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Field performance of pine stock types: Two-year results of a trial on interior lodgepole pine seedlings grown in Styroblocks™, Copperblocks™, or AirBlocks™

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Abstract

Copper-treated Styrofoam containers and containers with side slits have been designed to modify the root systems of seedlings grown in hardwall containers. By chemical- or air-pruning major lateral roots, they encourage a more fibrous, branched root system, which is more evenly distributed throughout the root plug.

In the study presented here, lodgepole pine (*Pinus contorta* var. *latifolia*) seedlings were grown in Copperblocks™, AirBlocks™, or conventional Styroblocks™ and planted into different rooting environments. Various laboratory tests were performed on the seedlings before planting, but these failed to predict responses to the treatments in the field. Container type influenced root development and potential root viability in the nursery; however, these differences had disappeared in the field after two growing seasons. Only in summer-planted seedlings was root egress near the top of the plug greater for copper-treated than for conventional seedlings in the field. Seedlings grown in Copperblocks with exclusively secondary needles were evaluated separately from those with only primary needles. The secondary-needle seedlings had greater height increments in both growing seasons, although no differences in root collar diameter were apparent. However, both types of seedlings were selected from a population grown under cultural conditions to induce secondary needles, and thus some of the differences may have a genetic basis. Spring-planted seedlings, grown on burnt slopes, grew 5–18% taller than those on screefed plots and 43–67% taller than seedlings on ripped landings. Our major conclusion is that, provided the seedlings are healthy, planting location is more important than stock type.

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Introduction

Several choices must be made when ordering coniferous seedlings for reforestation, such as among container type, container size, seedling age, and needle form. This article reports on a recent study that examined container type and its effect on shoot growth and root egress of interior lodgepole pine (*Pinus contorta* var. *latifolia*) two seasons after outplanting. We also briefly compare field performance of primary and secondary needle lodgepole pine.

Concern over perceived root system instability leading to toppling of planted container-grown pine seedlings in British Columbia has prompted the development of new containers that modify seedling root systems.

Container Type

Concern over perceived root system instability leading to toppling of planted container-grown pine seedlings in British Columbia has led to the development of methods to modify the root systems of container-grown seedlings (Burdett *et al.* 1986). At present, root systems are modified by a system of ribs and by chemical- or air-pruning. Copper (i.e., copper oxychloride) applied to the inside container walls of the commonly used hardwall Styroblock™ container (Beaver Plastics Ltd.) results in a product called the Copperblock™. When new seedling roots come in contact with the copper on the container walls they cease growing. This prompts the generation of more lateral roots (Arnold and Struve 1993), which results in a more evenly distributed, fibrous root system (Wenny 1988). Recently, hard plastic side-slit containers (i.e., AirBlock™), which air-prune seedling roots (Figure 1), have been developed by BBC Sylviculture Systems Inc. as an alternative to Copperblocks.

Copper-treated stock is more expensive to produce because of the greater initial cost of containers, increased mortality during initial nursery culture, and container disposal issues (Peter Richter, Pacific Regeneration Technologies Inc., Vernon, B.C., pers. comm., 1998). AirBlocks also have a greater initial container cost, and seedlings grown in them require more frequent irrigation than seedlings grown in the two other types of containers. Some advantages of AirBlocks over Copperblocks are that these containers may have a longer useful lifespan and carry no concerns about the environmental impacts of copper runoff (although more fertilizer runoff does occur because of the additional irrigation required during seedling production).

Although Copperblocks are used widely in western Canada to produce lodgepole pine seedlings (MacDonald 1991), more information is needed on whether Copperblocks and the newly introduced AirBlocks provide any real advantage in the field over the conventional Styroblock. Differences in root form have been observed for the first few years (2–5 years) after outplanting in seedlings grown in Copperblocks. For example, compared to conventional seedlings, lateral root egress in copper-pruned pine seedlings is more evenly distributed up and down the original plug (Burdett 1981; Winter 1990; Winter and Low 1990; Watt and Smith 1998), or occurs more from the upper portions (Clarke and Winter 1986; Clarke and Winter 1987; Wenny 1988; Priest 1991). This difference did not occur in a study by Winter and Low (1990). While increased root production from the upper portion of the plug is considered a desirable trait in cold soils (Balisky *et al.* 1995), earlier studies show no difference in survival (Burdett 1981; Clarke and Winter 1987; Wenny 1988; Winter 1990; Priest 1991), or only slightly increased survival (Clarke and Winter 1986; Winter and Low 1990) by copper-treated lodgepole pine stock. With a few exceptions (Burdett 1981; Priest 1991), no significant differences have been observed in height or root collar diameter between regular and copper-treated lodgepole pine trees 2–5 years after planting (Clarke and Winter

FIGURE 1. Lodgepole pine seedlings in an AirBlock.

