Fixing the Edsel - Can Bareroot Stock Quality be Improved?'

David G. Simpson2

Abstract.--Bareroot stock quality and subsequent field survival and growth can be improved by: (1) - growing seedlings at wider spacings which results in increased dry weight, lower shoot/root ratio, larger root collar diameter and in some cases increased root growth capacity (RGC); (2) - root culturing (undercutting or root wrenching) which increases RGC; and (3) - nutrient loading with fall applications of nitrogen fertilizers which increases both RGC and field growth.

INTRODUCTION

A B.C. Ministry of Forests report (Errico and Pelchat 1984) which, by means of computer assisted linear programming, compared several nursery stock type options to produce interior spruce (*Picea glauca* and/or *Picea engelmannii*) planting stock suggested that if field performance was ignored, 85% of the spruce trees planted in BC should be produced as 2+0 bareroot stock. However, when field performance and increased morphologic standards were included in Errico and Pelchat's model, only 5% of spruce planting stock was to be produced as 2+0 bareroot stock. Poor field performance (survival) of the 2+0 bareroot stock was the reason the model projected such a radical shift in spruce stock types. Field performance, survival, and growth data are limited for most species planted in British Columbia. Collective opinion, however, seems in agreement that the 2+0 seedlings produced are not surviving in great enough numbers and those that survive often grow poorly.

There are two choices to resolve the preceding problem:

a) abandon bareroot 2+0 stock in favor of more successful stock types, or
b) adjust or modify the 2+0 bareroot stock cultural regime so that survival and growth is improved.

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[2]The author is a Research Scientist with the British Columbia Ministry of Forests at Vernon, B.C.

To the recipient of nursery stock, the first option is the most obvious solution as he wants only a product that performs. However, if the field performance of the least cost stock type, the 2+0 bareroot seedling, can be improved by changing nursery cultural and field handling practices, the objective of obtaining the greatest number of surviving, "free-to-grow" seedlings at the least cost may be in reach.

This report has been prepared to present the results of several experiments conducted by the author since 1977 on various aspects of bareroot nursery culture. The common goal of all these experiments has been to improve the field performance of 2+0 bareroot planting stock by making relatively low cost changes to nursery cultural and handling practices. At the onset, 2+0 bareroot stock quality, or field performance potential, was considered to be so poor that any improvements made were certain to more than justify the research invested.

Within the bareroot seedlings' nursery environment, there are relatively few cultural factors which may be manipulated with great precision. Factors which may be controlled include: nursery location and soil, seedling espacement, root culturing, nutrients, irrigation, and lifting dates. The response, in terms of seedling field performance, to any specific cultural factor interacts somewhat with genotype and prior nursery culture. For this reason, a series of experiments were conducted with various species to investigate the separate effects of several nursery cultural factors on field performance. The combined effect of simultaneous changes to several cultural practices is best seen as the change in field performance of stock produce in past years relative to field performance of present day 2+0 planting stock planted on similar sites. Due to the scarcity of field performance data, quantitative comparison of past and present 2+0 stock is rarely possible. However, collective opinion would suggest that some field performance improvement has occurred, but certainly greater success must occur to attain the goal of least cost for surviving free to grow trees.

NURSERY LOCATION AND SOIL

Implementation of a root growth capacity (RGC) testing program in 1977 for testing of nursery stock at the B.C. Ministry of Forests' Red Rock (Prince George) and Skimikin (Salmon Arm) nurseries and casual observations of the relative field performance of stock from these two nurseries resulted in the perception that there were substantial and consistent stock quality differences between the two nurseries.

To determine to what extent "nursery" and soil" affected stock quality and field performance, a reciprocal soil transfer experiment was undertaken. At each nursery, raised beds of each nursery's soil were established and along with a regular nursery bed, sown with lodgepole pine and interior spruce seed. Using similar fertilizer and root culturing regimes in all soil treatments, the seedlings were grown for 2 years. On Oct. 20 of the second growing season, the seedlings were handlifted and stored overwinter (ca. 6 mos.) at -2°C. In the spring (May), stored seedlings' RGC's were determined, and the seedlings were outplanted onto a forest site near Vernon, B.C.

