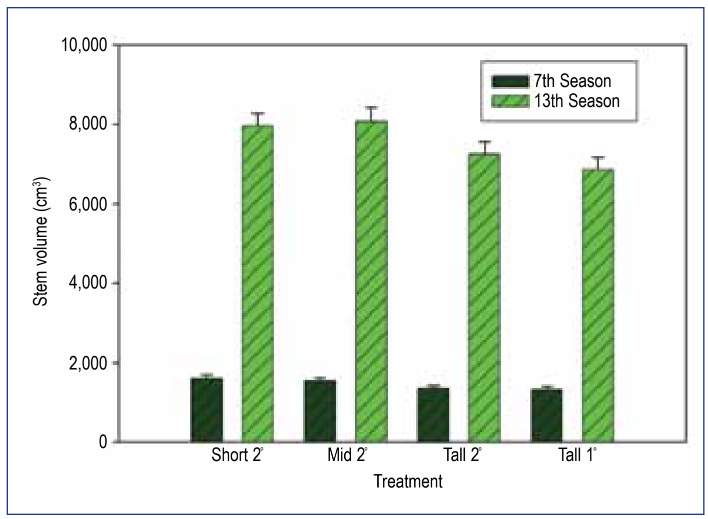

Figure 5. Average stem volume (cm^3) of seedlings in the four lodgepole pine seedling size/needle morphology treatments in October 2005 and October 2011. Vertical bars represent standard errors of the mean.

Table 2. Mean height-to-diameter ratios of seedlings in each treatment during the 13 growing seasons.

Date	Short 2°	Mid 2°	Tall 2°	Tall 1°
At planting	25	41	67	72
Fall 1999	41	51	64	69
Fall 2000	37	41	49	52
Fall 2001	38	39	43	46
Fall 2003	39	39	40	40
Fall 2005	39	41	40	40
Fall 2011	71	70	71	70

2° = primary needles. 1° = secondary needles.

vegetation or woody shrubs during initial seedling establishment. This likely explains the fact that all seedlings were the same height after 3 years, although the Short 2° stock started out two and three times shorter than the Mid 2° and Tall stock, respectively.

Tall, skinny (i.e., high HTDR) seedlings are also not favored by silvicultural practitioners (L. Cosman 1999, personal communication) because they are less able to withstand vegetation, snow press, and other potentially damaging agents compared with more sturdy stock (Noland and others 2001). The initial HTDR of seedlings in the Mid 2° treatment was the same during the first seven growing seasons after planting (table 2), and seedlings in the three other treatments converged around that same HTDR within 3 to 5 years, suggesting that the target height and RCD specifications for this stock type are appropriate. For the first 5 years after planting, the less sturdy Tall seedlings allocated more resources into stem diameter than to height, while in contrast, the Short 2° seedlings initially allocated more resources to height growth. Although Tall seedlings were less sturdy than seedlings in the shorter treatments, it is worth noting that, with an average HTDR of 70, the Tall seedlings were still considered adequately sturdy; the maximum height divided by minimum RCD results in a maximum allowable HTDR of 114 for this stock type. The fact that initial seedling sturdiness had no influence on survival or growth on this site is likely due to the lack of vegetative competition. In addition, Thomson and McMinn (1989) reported that growth rate in northern B.C. was related to size at first measurement for white spruce (*Picea glauca* [Moench] Voss), but not for lodgepole pine.

Although primary-needle pine has less foliage, and thus less transpirational area, secondary-needle pine is often considered more resistant to drought stress. Presently, this assumption is based more on appearance than anything, because no significant evidence in the literature supports enhanced field performance of one needle type over the other (Omni and others 1992, Mustard and others 1998). Either way, this hypothesis was not fully put to the test in this trial since drought was not an issue during establishment on this cold, northern site. Some silviculture practitioners are also concerned that primary needles may have a greater vulnerability to solarization soon after planting in comparison to secondary needles. This greater vulnerability was the case in this trial because solarization was responsible for the initial low vigor ranking of the Tall 1° treatment. Although this lack of vigor initially makes the tree look rather unsightly, frozen-stored, spring-planted stock have bud-flush and grow new secondary foliage within a couple weeks after planting. Primary-needle pine has been shown to have greater shoot growth potential after planting because of the increased stem units in the single, large terminal bud compared with the whorl of buds and smaller terminal bud found on secondary-needle pine (Thompson 1976, 1981). The whorl of buds on secondary-needle pine initially result in a bushier seedling and are also considered to be advantageous on frost or browse prone sites, providing a backup if the terminal bud is damaged.

As a cultural treatment, a more valid comparison of needle types would be between seedlings grown under conditions to maintain primary needles versus conditions to promote secondary needles. The small minority of seedlings in this trial that maintained primary needles under an extended photoperiod may have resulted from variations within the greenhouse environment or from genetic differences among the seedlings (Clapham and others 2002). Although it is not known why some seedlings maintained primary needles in the nursery, it is clear that on this site there was no advantage to cull seedlings that did not have secondary needles at the time of lift.

Along with growth, survival is an important component of meeting the silviculturist's reforestation goals. In this trial, survival rates were relatively high and similar among all treatments except the Mid 2° treatment, which experienced a slight increase in mortality from insects and disease. The reason for the greater mortality from pests on this treatment is not known, although its middle size ranking among treatments suggests that seedling size was not responsible.

This trial was not designed to determine the optimum seedling size, defined by South and Mitchell (1999) as the stock type that will minimize overall reforestation costs while achieving established goals for initial survival and growth. Rather, results from this trial suggest that grading guidelines for lodgepole pine seedlings grown for sites with minimal herbaceous competition in the central interior of B.C. need not be overly conservative. In the nursery, biological limitations exist for what any given container size can produce for each species. Although the nursery grows to the target specifications of the particular stock type, some variation will always exist because seedlings are biological organisms. Ideal seedling specifications reflect what can be reliably grown in the various container sizes in a cost-effective manner (van Steenis 1994). Thus, seedling specifications for a particular species-stock type combination need not be based primarily on field performance, but based more on what can be economically produced in that container in the nursery year after year. In regard to seedling size, field performance is primarily a function of the silvicultural practitioner choosing the correct stock type for a particular site, based on the specific height and RCD specifications in place for that species-stock type combination.

Since the establishment of this trial, two significant factors affecting reforestation in the interior of B.C. have occurred. The first factor being the gradual switch to more expensive, genetically improved seed from seed orchards, and the scarcity of wild natural seed in some areas due to the mountain pine beetle (*Dendroctonus ponderosae* [Scolytidae]) epidemic. The other being the general economic slump in the forest product industry and the resulting cost cutting by forest companies. In response, some lodgepole pine seedlings are now lifted without specifications, a process often termed as a block run with extractable plug. This process results in a savings by not wasting expensive or scarce seed, and the greater seedling recovery results in reduced seedling production costs. Results from this trial support the move towards relaxed seedling specifications in lodgepole pine planted in the central interior of B.C. on sites with minimal vegetation competition.

Conclusions

The lack of difference among morphological grades of a stocktype in height, DBH, or stem volume after 13 growing seasons suggests that initial seedling size or sturdiness is not a major factor in determining lodgepole pine reforestation success on this type of site with minimal vegetation competition. Also, results from this trial give no reason to cull primary needle lodgepole pine from a population of lodgepole pine seedlings grown under conditions promoting secondary needles. Different results are likely to occur with other species and sites with vegetation competition.

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