1986; Clarke and Winter 1987; Winter 1990; Winter and Low 1990; Kooistra 1991). Thus, though commonly inferred or suggested, little evidence exists that trees originating as Copperblock seedlings perform any better in the first few years following outplanting, or are less susceptible to toppling (Krasowski *et al.* 1996), than conventional Styroblock seedlings. Field performance of lodgepole pine seedlings produced in AirBlocks has not been evaluated. The first objective of this study was, therefore, to compare root system development and shoot growth of interior lodgepole pine seedlings produced in Styroblocks, Copperblocks, and AirBlocks after two growing seasons in the field.

Primary Versus Secondary Needles

The first needles formed on pine are called primary needles. On lodgepole pine these may be produced until the end of the first growing season. They are not found after the second growing season under normal conditions in northern temperate (e.g., British Columbia) nurseries (Thompson 1981, 1982). Normally, starting in the second year, mature or secondary needles are formed (i.e., fascicle needles). In the nursery, secondary needles can be induced in the first growing season through the use of long photoperiods (Wareing 1950).

Foresters often order pine seedlings with secondary needles because, with their mature foliage, they are thought to be more robust than comparable primary-needle pine seedlings. However, very few studies have compared field performance of primary- and secondary-needle pine. Work on Scots pine showed that primary-needle seedlings had greater shoot growth potential after planting because of increased stem units in the bud (Thompson 1976, 1981). Two-year results from a recent trial established on lodgepole pine in north-central British Columbia (Mustard *et al.* 1998) suggest little growth advantage of secondary- over primary-needle pine. Thus, no significant evidence to date has shown greater survival and field growth potential of secondary-needle over primary-needle pine seedlings, even though this topic has been debated for some time (Omi *et al.* 1993; van Steenis 1993). Because supplemental lighting is required, production of secondary-needle seedlings is more expensive than comparable primary-needle seedlings. The second objective of our study was to compare shoot and root growth in primary- and secondary-needle Copperblock seedlings after two growing seasons in the field.

Laboratory Predictors

To cull seedlings that have no chance of survival in the field, many morphological and physiological criteria are used to rate nursery stock quality. However, the laboratory tests currently in use are not sophisticated enough to correlate with field performance (Mohammed 1997). In this project, we used several tests (e.g., drought stress resistance, root growth capacity, and root viability) to measure performance attributes (Mattsson 1997). These variables were measured in the laboratory before outplanting of both spring and summer stock. Earlier work on lodgepole pine had shown that root viability, measured by triphenyl tetrazolium chloride (TTC) analysis before outplanting, was a better predictor than root growth capacity of seedling performance in the field (Lukic 1997). A similar result was found for Scots pine by Lassheikki *et al.* (1991). Carbohydrate levels were measured because of their correlation with drought and freezing stress (Niederer *et al.* 1992). These variables were measured to determine whether any would be useful in testing stock quality and predicting field performance before outplanting.

Methods

Production of Seedlings

From 1997 to 2000, we ran two field trials comparing the growth performance of one-year-old (1+0) interior lodgepole pine grown in Styroblocks (PSB 410, 80 ml), Copperblocks (PCT 410, 80 ml), or AirBlocks (PAB 410, 80 ml). The first experiment (spring-planted seedlings) used seedlings from seedlot 32810 sown into an outdoor compound in mid-April of 1997, lifted in November, stored frozen at –2°C, and planted the next May. Seedlings were grown following cultural practices currently used for commercial seedling production and appropriate to each container type. Fertilizer with a 2-1-2 nitrogen-phosphorus-potassium ratio was applied at 100 ppm N for the first 60% of the growing season and at 50 ppm N for the latter 40%. During production of the spring-planted seedlings, the Copperblock seedlings received an extended photoperiod (21 hours) to encourage the development of secondary or mature fascicle needles. Thus, both primary-needle and secondary-needle seedlings were produced in Copperblocks; these were separated during lifting and then compared. Seedlings grown in other block types had no photoperiod extension. Any secondary-needle seedlings were excluded from these groups at lifting. Seedlings from different blocks within a treatment were randomly combined into bundles of 15 for cold storage.

The seedlings (seedlot 39033) for the second experiment (summer-planted seedlings) were greenhouse-sown in early February 1998, then hot-lifted and planted in early June. As one-year-old stock for summer planting is sown in mid-winter when the days are short, supplemental photoperiod was used during the initial production of this stock. However, the length and timing of the photoperiod extension were such that it did not promote secondary needle production in any of the summer stock. For the first nine weeks of growth, greenhouse temperatures were set at 22°C during the day and 20°C at night. For weeks 10 and 11, temperatures were gradually lowered to ambient; at week 12, seedlings were moved outside the greenhouse and exposed to ambient (Vernon, B.C.) temperatures. Fertilizer with a 2-1-2 nitrogen-phosphorus-potassium ratio was applied at 100 ppm N throughout the growing period.