First year field survival of the interior spruce was high (86 to 97%) and there were no significant ($p \leq 0.05$) nursery or soil effects. Lodgepole pine seedlings grown in raised nursery beds at Skimikin nursery had reduced survival, perhaps due to some unmeasured quality differences (fig. 1). Growth of surviving

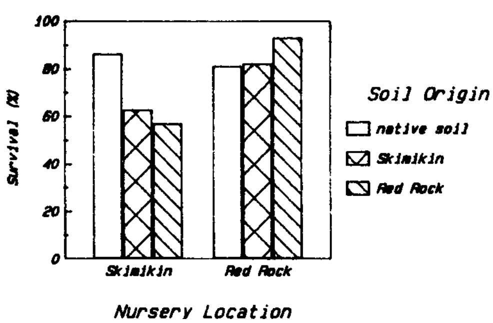

Figure 1.--First year field survival (Z) of lodgepole pine grown at Skimikin and Red Rock nurseries in soil from those two nurseries.

seedlings was not affected by nursery soil and only slightly by nursery location (for example, fig. 2).

There were no consistent effects of either nursery or nursery soil on RGC after storage (fig. 3); however, it was noted that lodgepole pine RGC's were consistently greater than those of interior spruce.

The conclusion drawn from this experiment was that the previously observed RGC differences between Skimikin and Red Rock nurseries must have been due to some cultural factor rather than nursery climate, or nursery soil.

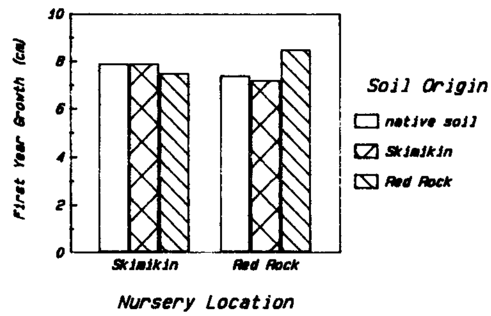

Figure 2.--Growth of surviving field planted lodgepole pine seedling grown at Skimikin and Red Rock nurseries in soil from those two nurseries.

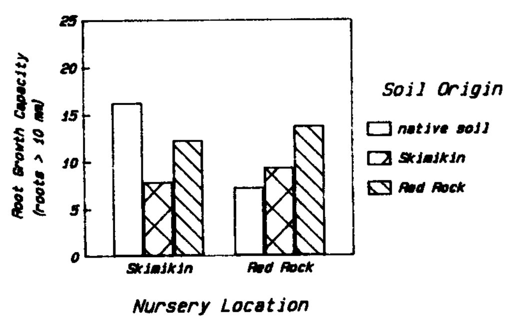

Figure 3.--Root growth capacity (RGC) of lodgepole pine grown at Skimikin and Red Rock nurseries in soil from those two nurseries.

SEEDBED DENSITY

Whether a stand of trees be in a nurserybed or on a forest site, competition occurs between individuals. In the bareroot nurserybed, conventional sowing machines scatter seed in six to eight parallel drill rows that are approximately 15 cm apart. The distribution of seed within the drill rows is often not uniform resulting in clumps of seedlings. To demonstrate that field performance of Douglas-fir and ponderosa pine 2+0 planting stock could be improved by growing the seedlings at reduced and more uniform seedbed densities, two experiments were initiated.

In May 1978 plots with four seedbed density levels: 74, 118 172, and 259 Douglas-fir seedlings per mZ, were established by thinning seedbeds sown to create an operational density of 259 seedlings per m^2. After two growing seasons the 2+0 seedlings were lifted and planted on a forest site. Survival of all treatments was near 100%, however, there were significant growth differences in both the first and second year after outplanting (fig. 4).

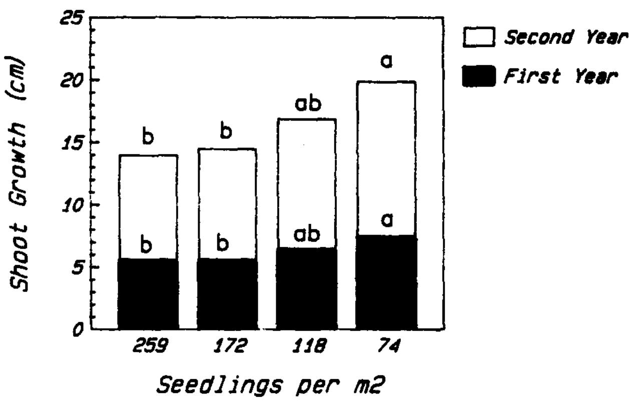

Figure 4.--Shoot growth (cm) of Douglas-fir seedling one and two years after planting on a forest site. For each year, means followed by a similar letter are not significantly different (p< 0.05).

