The Influence of Nursery Systems on Plantation Establishment in British Columbia

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ABSTRACT

The Styroblock Reforestation System now accounts for 91% of the total of 299 million trees sown this year fo outplanting in British Columbia, largely replacing conventional bare-root stock. This paper compares the survival an growth over a 10- to 11-year period of some of the major tree species outplanted in research trials over a range of site using both reforestation systems. Container-grown seedlings had significantly higher survival than bare-root stock an grew at comparable rates for all species except Douglas fir. This, plus competitive costs for producing, transporting an planting container-grown seedlings, yields a significant cost-saving to the industry when establishing new forest plantations.

KEYWORDS: Bare-root, container, economics, *Pseudotsuga menziesii, Tsuga heterophylla, Picea glauca, Pinus contorta*

INTRODUCTION

Container reforestation systems are not new in Canada or throughout the world. In the early 1960s, several types of container were developed in Scandinavia (Räsänen, 1981) and Canada (Cayford, 1972; Kinghorn, 1970; Walters, 1961). The main impetus behind this development was the rapid expansion of reforestation programs in these regions and the belief that containerisation would provide the means of attaining these new reforestation targets in a cost effective manner. It was claimed that containerised reforestation systems would increase planting productivity, improve growth performance, and lend themselves to mechanisation, thus reducing labour input, and hence cost.

The most successful system to emerge in western Canada was the Styroblock Reforestation System (Arnott, 1973). After its introduction in 1971, when it accounted for 1.5% of total nursery sowings (Bamford 1974), it went through a decade of slow but progressive growth and has since expanded very rapidly. Presently, it accounts for more than 90% of all nursery sowings (Fig. 1). One of the underlying reasons for the successful introduction of the Styroblock Reforestation System was that container-grown seedlings survived better and grew as well as bare-root stock for most tree species in British Columbia. This, combined with the efficiencies attained with container reforestation systems, and their cost competitiveness has contributed greatly to its current success.

The purpose of this paper is, firstly, to describe results from experiments where the field performance of styroplug seedlings was compared with that of bare-root stock for some of the most important reforestation species in British Columbia, and, secondly, to provide an economic analysis which demonstrates the cost effectiveness of the Styroblock Reforestation System. The tree species selected were Douglas fir (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), white spruce (*Picea glauca* (Moench) Voss) and lodgepole pine (*Pinus contorta* Dougl.), which account for a respective 4, 2, 36, and 29% of the total 299 million seedlings sown in 1989. Douglas fir and western hemlock were evaluated in trials established in 1973 on southern Vancouver Island within the Coastal Forest Region. Results from work with the remaining two species were obtained from trials established in the central interior of the province between 1970 and 1972.

MATERIALS AND METHODS

Seedling Culture: Container Stock

Container seedlings were grown in BC/CFS Styroblock 2 containers (Beaver Plastics Ltd., Edmonton, Alberta) in the nursery of the Pacific Forestry Centre, Victoria, British Columbia (Lat. 48°28'N; Long. 123°24'W). The cavities in these styrofoam blocks have a top diameter of 24 mm, a

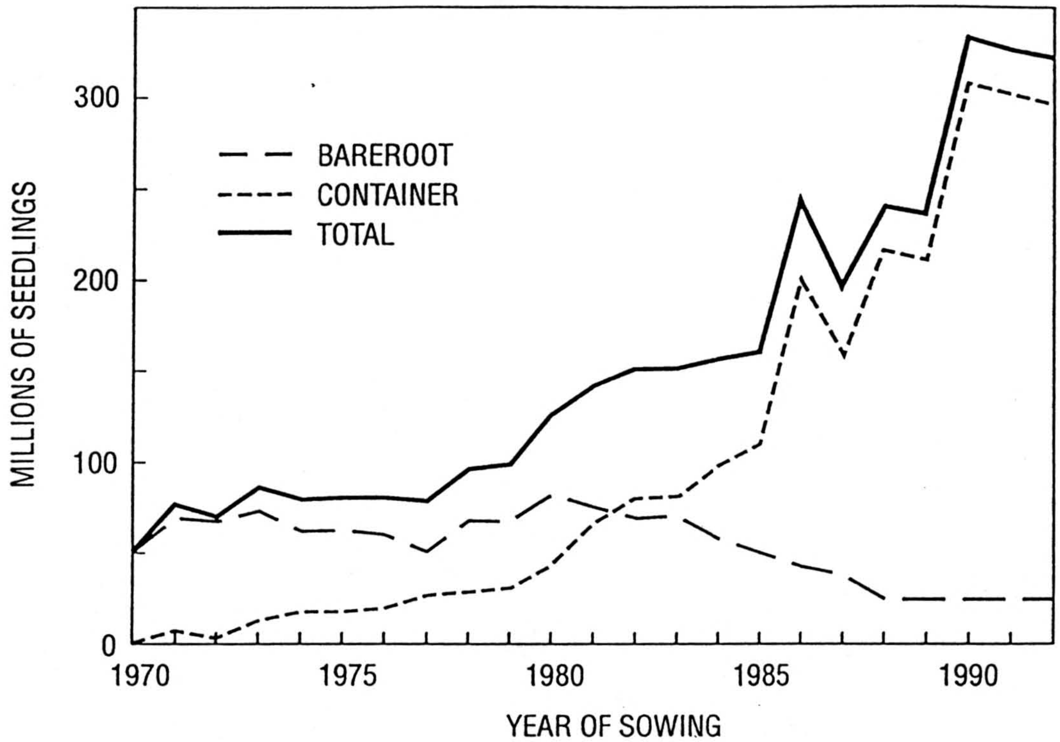

FIGURE 1 - Numbers of container and bare-root seedlings sown and projected in British Columbia forest nurseries, 1970-1992 (Source: R. Huber, Silviculture Branch, B.C. Ministry of Forests).