Laboratory Analyses

Laboratory analyses were performed on spring-planted seedlings after three and one-half months of frozen storage, and on summer-planted seedlings immediately after lifting. Root viability testing followed the triphenyl tetrazolium chloride method of Steponkus and Lanphear (1967). Root growth capacity was tested according to Johnson-Flanagan and Owens (1985).

Drought stress was applied by planting nine seedlings per treatment into dry substrate in a growth cabinet. Control seedlings were watered to the point of runoff on days 0, 1, 4, and 8. After 10 days, conductivity was measured on samples of roots and needles (McKay 1992). Stress was expressed as percent root injury, as calculated by Blum and Ebercon (1981).

Soluble carbohydrates in flash-frozen, ground roots were quantified according to the methods of Dubois *et al.* (1956). For starch analysis, the enzymatic method of Rose *et al.* (1991) was employed.

Planting and Field Assessments

Spring-planted seedlings were planted on two cutblocks at approximately 1450 m in elevation near Princeton: 667-2, a 46-ha cutblock with a northeast aspect in the Montane Spruce, dry mild biogeoclimatic subzone (MSdm2); and 619-7, a 18.5-ha bowl-shaped cutblock in the MSdm2. On 667-2, the four treatments (primary-needle seedlings grown in each of the three container types and secondary-needle seedlings grown in Copperblocks) were planted in three regions of the cutblock in a split-plot design. In each region, seedlings were planted onto a landing, an adjacent mechanically spot-screefed area, and an adjacent non-screefed burned area. Thus, nine plots were located on 667-2—three replicates each of landings, screefed, or burned planting sites. On 619-7, the four treatments were planted in two plots only. Both plots were in mechanically spot-screefed locations. Each plot on both cutblocks was planted with 50 randomly arranged seedlings of each nursery treatment.

Later that summer, 50 hot-lifted seedlings from each of the three container types were planted in an interspersed pattern in a split-plot design on three replicate cutblocks (summer-planted seedlings). On each cutblock, plots were established on one landing and an adjacent area of the cutblock. The landings had been mounded, but the adjacent cutblocks had not been site-prepared. Seedlings were planted on the tops of mounds on the landings and on raised microsites on the cutblocks.

Twenty randomly selected seedlings were assessed per treatment per plot in late September 1998 and 1999 for both spring- and summer-planted stock. No attempt was made to measure the same seedlings in both years. In September 1999, three randomly selected seedlings per treatment per plot were excavated and returned to the laboratory. The number and weight of roots produced in the upper, middle, and lower third of the root plug were quantified.

Results And Discussion

Effects of Container Types: Spring-Planted Seedlings

Measurements in the laboratory on spring-planted seedlings before outplanting indicated that AirBlock seedlings significantly outperformed ($P < 0.05$; one-factor ANOVA) seedlings produced in conventional Styroblocks with respect to most of the growth and physiological variables measured. AirBlock seedlings also performed as well as, or better than, primary-needle Copperblock seedlings for all variables except drought tolerance. Specifically, the seedlings grown in the AirBlocks produced a higher proportion of new roots in the upper two-thirds of the plug (Figure 2)

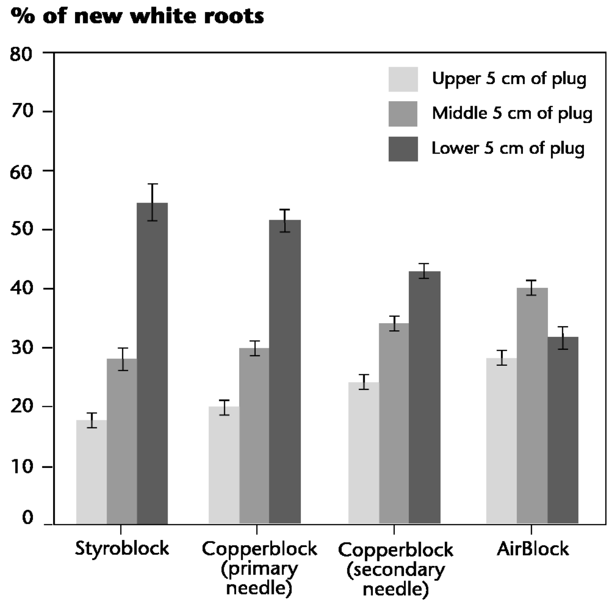

FIGURE 2. Location of new root growth from frozen-stored, spring-planted lodgepole pine seedlings after 10 days under optimal conditions (root growth capacity test). A one-factor ANOVA detected differences among containers for each rooting location at $P = 0.001$.

and had higher root viability following frozen storage compared to primary-needle seedlings from Copperblock or conventional Styroblock containers. The total number of new roots produced during the root growth capacity test, and the carbohydrate concentrations did not differ significantly among treatments. Root injury after 10 days of drought in pots was lower in primary-needle Copperblock seedlings than for any other seedlings. Needle injury differed less among treatments ($P = 0.03$), but primary-needle Copperblock seedlings had significantly less damage than AirBlock seedlings, with Styroblock seedlings intermediate in drought-stress resistance. The unique traits of the primary-needle Copperblock seedlings could be due to several factors: the container treatment, genetic differences, or the photoperiod treatment in the nursery.