The positive effect of reduced seedbed density on field performance was likely the result of larger seedlings being produced at the lower densities. While shoot height in the nursery was not affected by bed density reductions, both root collar diameter and seedling dry weight increased as density decreased (table 1).

Table l.--Seedling spacing effects on Douglas-fir root collar diameter (mm), total dry weight (g) and shoot/root ratio. Means underlined by the same line are not significantly different (p<0.05).

	Seedling Spacing (seedlings per m2)			
	259	172	118	74
Root Collar	3.5	4.5	4.9	5.8
Dry Weight	3.9	5.3	6.5	9.2
Shoot/Root	1.97	1.75	1.56	1.23

In 1979 a second experiment was established using ponderosa pine to investigate seedbed density levels of 80, 160, 240, and 290 seedlings per m^2. As in the earlier experiment with Douglas-fir, as ponderosa pine seedbed densities decreased; root collar diameters increased, seedling weights increased, and shoot:root ratios deceased (table 2).

Table 2. -Seedling spacing effects on ponderosa pine root collar diameter (mm), total dry weight (g) and shoot/root ratio. Means underlined by the same line are not significantly different (p<O.05).

	Seedling Spacing (seedlings per m2)			
	290	240	160	80
Root Collar	4.2	5.1	5.2	6.3
Dry Weight	4.2	6.0	6.5	9.2
Shoot/Root	1.97	1.74	1.89	1.63

Significant positive improvements in both first year field survival and growth due to seedbed density reductions occurred when the ponderosa pine seedlings were planted on a forest site (fig. 5).

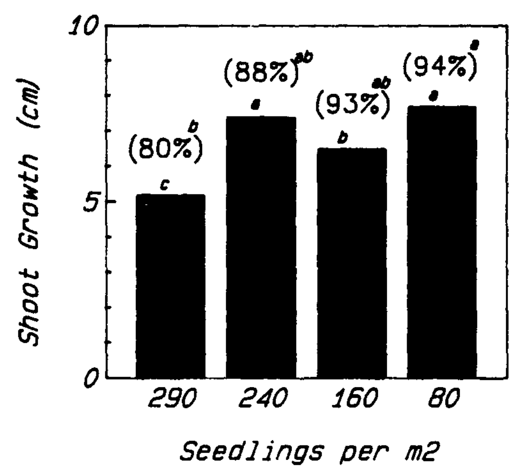

Figure 5.--Nursery bed spacing effects on first year survival (indicated in brackets) and shoot growth (bars) of outplanted seedlings. Means followed by similar letters are not significantly different (p<0.05).

Often physical measures of nursery stock quality such as root collar diameters and shoot:root ratios are poor predictors of field performance because of variation in physiologic vigor or quality. Stored tissue nutrient levels and root growth capacity were measured to determine what seedbed density effects, if any, occurred. With Douglas-fir no significant differences in root growth capacity levels of seedlings raised at different seedbed density were observed, and of N, P, K, Ca, and Mg measured in root, stem and foliage tissue, only stem N levels were shown to increase as density decreased. This increase in stem N may reflect the proportionately greater amounts of bark and phloem tissue on the larger seedlings produced at low densities.

With ponderosa pine, tissue nutrient levels were not affected by seed bed density reductions. However, root growth capacity of seedling after over winter storage was higher in those seedlings grown at wider spacing (fig. 6).

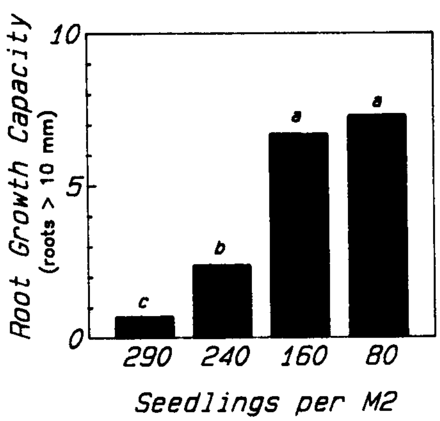

Figure 6.--Nurserybed spacing effects on root growth capacity (number of new roots longer than 10 mm per seedling) of ponderosa pine seedlings. Means followed by number letters are not significantly different ($p<0.05$).

