FIELD PERFORMANCE OF SMALL-VOLUME CONTAINER-GROWN SEEDLINGS IN THE CENTRAL INTERIOR OF BRITISH COLUMBIA

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Abstract.--Operational plantations of interior spruce (*Picea glauca* [Moench] Voss, *Picea engelmannii* Parry), lodgepole pine (*Pines contorta* var. *latifolia* Engelm.), and interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) in the central interior of British Columbia were examined to compare field performance of small-volume container-grown seedlings and bare-root seedlings and transplants. The performance of interior spruce container-grown seedlings was judged superior to that of bare-root seedlings and transplants. Lodgepole pine container-grown seedlings survived and grew as well as bare-root seedlings. The performance of a limited number of Douglas-fir plantations was less than satisfactory for both stock types.

Résumé.--On a examiné des plantations d'épinettes (*Picea glauca* [Moench] Voss, *P. engelmannii* Parry), de pin tordu latifolié (*Pinus contorta* var. *latifolia* Engelm.) et de Douglas taxifolié (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) établies dans le centre de la Colombie-Britannique continentale en vue de comparer la performance en plein champ des semis en récipents de faible volume, des semis à racines nues et des semis repiqués. On a jugé que les semis d'épinettes en tubes ont présenté une meilleure performance que les semis à racines nues ou les semis repiqués. La survie et la croissance des semis en tubes de pin tordu latifolié ont été semblables à celles des semis à racines nues. Dans certaines plantations établies avec l'un et l'autre type de semis, la performance du Douglas taxifolié n'a pas été satisfaisante.

INTRODUCTION

Field performance assessments are an essential ingredient in the evaluation of any reforestation system. To adapt an old saying, "the proof of the system is in the growing". If the trees do not survive and grow, considerations such as low cost, manpower savings or technological innovations are irrelevant.

In the past the biological performance of container systems in British Columbia has been evaluated on the basis of experimental field trials or small-scale operational trials (Arnott 1974). The early results of such trials were sufficiently encouraging that, despite their limitations in terms of site coverage and favored treatment (e.g., quality nursery care, limited stock handling, and planting by research crews), the province embarked on a substantial program of containerization. Some 230 million "plug" seedlings grown in small-volume (40 cm^3) BC/CFS styroblock containers have been planted to date, and the number planted is currently increasing at a rate of 66 million per year. Therefore, it is now possible to rectify some of the problems associated with field performance assessments of experimental trials by examining performance of seedlings planted under more demanding operational conditions.

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The purpose of this paper is to present the results from 38 plantations of one-year-old container-grown seedlings of interior spruce (*Picea glauca* [Moench] Voss, *Picea engelmannii* Parry or a naturally occurring hybrid of the two species), lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), and interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) established across a range of sites in the central interior of British Columbia (Fig. 1). The plantations were established between 1972 and 1978 as part of the British Columbia Ministry of Forests' reforestation program in the Cariboo Region. The performance of container-grown plug seedlings will be compared with results from 214 plantations of two-year-old bare-root seedlings (2-0) and three-year-old transplants (2-1) of the same species established across a similar range of sites.

Figure 1. Map of British Columbia showing location of Cariboo Region and general location of the operational plantations sampled for this study.

PLANTATION PERFORMANCE CRITERIA

Most authors examining the performance of seedlings and plantations use one or more of the following biological criteria:

1) mortality (usually expressed as survival)
2) relative condition (e.g., good or poor)
3) absolute size (height, diameter, weight)
4) size increment (height, diameter, weight)
5) indices which are products of 1) and 3).

Each has its own peculiarities and problems. Percent survival, for example, can be misleading because it is a snapshot of a dynamic process; many seedlings might be in poor condition and on the verge of death at the time of assessment. Experimental investigation usually includes seedling condition as a second measure of performance in an attempt to assess probability of mortality, but this is a subjective measure and difficult to apply on a large scale. Absolute size is an objective criterion, and integrates all previous effects until time of measurement. However, a small seedling that is growing fast in relation to its size could be judged inferior to a large seedling growing slowly in relation to its size. Increment measures made over several years are more satisfactory because they permit reconstruction of the growth curve for individual seedlings without precluding use of the absolute size criterion. Performance indices are intuitively attractive because they permit a summary of two or more factors. For example, height and survival are combined in the concept of aggregate height proposed by Mullin and Howard (1973). However, such indices can also be very misleading because they exhibit the faults of the combined factors, while hiding their absolute values (e.g., an aggregate height of 2,000 cm can be achieved if all the trees in a plot of 100 reach 20 cm, or if half of them reach 40 cm). When costs are added in an attempt to provide an economic tool for decision making (Mullin and Howard 1973, Ball 1980), the potential for serious misjudgments is increased further.