At the end of the first growing season (September 1998), total shoot heights of the AirBlock and primary-needle Copperblock seedlings in the field were greater than those of the conventional Styroblock seedlings (Figure 3), although no difference was observed in root collar diameter. By the end of the second growing season (1999), however, seedlings from the three container types no longer differed significantly in shoot size (Figure 3), location of root egress along the plug, or weight of egressed roots.

On cutblock 667-2, the seedlings were planted in three different types of plots: ripped landings, mechanically screefed planting spots, and burned slopes. Although the effect of container type on growth was the same regardless of planting environment (no significant planting site × container type interaction), the planting environment had a major effect on seedling growth. Seedlings planted in the burned plots had greater second-year height increments, larger root collar diameters, and greater root weights than seedlings planted in the two other environments (Table 1). Seedlings in burned plots produced fewer roots than seedlings in screefed plots. Seedlings grown on burnt slopes, were 5–18% (3 cm) taller than those on screefed plots and 43–67% (6 cm) taller than seedlings on ripped landings.

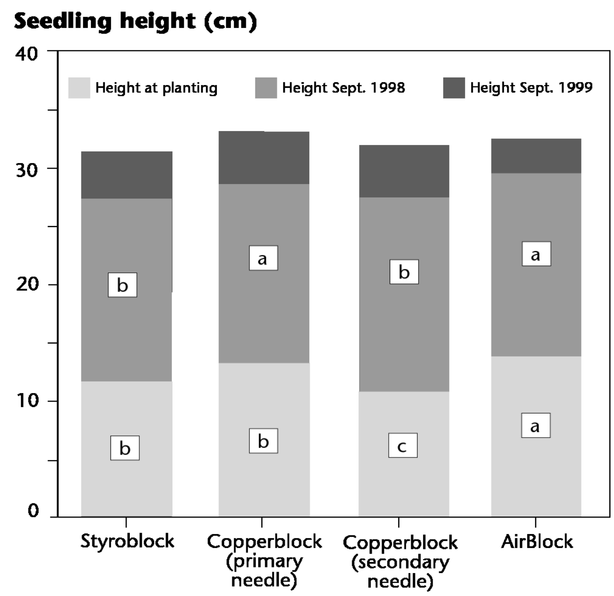

FIGURE 3. Total height (from soil surface to top of needles) for spring-planted lodgepole pine (all planting sites combined). Different letters within the same stippling pattern indicate significant differences according to a Fisher's PLSD test at $P = 0.05$. At planting, heights differed at $P = 0.001$ according to a one factor ANOVA. At the end of the first growing season, heights differed at $P = 0.002$ according to a two-factor ANOVA. At the end of the second growing season, no differences in total height were evident among container treatments.

TABLE 1. Second-year field assessment of *Pinus contorta* seedlings planted in late May 1998 (spring-planted seedlings) on mechanically spot-screefed sites, burned sites, or ripped landings on cutblock 667-2. Assessments were performed in early September 1999. Data have been combined for primary- or secondary-needle seedlings from all container types. *P*-values are from two-way analyses of variance, with container type and planting location as factors. Within a column, numbers followed by different letters differ at $\alpha = 0.05$ in a Tukey's *a posteriori* test.

	Height at planting in 1998 (cm)	1999 height increment (cm)	Total height (cm)	Root collar diameter (mm)	Wt. roots produced since planting (g)	No. roots produced since planting
Screefed	12.3 ± 0.5	16.4 ± 0.6 b	35.8 ± 0.6 a	8.3 ± 0.2 b	1.7 ± 0.2 b	97.4 ± 3.8 a
Burned	12.7 ± 0.6	19.1 ± 0.6 a	37.9 ± 0.7 a	10.0 ± 0.2 a	2.6 ± 0.0 a	68.1 ± 5.5 b
Landings	12.4 ± 0.6	9.8 ± 0.7 c	26.8 ± 0.7 b	6.0 ± 0.3 c	1.26 ± 0.1 b	82.1 ± 8.1 ab
P-value	0.85	0.0001	0.0001	0.0001	0.0002	0.003

Effects of Container Types: Results for Summer-Planted Seedlings

Due to the side slits in the container walls, AirBlock stock required additional water during production compared to stock produced in the two types of Styrofoam containers. Because of the difficulty of applying extra water to a small number of AirBlock seedlings grown operationally among a large amount of Styroblock and Copperblock stock, the AirBlock seedlings attained only 58% of the height of the other seedlings when they were lifted (Figure 4). In spite of the major difference in shoot size, most of the physiological and growth tests did not detect any differences among seedlings grown in the three container types. The only difference was in the total number of new roots produced in the root growth capacity (RGC) test, where they were significantly higher ($P = 0.0001$) for Copperblock seedlings than the other two treatments. In contrast to the spring-planted seedlings, no difference was evident in the location of root egress among treatments in the RGC test.