To summarize, in both experiments, seedlings produced at lower bed densities had better morphologic quality (greater dry weight; lower shoot:root ratio; larger root collar diameter) and in the case of ponderosa pine had improved root growth capacity levels. It is supposed that improvements to both morphologic and physiologic quality contributed to the superior field performance of the seedlings raised at lower densities.

ROOT CULTURING

Left undisturbed in the nursery bed, conifer seedlings produce a root system with long primary and secondary roots. This type of root system is well suited to exploitation of moisture and nutrients in the natural environment. However, if seedlings with a natural type root system are lifted, many of the second and higher order lateral roots necessary for new root regeneration on replanting are lost. A bareroot seedling for field planting must therefore be encouraged to develop a compact root system that will not be lost on lifting. Root culturing is used to produce compact fibrous root systems. There are three main root culturing practices: lateral root cutting, undercutting, and root wrenching.

Root pruning, as opposed to root cutting, refers to trimming of seedlings' root systems that may occur after the seedlings have been lifted from the nursery bed.

Lateral root cutting is accomplished by passing vertical blades or rolling coulters between the drill rows. This treatment is usually done during the second growing season, and promotes a bi-lateral shaped root system and tends to reduce the amount of root tearing which occurs during lifting and grading. Undercutting is done by passing a reciprocating horizontal blade through the seedbed to sever the primary and secondary roots at a depth of between 10 and 20 cm. In the late 1970's there were two main types of equipment used in B.C. forest nurseries: a "Marsh" undercutter having a fairly thick (5 mm) rigid blade that reciprocates fairly slowly, and a second, more recently introduced machine, the "Lotus" undercutter having a thin (2 mm) spring steel blade that reciprocates somewhat quicker. The Lotus machine makes a cleaner cut through the seedlings' root systems resulting in less bed disturbance such that a more shallow undercutting treatment is possible. The Marsh machine, by virtue of its more robust construction can travel through the seedbed at somewhat greater speeds.

Root wrenching is done using a non-reciprocating blade that is passed under the seedbed at an angle. This treatment results in a loosening of the bed, the degree dependent on the blades angle and speed through the seedbed. Root wrenching is usually done in the second growing season and often at a slightly greater depth than undercutting.

The effectiveness of root culturing, in particular, of undercutting and root wrenching, in promoting a more compact root system varies with species and nursery soil as well as severity, timing and frequency of treatment. To investigate the effectiveness of undercutting and wrenching in improving field performance potential, two experiments were conducted at the B.C. Ministry of Forests' Surrey, Skimikin, and Red Rock nurseries. The first experiment manually simulated shallow undercutting and root wrenching at weekly intervals from late July until mid-October of the 2+0 stock's second growing season.

There were no consistent effects on seedling height, root collar diameter or shoot and root dry weights which would be attributed to the undercutting and wrenching treatments. However, root systems of seedlings receiving undercutting or wrenching treatments were noted to be more compact and fibrous than were the root systems of seedlings receiving no root culturing.

Seedlings produced in this experiment were not field planted, however, root growth capacity measurements made in the spring after 24-weeks of -2°C cold storage suggests that the undercutting and wrenching treatments in some cases significantly increased this indicator of field performance potential (fig. 7).

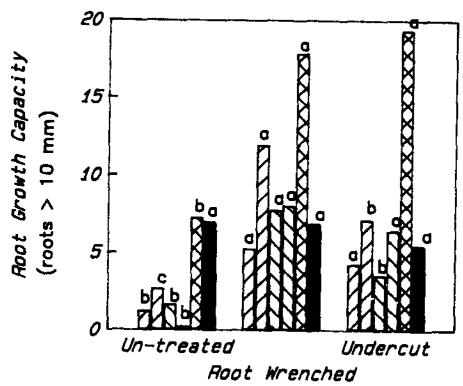

Figure 7.--Root culturing effects on root growth capacity (number of new roots longer than 10 mm per plant) of white spruce (right hatch), Engelmann spruce (left hatch), lodgepole pine (cross hatch) and Douglas-fir (solid). Within each species, means followed by similar letters are not significantly different ($p<0.05$).

Except in Douglas-fir, the effects of the root wrenching treatment on post-storage root growth capacity was equal to or better than the undercutting treatment.