In this study, three criteria will be used: survival, height increment expressed in the form of a growth curve from the time of plantation establishment, and relative height growth rate. Relative growth rate (RGR) is not a new concept but it has been used only occasionally in studies of forest seedling growth (e.g., Sweet and Wareing 1966). Defined precisely, RGR is the amount of growth per unit of plant material at the beginning of the growth period, per unit of time over which growth takes place. Agricultural crop physiologists first used the concept 60 years ago and its application has been vastly expanded since then (Hunt 1978). RGR is useful in the context of tree seedling performance because it allows an investigator to assess the *efficiency* of growth in relation to size. Since container-grown seedlings are often compared with bare-root seedlings that are much larger at the time of planting, the use of RGR is particularly appropriate in this study.

Expressed in mathematical terms, final plant size is related to initial plant size in the following way:

$$W_2 = W_1 \cdot e^{R(T_2-T_1)}$$

$$\text{thus } R(T_2-T_1) = \frac{\log_e W_2 - \log_e W_1}{T2 - T1}$$

where W_1 and W_2 are plant size at time T1 and T2, and R is relative growth rate.

PLANTATION ASSESSMENT METHOD

Height growth of 252 plantations was measured for three seasons according to the method outlined by Vyse (1981). Details of a slightly revised method are available from the Silviculture Branch, B.C. Ministry of Forests.

Second or third season survival data for most of the plantations that were measured for height growth and for additional lodgepole pine plantations (a total of 193) were extracted from Ministry of Forests records. Almost all the plantations measured were located in the moist eastern half of the region (Fig. 1) where annual precipitation ranges from 600 mm to 1,200 mm. They were distributed among three biogeoclimatic zones: sub-boreal spruce; interior cedar-hemlock; and Engelmann spruce-subalpine fir (Annas and Coupe 1979). The distribution of plantations by species and stock type is shown in Table 1, and represents approximately 90% of those planted with interior spruce and interior Douglas-fir between 1972 and 1978. The low number of lodgepole pine plantations is due to insufficient operational survey work, but the low number of Douglas-fir container plantations reflects the limited scale of planting with that species and stock type.

Most of the plantations assessed were established on areas treated by prescribed burning or mechanical means to remove slash, and rarely suffered from severe brush competition.

The analysis of plantation assessment data is based on means of sample tree internode lengths, and the growth curves and relative growth rate are based on means of plantation means.

Table 1. Number of plantations assessed for height growth by species and stock type.

Species	No. of plantations per stock type[a]			
	1-0 P	2-0 BR	2-1 BR	Total
Interior spruce	27	115	74	216
Interior Douglas-fir[b]	4	17	2	23
Lodgepole pine	7	6	0	13
Total	38	138	76	252

[a]P = plugs or container seedlings; BR = bare-root

[b]All plantations located in interior cedar-hemlock zone

RESULTS AND DISCUSSION

Survival

The survival records for operational plantations (Table 2) show that plug seedlings of all three species examined perform at least as well as conventional bare-root stock. In the case of interior spruce and lodgepole pine the probability of high rates of survival (>90%) is, in fact, considerably greater for plugs than for either seedlings or transplant bare-root stock, a result which is supported by work in the southern interior (Clark and Elmes 1980) and by the opinions of local foresters. An examination of the survival records also indicates that the performance of spruce plug stock has improved over time (performances below 80% in Table 2 date back to 1974), whereas bare-root spruce performance has remained quite variable. Conversely, bare-root pine performance has improved in recent years. Some poor performances at an early stage were the result of low root growth capacity of seedlings before planting (Burdett 1979).

There were insufficient interior Douglas-fir plug plantations to allow a comparison with bare-root plantations. The growing of fir plug stock has been restricted because the standard low cost techniques used in British Columbia container nurseries have failed to produce fir seedlings with a satisfactory root plug[2]. However, bare-root survival of interior Douglas-fir varies as it

[2]E. Van Eerden, 1981 (Personal communication)

Table 2. Distribution of plantation survival by percentile classes for species and stock type.