The difference in shoot size observed in the nursery remained throughout the two seasons of the field trial (Figure 4). The dry weight of roots produced after planting was also significantly lower in AirBlock seedlings planted on the cutblock compared to the other seedlings (Figure 5). Interestingly, a significant interaction was evident between container type and planting location with respect to height increment in 1999 (Table 2). This is because the Copperblock seedlings, which had (on average) the largest shoot systems, showed the greatest reduction in growth on the landings. Copperblock seedlings planted on landings had a mean height increment 62% that of Copperblock seedlings planted in the cutblock; the corresponding value was 73% for Styroblock seedlings and 80% for AirBlock seedlings. An interaction between planting location and container type for root growth was also observed (Figure 5). The dry weight of egressed roots differed significantly among the three container types on the cutblock, but not on the landings; this was attributed to the relatively better root growth of AirBlock seedlings on landings.

Following two field growing seasons, Styroblock summer-planted seedlings produced a significantly higher proportion of roots from the bottom third of the plug than the Copperblock or AirBlock seedlings (Figure 6). Over the short length of the study, these differences in the location of root egress were not correlated with shoot or total root biomass. Generally, we feel that it is inappropriate to speculate on how the AirBlock summer-plant seedlings would have performed had they not been so much smaller than the other seedlings initially. Nevertheless, the difference in the distribution of new roots between the Copperblock and Styroblock seedlings should be a robust observation because these two groups of seedlings did not differ in size at planting.

Differences Among Primary- and Second-Needle Spring-planted Pine Grown in Copperblocks

The secondary-needle Copperblock seedlings had higher root viability and a lower percentage of roots produced near the bottom of the plug in the root growth capacity test than the primary-needle Copperblock seedlings (Figure 2), but had lower drought stress resistance and produced a shorter shoot in the nursery (Figure 3). Root collar diameter and needle length did not differ.

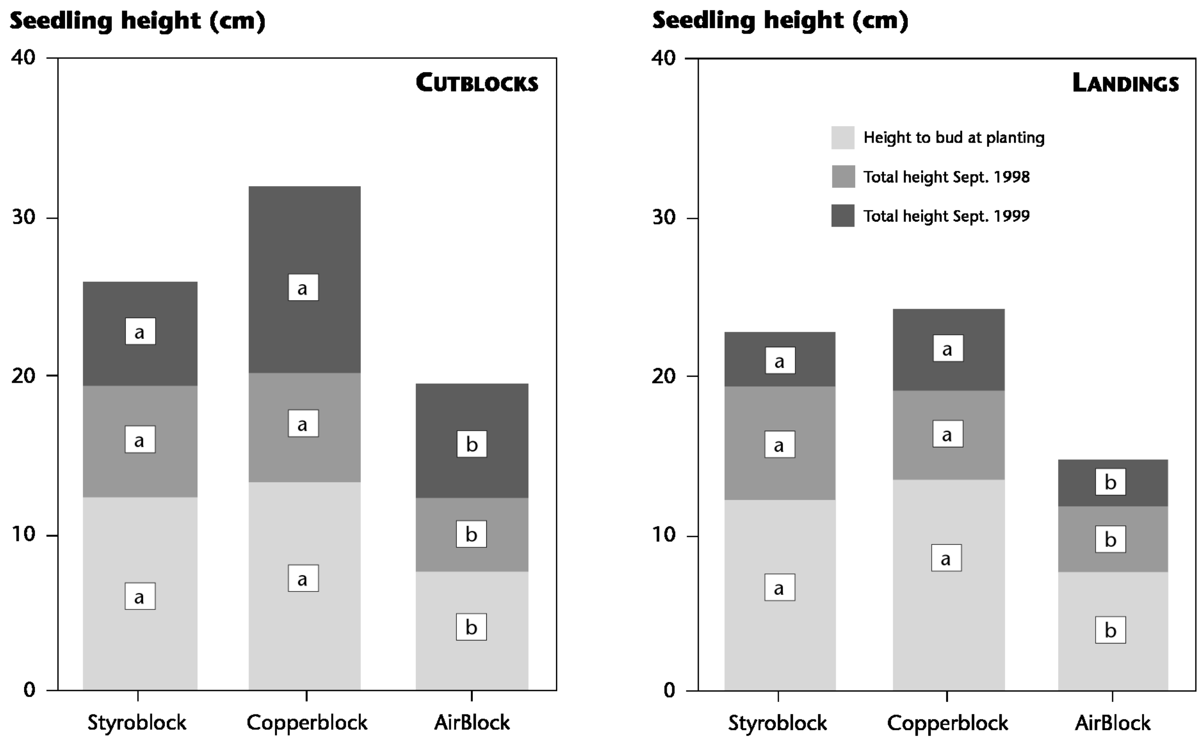

FIGURE 4. Height to bud at planting, as measured on a subset of seedlings in the lab, and total height (soil surface to end of needles) at the end of the first and second growing seasons for lodgepole pine planted in July 1998 (summer-planted) on cutblocks or adjacent site-prepared landings. For each planting location, different letters within the same stippling pattern indicate significant differences according to a Fisher's PLSD test at $P = 0.05$. P-values for one factor ANOVAs between container types were as follows: cutblock and landing at planting, $P = 0.0001$; cutblock in September 1998, $P = 0.0005$; cutblock in September 1999, $P = 0.001$; landings in September 1998, $P = 0.0002$; landings in 1999, $P = 0.004$.