The manual root wrenching treatment used in this experiment was more severe, and at a shallower depth than the machine root wrenching usually practiced in British Columbia nurseries. A second experiment to determine if similar results could be obtained using a standard wrenching bar for the root wrenching and the thin blade "Lotus" undercutter was conducted at the B.C. Ministry of Forests' Skimikin Nursery beginning in 1981.

The results from this experiment (fig. 8) suggests that root wrenching (RW) resulted in slightly shorter seedlings, but that the field growth of these seedlings was similar to seedlings receiving the undercut (U) treatment.

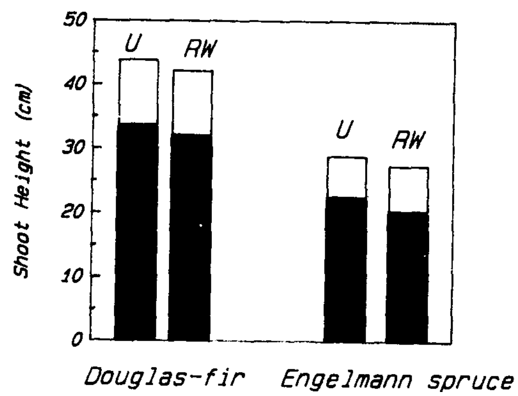

Figure 8.--Root culturing effects on average height of seedlings in the nursery (solid bar) and after one year on a forest planting site (open bar). U= undercut only; RW= root wrenched.

The conclusion drawn from these root culturing experiments is that as field performance of root wrenched and undercut seedlings seems to be similar, and likely better than non-root cultured seedlings, that the choice of root culturing method should be based on operational preference.

NUTRIENT LOADING OR FALL FERTILIZATION

Moisture stress and reduced fertilization are often used in forest nurseries to slow shoot growth, induce dormancy, and promote cold hardening of conifer nursery stock (Burdett and Simpson 1984). These practices can contribute to reduced tissue nutrient levels. Several authors (Anderson and Gessel 1966; Benzian et al. 1974; van den Driessche 1984) have reported improved field performance attributable to fall fertilization. Earlier experiments in B.C. nurseries (Donald and Simpson 1985) found that fall fertilization of seedlings with a balanced fertilizer (4-12-8) improved both root growth capacity and first year growth after outplanting.

To separate the effects of nitrogen (N), phosphorus (P), and potassium (K) on RGC and performance of outplanted stock, an experiment was undertaken at two interior nurseries (Red Rock near Prince George, B.C. and Skimikin near Salmon Arm, B.C.) and one coastal nursery (Surrey near Vancouver, B.C.). Four species were treated: white spruce ; Engelmann spruce ; lodgepole pine ; and interior Douglas-fir . Fifteen fertilizer treatments were applied to 2+0 bareroot seedlings 6 to 8 weeks before their being lifted to overwinter cold (-2°C) storage.

Root growth capacity was measured after a storage period of approximately 6 months (October-November to early May) and outplantings

were established in irrigated but not fertilized transplant beds at Skimikin nursery.
Significant RGC improvements in spruce from both Red Rock and Skimikin nurseries occurred only in those fertilizer treatments containing N (fig. 9). The RGC response was greater in Skimikin-grown stock than in Red Rock-grown stock and may be related to the higher N-uptake. Spruce stock which received N at a rate of 500 kg/ha 34-0-0 had foliage N levels increased from a level of 1.9% to 3.1% at Skimikin nursery and 1.5% to 2.0% at Red Rock nursery. Spruce stock treated at Surrey Nursery failed to show a RGC improvement, perhaps because little uptake of N was observed.

Lodgepole pine from Red Rock nursery regenerated large numbers of roots in all treatments, and there were significant RGC improvements in those fertilizer treatments containing N. Douglas-fir at Skimikin Nursery responded similarly, having higher RGP levels in those treatments containing N (fig. 9).

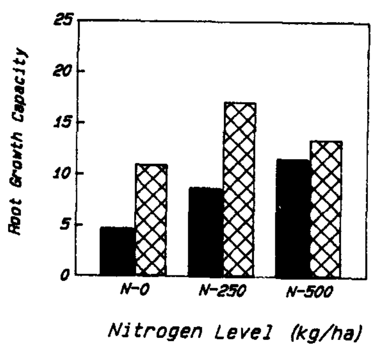

Figure 9.--Nutrient loading effects on root growth capacity (number of new roots longer than 10 mm per plant) of interior spruce (solid bar) and Douglas-fir (cross hatch bar). Means indicated are pooled values for treatments at Skimikin nursery where nitrogen (as 34-0-0) was applied at 0, 250, or 500 kg/ha.