Species	Stock type	No. of plantations per survival class[a] 90	80	70	60	50	40	30
Interior spruce	1-0 P	17	-	3	1	2	-	-
	2-0 BR	15	16	11	10	6	3	3
	2-1 BR	19	8	5	4	1	1	1
Interior Douglas-fir[b]	1-0 P	1	1	1	-	-	-	-
	2-0 BR	7	6	2	1	1	3	-
Lodgepole pine	1-0 P	12	2	2	-	-	-	-
	1-0 BR	6	6	6	3	5	2	-

[a]10 percentile classes (e.g. 80%-89%); 90 percentile class includes plantations with 100% survival.
[b]All plantations located in interior cedar-hemlock zone.

does with the other species, a factor which gives rise to the possibility that extensive use of plug stock might lead to improved survival, provided that nursery problems can be solved and large numbers of satisfactory seedlings can be produced.

Height Growth and Relative Growth Rate

Figure 2 presents the height-age and relative growth-age curves for each species and stock type. Performance of the 2-1 spruce stock type is not recorded because it is very similar to that of 2-0 stock. The initial height advantage of bare-root stock was maintained and, in the case of lodgepole pine and interior Douglas-fir, actually increased. The differential in absolute size amounted to less than one year of growth after six years in the case of pine, and two years of growth after five years in the case of fir. However, with interior spruce the initial size differential was not maintained and after five seasons of growth the mean height of plug stock plantations surpassed that of bare-root plantations.

The relative growth rate curves (Fig. 2 d, e, f) in effect measure the slope of the height-growth curve, and permit closer examination and partial explanation of the growth pattern. For spruce the eventual superiority in absolute size of plug stock is attributable to higher RGR in each year following planting, and thus a steeper height-age curve, despite a precipitous drop in RGR after one year. Possible explanations for this marked second year "decline" have been examined by Vyse (1981). The early growth of pine plug stock growth in relation to size was higher than for spruce and reduced some of the initial advantage held by bare-root stock. But after three years the RGR of both stock types went into decline also and there was no further reduction in the size gap.

The initial size difference between stock types was largest for Douglas-fir. Consequently, the small advantage in RGR of the smaller plug stock did not have much effect on the height advantage of the bare-root stock.

Figure 3 provides some further explanation of the growth trends. The curve of RGR against mean seedling size at the beginning of each growing season shows that, for each species, plug stock grew faster than bare-root seedlings of the same size up to about 30 cm in initial height.

Only for spruce was there any indication that the superior performance continues beyond the initial years. This apparent trend must, however, be treated with some caution. At least one plantation on a good growing site (93B16-15) with a side by side comparison of plug and 2-0 stock types showed superior early RGR of plug stock (Table 3), but unlike the aggregate plantation trend, the superiority did not continue beyond 30 cm initial height. It is possible that the combined data for spruce plug stock plantations contain a bias which elevates the mean performance of that stock type in later years. Alternatively, the early advantage of plug stock may be accentuated and extended on poorer sites.

CONCLUSIONS

A comparison of survival and growth records obtained from operational plug and bare-root plantations established on prepared sites in the Cariboo Region of British Columbia permits several conclusions of practical significance:

1. Valuable information on the comparative performance of stock types can be gleaned from operational survival and growth assessments despite the problems associated with analyzing data collected from heterogenous plantations by staff with little interest in research.

2. Plug seedlings from small-volume containers suffer less mortality than bare-root seedlings or transplants established on similar sites. For lodgepole pine and interior spruce plug plantations the probability of any plantation suffering