TABLE 2. Second-year field assessment of primary-needle *Pinus contorta* seedlings planted in June 1998 (summer-planted seedlings) on site-prepared (mounded) landings or adjacent cutblocks. Assessments were performed in September 1999. P-values are from two-way ANOVAs, with container type and planting location as factors. Within a column, numbers followed by different letters differ at $\alpha = 0.05$ according to a Tukey's *a posteriori* test.

	1999 height increment (cm)	**Root collar diameter (mm)**
Styroblock	12.7 ± 1.0 ab	5.6 ± 0.2 a
Copperblock	15.1 ± 1.7 a	5.7 ± 0.3 a
AirBlock	10.2 ± 0.8 b	4.7 ± 0.3 b
Container type *P*-value	0.0006	0.007
Cutblock	14.9 ± 0.9	5.6 ± 0.2
Landing	10.4 ± 0.5	5.0 ± 0.2
Planting location *P*-value	0.0001	0.02
Container × Location *P*-value	0.05	0.4

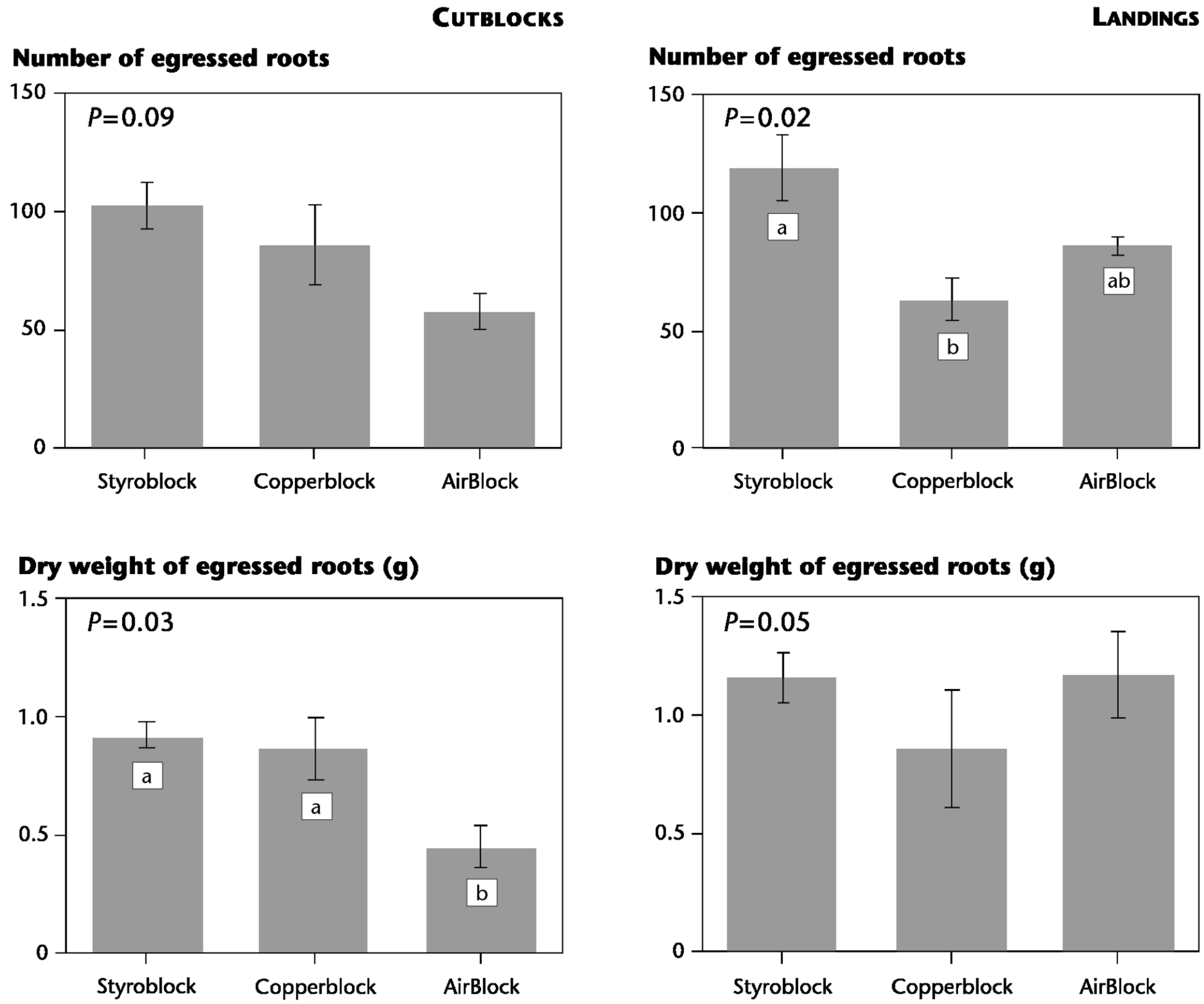

FIGURE 5. Root egress of summer-planted lodgepole pine during 1998 and 1999. *P*-values are those of one-factor ANOVAs and letters within the bars indicate differences detected by a Fisher's PLSD test at $P = 0.05$. A two-factor ANOVA on root number gave $P = 0.006$ for container, $P = 0.3$ for site and $P = 0.09$ for container × site interaction; a two-factor ANOVA on root weight data gave $P = 0.3$ for container, $P = 0.02$ for site, and $P = 0.09$ for container × site interaction.