Phosphorus applied singly, or in combination with other nutrients as top dressings was not taken up by any of the species, and there were no treatment effects on RGP or growth after outplanting. Potassium content was only slightly increased by fall applications of K; however, it was noted that N application decreased foliar K levels.

First year growth responses after outplanting were similar (fig. 10) to the RGC responses to fall fertilization treatment wherein those treatments containing N resulted in improved shoot growth.

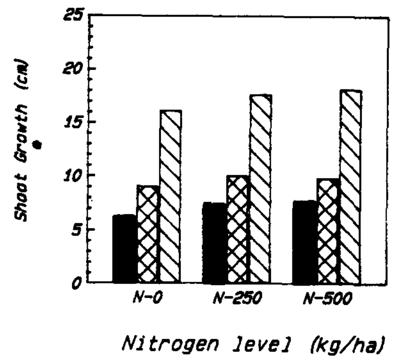

Figure 10.--Nutrient loading effects on root growth capacity (number of new roots longer than 10 mm per plant) of interior spruce (solid bar), Douglas-fir (cross hatch), and lodgepole pine (right hatch). Means indicated are pooled values for treatments at Skimikin and Red Rock nurseries where nitrogen (34-0-0) was applied at 0, 250, or 500 kg/ha.

In summary, significant positive improvements in post-storage RGC and subsequent field performance of 2+0 bareroot spruce, Douglas-fir and lodgepole pine nursery stock at interior nurseries should be expected with addition of N as 34-0-0 at rates of 250-500 kg/ha 6 to 8 weeks prior to lifting to overwinter (ca. 6- to 8-month) storage at -2°C. Spruce at coastal nurseries, such as Surrey, are not expected to respond to late season fertilizations as undertaken in this experiment.

OPERATIONAL TRIAL

Once it had been established that substantial improvements to bareroot nursery stock quality could be obtained by bed density reduction, root culturing, and nutrient loading, an operational demonstration of the combined effectiveness of these practices was undertaken.

The demonstration consisted of **six** 120 m long seedbeds sown with interior Douglas-fir, lodgepole pine, and white spruce. These beds were divided in half with the first 60 m of each bed receiving "normal" nursery culture (circa 1980-81) and the second 60 m receiving "improved" culture.

Seedbed density was reduced about one-half (table 3). Root culturing in the "improved culture" consisted of fortnightly wrenching at 15 cm depth from July 15-Sept. 30, while root culturing in the normal culture area was done much less frequently (exact details not available). Fall fertilization was applied as a single application of 34-0-0 fertilizer at

250 kg/ha on Sept. 1, which was 6 weeks prior to lifting. With the exception of the single fall fertilization, both normal and improved seedbeds received identical fertilizer applications.

First year field performance of the spruce was not measured; however, one Douglas-fir seedlot was outplanted as were two lodgepole pine seedlots. The results from these plantings (fig. 11) suggest that the seedlings grown with the improved cultural practice had significantly better first year field performance.

Table 3.--Operational demonstration.

Factor	*Normal Culture*	*Improved Culture*
Bed Density	*180-360*	*115-130*
Root Culture	occasionally	fortnightly
Nutrient Loading	none	250 *(34-0-0)*

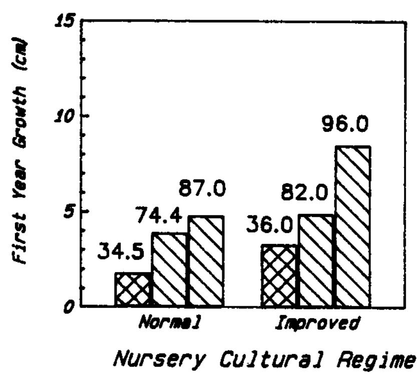

Figure 11.--First year survival (%) and growth (cm) of Douglas-fir (cross hatch) and lodgepole pine (right hatch) which received "normal" and "improved" nursery cultural regimes.

CONCLUSION

The data obtained in the preceding experiments suggests that there is potential to improve the field performance of 2+0 bareroot seedling for use in reforestation through relatively low cost changes to the nursery cultural practices used to grow this stock type. The economic efficiency of this stock *type* suggests it should receive serious consideration as a reforestation alternative.

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