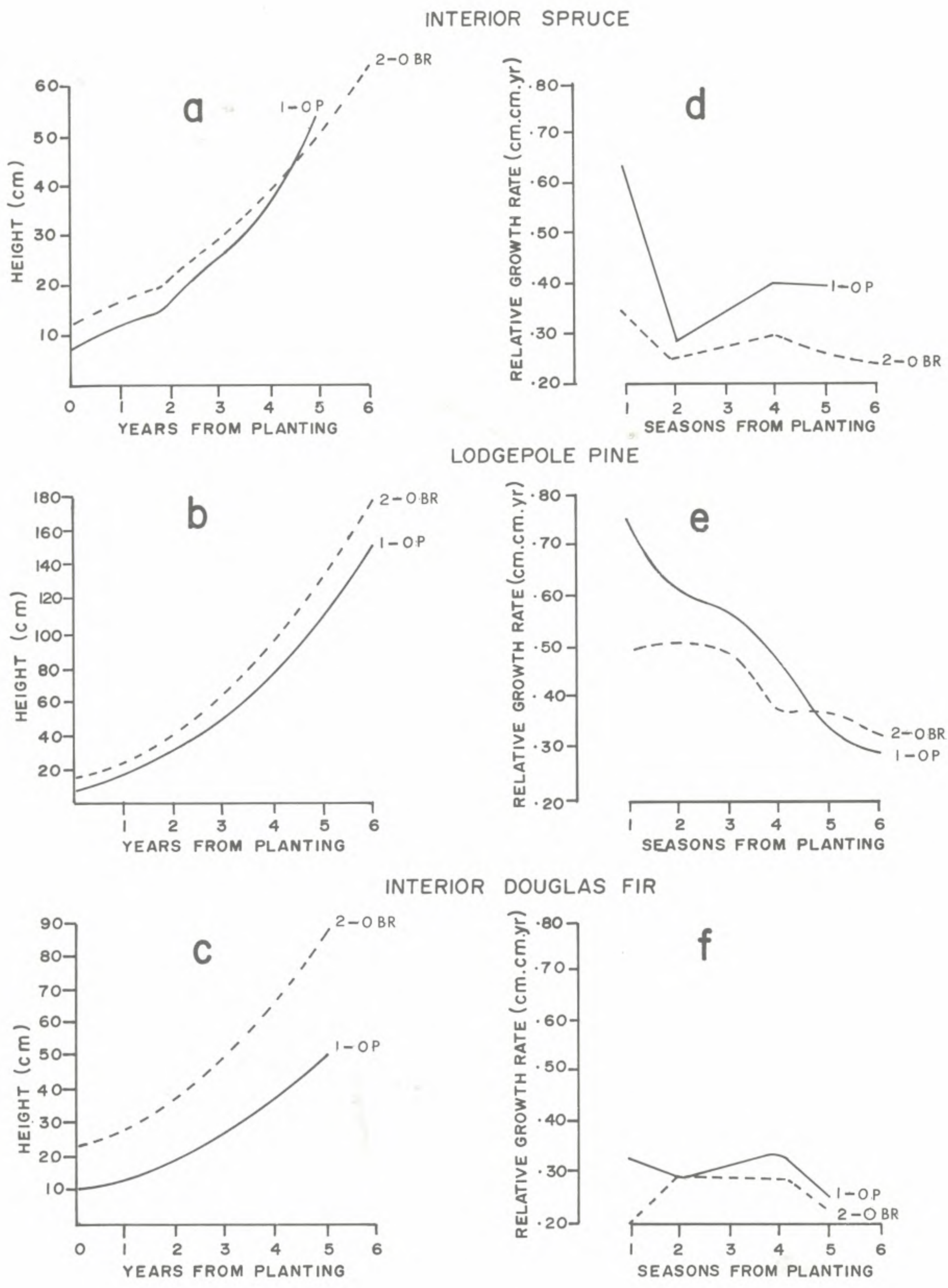

Figure 2. Height growth and relative growth rate of interior spruce, interior Douglas—fir and lodgepole pine 1-0 plug and 2-0 bare—root seedlings in operational plantations.