By the end of the second growing season (1999), however, the primary- and secondary-needle seedlings no longer differed in shoot height or diameter, location of root egress along the plug, or weight of egressed roots. The change in relative shoot height was because the secondary-needle Copperblock seedlings, which were shorter initially, had higher mean height increments in both growing seasons. If this pattern continues, they will be larger than the primary-needle pine in subsequent growing seasons.

Comparisons between the primary- and secondary-needle seedlings should be interpreted with caution, as genetic differences among the seedlings may be confounding the results. The primary-needle seedlings were selected from a population of pine grown under cultural conditions to produce secondary needles (which the majority of seedlings did), not under separate cultural conditions to induce primary needles.

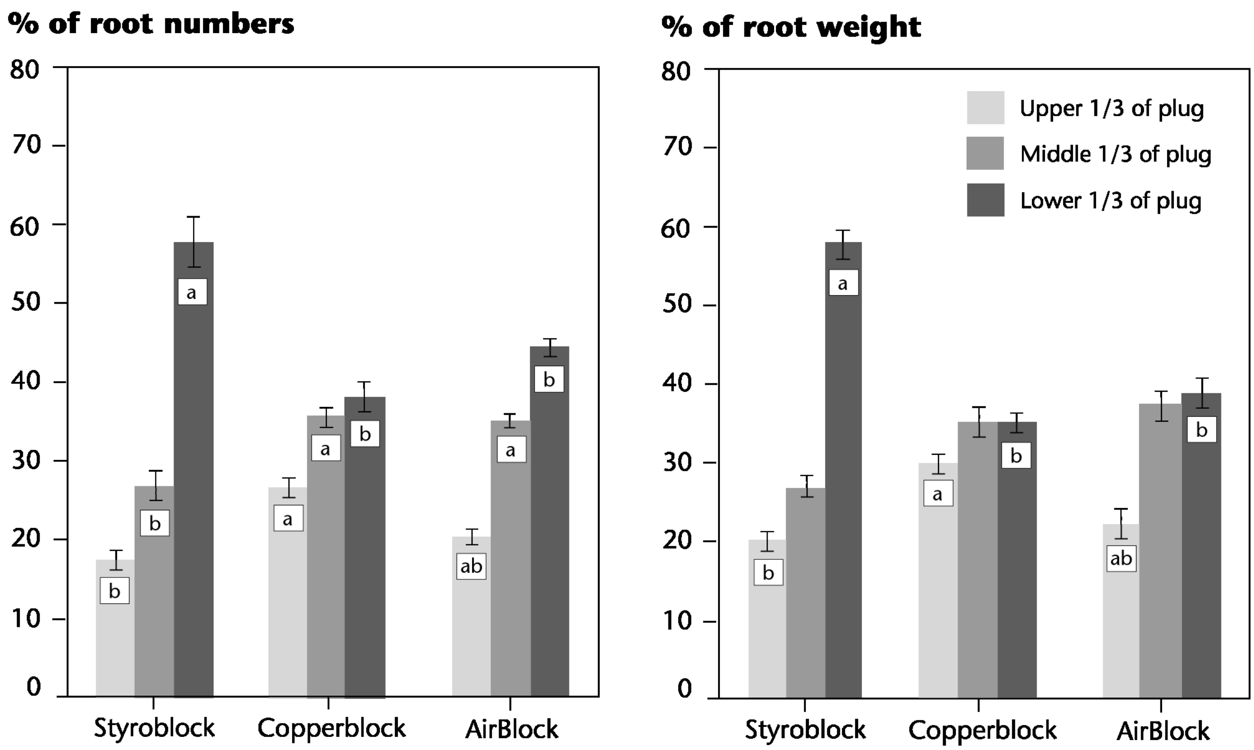

FIGURE 6. Distribution of egressed roots on summer-planted lodgepole pine at the end of the second growing season in the field for both types of planting sites combined. One factor ANOVAs were performed separately for each portion of the root plug. If bars of the same tone have different letters, they differ at $P = 0.05$ according to a Fisher's PLSD test.

Comparison of Laboratory and Field Results

None of the physiological measurements or growth tests performed in the laboratory predicted the relative performance of the different stock types in the field. For spring-planted seedlings, root growth capacity tests predicted differences in root egress patterns, whereas no differences in root production or distribution were observed in the field. Before planting, laboratory tests predicted that field performance would be best in spring-planted AirBlock or Copperblock seedlings because root viability was highest in AirBlock seedlings and damage due to drought stress was lowest in Copperblock seedlings with primary needles. In spite of these predictions, no differences in shoot size were present at the end of two field growing seasons. It is especially interesting that drought stress injury was not a useful variable given that the summer of 1998 was extremely dry.

For summer-planted stock, the distribution of roots produced in the field differed between Styroblock and Copperblock seedlings, whereas this had not been predicted by the root growth capacity test done before planting. The laboratory tests predicted that Copperblock seedlings would produce the largest number of roots in the field, but this did not occur. No other tests detected differences among the treatments.

Management Implications

1. The major conclusion of this study is that, provided seedlings are healthy, planting site is more important than nursery treatments in affecting growth. Spring-planted seedlings in burned plots had the fastest growth rates, regardless of container type, whereas those planted on landings grew the slowest. Moreover, seedlings planted in one cutblock (619-7) grew significantly faster than seedlings planted at the same time on similar microsites in a second, nearby cutblock (667-2) at the same elevation. This suggests that even subtle site differences can be important. Other studies have shown that root morphology (McMinn 1978) and stand stability (Krasowski *et al.*

1996) are more heavily influenced by site conditions such as soil characteristics and stocking density than stock type. This justifies the increased attention currently placed on planting spot selection and planting depth, which can positively influence the amount and location of root egress from planted seedlings by placing seedling roots into the most favourable growing environment (Anonymous 2001).

2. The studies cited in the introduction found that root systems of copper root-pruned seedlings generally differed from the root systems of seedlings grown in conventional, untreated containers (e.g., Styroblock) for at least the first few years after planting. In our study, after two years of field growth, summer stock grown in Copperblocks had a more even distribution of roots along the height of the root plug, but this did not result in differences in shoot growth when compared to Styroblock seedlings. Spring-planted lodgepole pine seedlings grown in conventional Styroblock and Copperblock (with primary or secondary needles), or hard plastic AirBlock containers did not differ significantly in shoot height, root collar diameter, or weight or location of egressed roots after two years growth in the field. Our results are consistent with earlier studies, which generally failed to show any significant benefit of copper-treated blocks to shoot growth. Furthermore, they suggest that any of the three types of container produced stock of equal growth potential.

   We conclude that the root system produced by the conventional Styroblock container does not limit seedling growth and establishment relative to the other container types tested. This may be because, since the development of the Copperblock, the culture and root form of seedlings grown in Styroblock containers in western Canada have improved, which reflects subsequent modifications to the original design. For example, vertical ribs have been added to the original Styroblocks to reduce root spiralling, average seedling container size has steadily increased, and the bulk density of the growing media has been decreased substantially, allowing more vigorous root growth without plug compaction. Moreover, present production methods are such that seedlings are sown at the optimal date to produce the required shoot and root growth, and not left in their containers for unnecessarily long periods of time, thus reducing the possibility of seedlings becoming root-bound (Peter Richter, Pacific Regeneration Technologies Inc., Vernon, B.C., pers. comm., 1998). After only two years growth, it is too early to know whether any of the differences in initial root form of the summer-planted seedlings will have any influence on future tree stability and growth. However, as no significant differences in rooting among the spring-planted container types were evident after two seasons growth, future differences in rooting are unlikely.

3. Laboratory tests performed on seedlings before planting did not predict seedling growth in the field for either spring- or summer-planted stock. Even though some of these same tests predicted field performance in lodgepole pine in a trial on lifting date conducted previously in our laboratory (e.g., Lukic 1997), the results described here again suggest that site factors are more important than container types in determining both shoot and root growth in the field.

4. The secondary-needle Copperblock seedlings were significantly (> 3 cm) shorter than primary-needle seedlings at planting, but had reached the same height as primary-needle seedlings by the end of the trial. This is attributed to higher mean height increments. Comparisons between the primary and secondary needle classes should be interpreted with caution, however, as genetic differences among the seedlings may be confounding the results. The primary-needle seedlings were selected from a population of pine grown under cultural conditions to produce secondary needles. Therefore, results from this study should not be used for general growth comparisons between primary- and secondary-needle pine seedlings.

The major conclusion of this study is that, provided seedlings are healthy, planting site is more important than nursery treatments in affecting growth.

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