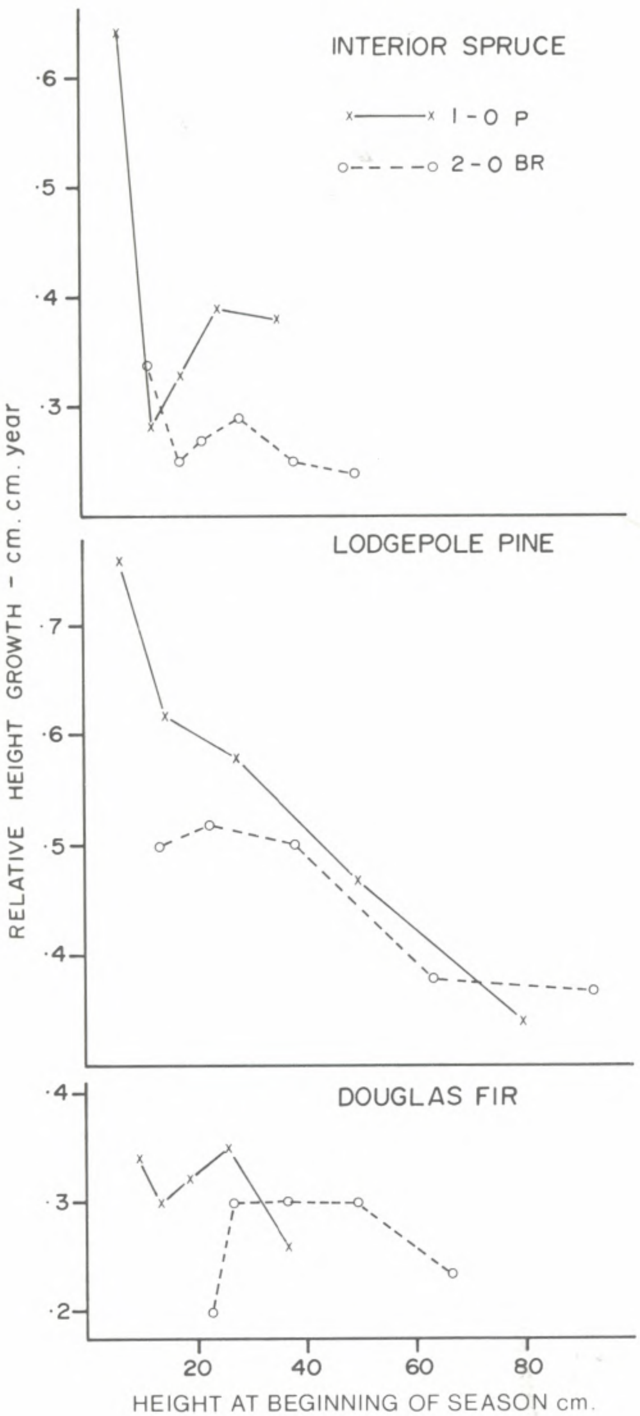

Figure 3. The relationship between RGR and mean seedling size at the beginning of each growing season.

losses of less than 10% after two years is very high. And it seems probable that Douglas-fir plug plantations will match this record once nursery production problems are resolved.

3. The early growth performance of small plug stock is superior to that of standard sized bare-root stock. Within a height range of 15 to 30 cm, plug seedlings of all three species examined outgrew bare-root plants of the *same size* established on a similar range of sites, and beyond that range, growth rates were similar except for interior spruce. However, the continued superior growth of spruce plug stock should be treated with considerable caution until more detailed supporting evidence is available.

4. According to widely held views about stock type performance, the bare-root stock should have outperformed the plug stock because it was larger at the time of planting. The results do not provide any evidence to support this influential "bigger is better" dogma. Indeed, some of the results clearly contradict it. And even though the bare-root stock of fir and pine was larger than equivalent plug stock after five or six years of growth, the similarity in *growth rate* of both stock types suggests that the present absolute size differential will change with the increment pattern of the species, and that the relative size differential will decrease substantially. As it is doubtful if a mean difference of one or two years of increment will be detectable after 60 or 70 years of growth, claims of superiority on this basis are of dubious practical significance. Although the results of the study are not sufficient to relegate the "bigness" fixation to the status of an unsubstantiated slogan, they do indicate that some reformulation of ideas is necessary before British Columbia foresters have a useful theory with which to predict stock type performance. Such a task is beyond the scope of this paper. In the meantime the practitioner should take full advantage of the fact that vigorous seedlings, grown in and extracted from small-volume containers, are capable of matching and even exceeding the performance of larger bare-root plants on a wide range of prepared sites in the central interior of British Columbia.

Table 3. Height growth and RGR for selected superior plantations with 1-0 plug and 2-0 bare-root of same species planted on similar sites.

Species	Plantation	Stock type	Performance criterion[a]	Seasons following planting 0	1	2	3	4	5	6
				(cm or cm/cm/yr)						
Spruce	93B16-15	1-0 P	H	5	9	18	31	48	67	86
			RGR		.59	.69	.54	.44	.33	.25
Spruce	93B16-15	2-0 BR	H	13	19	27	43	64	83	102
			RGR		.38	.36	.46	.38	.28	.20
Douglas-fir	93A11-6	1-0 P	H	8	12	18	29	41	57	79
			RGR		.40	.41	.48	.34	.33	.33
Douglas-fir	93A11-3	2-0 BR	H	19	24	30	42	61	84	110
			RGR		.24	.22	.34	.37	.32	.27
Lodgepole pine	93G1-47	1-0 P	H	5	9	21	43	69	97	132
			RGR		.59	.84	.72	.47	.32	.31
Lodgepole pine	93G1-49	2-0 BR	H	13	20	36	60	86	114	151
			RGR		.44	.58	.51	.36	.29	.29

[a]H = Height growth measured in cm; RGR = Relative growth rate measured in cm per cm of initial height per year or season.

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