volume of 36 cm³ and a spatial density of 1055 cavities/m². Stock grown in these containers are known as styroplug seedlings. The growing medium used in the styroblocks was a 3:1 mixture of sphagnum peat and horticultural grade vermiculite containing 3 kg/m³ dolomite lime (1.4 mm and finer). Seed sources of container-grown and bare-root seedlings were matched to the planting locations. Container seedling culture of the coastal species (Douglas fir and western hemlock) was different from that used for the interior species (white spruce and lodgepole pine); they will be described separately.

The coastal species were sown in early April 1972, germinated in a heated (21 °C) greenhouse, and transferred to an outdoor growing area where shadecloth provided 20 and 46% shade to the Douglas fir and western hemlock, respectively. Irrigation water and soluble fertilizers were applied with fixed sprinklers. Seedlings were fertilized twice a week with 10-52-10 (N-P-K) (Plant Products Ltd., Bramalea, Ontario) at a concentration of 625 mg/*l* for 2 weeks following germination. Thereafter, 28-14-14 (N-P-K; Plant Products Ltd.) was applied twice a week at a concentration of 310 mg/*l* from June to August. Every two weeks throughout the fall, 10-52-10 was applied at the above concentration. Research had demonstrated that additional phosphorus applied during the autumn substantially increased seedling dry weight (Van Eerden, 1974). The seedlings were overwintered in the nursery where they were fed 10-52-10 (625 mg/*l*) from one to three times a month until planted. Morphological characteristics of the seedlings are shown in Table 1.

TABLE 1 – Mean seedling size of 1-0 styroplug and 2-0 bare-rootstock at the time of planting

Species	Stock type	Shoot length (cm)	Dry weight (g)[1]		
			Shoot	Root	Total
Douglas fir	Styroplug	12	0.63	0.46	1.09
	Bare-root	20	1.65	1.14	2.79
Western hemlock	Styroplug	15	0.51	0.25	0.76
	Bare-root	15	1.30	0.47	1.77
White spruce	Styroplug	13	0.44	0.24	0.68
	Bare-root	18	1.53	0.48	2.01
Lodgepole pine	Styroplug	14	0.58	0.28	0.86
	Bare-root	17	2.14	0.58	2.72

[1] 24 hours at 65 °C.

In 1970/71, the interior species were sown in early March in a heated (21 °C) greenhouse with an 18-h photoperiod (natural day length plus incandescent lighting at 36 μmol/m²s). Seedlings remained in the greenhouse for approximately 12 weeks, at the end of which time, they were transferred to an outdoor growing area where shadecloth provided 30% shade for lodgepole pine and 46% for white spruce. The seedlings were fertilized fortnightly with applications of 28-14-14 at 187–374 mg/*l* from late March to late June when they were shipped to the planting sites near Prince George. In 1972, the spruce and lodgepole pine seeds were sown in early January in the same greenhouse using similar heating and photoperiod conditions. Following germination, the seedlings were fed using the same fertilizers, concentration and frequency of application described above for Douglas fir and western hemlock; 28-14-14 was applied at a slightly higher concentration of 375 mg/*l*. During the third week of May, the stock was shipped in the containers to Red Rock nursery (Lat. 53°41'N; Long. 122°40'W) near Prince George where they were held and fed 10-52-10 twice weekly until planting in early July, 1972. The mean morphological characteristics of these seedlings are shown in Table 1.

Seedling Culture: Bare-root Stock

The coastal and interior 2-0 bare-root stock was grown at the British Columbia Ministry of Forests' nurseries at Duncan (Lat. 48°47'N; Long. 123°42'W) and Red Rock, respectively. The cultural procedures for rearing this stock are given by van den Driessche (1969). All bare-root stock was lifted in early winter (interior) to mid- winter (coastal) when fully dormant (Burdett and Simpson, 1984; Lavender, 1984) and cold stored at 2 °C (Douglas fir and western hemlock) and at –2 °C (white spruce and lodgepole pine) until planting. Morphological characteristics of the bare-root stock are shown in Table 1.

Study Areas: Coastal Region

Douglas fir and western hemlock were outplanted in the upper valleys of the Robertson (Lat. 48°44'N; Long. 124°03'W) and Leech (Lat. 48°32'N; Long 123°48'W) rivers on southern Vancouver Island. Both locations fell within the Coastal Western Hemlock biogeoclimatic zone (Klinka *et al.* 1984). At Leech River, test plots were established on both the north and south facing slopes of the valley. Elevation above sea level ranged from 640 to 550 m at Robertson and Leech, respectively. Mean annual precipitation in this area ranges from 2500 to 3000 mm, less than 5 to 10% of which falls during June, July and August (Korelus and Lewis, 1976; Roemer and Korelus, 1975). Mean annual temperature is 9 °C with a seasonal mean temperature (April-September) of 17 °C. Growing degree days greater than 5 °C are 1540. Soils are well drained, coarse textured, mini to orthic humo-ferric podzols (Korelus and Lewis, 1976). Average soil depth to glacial till at the planting sites was 60–80 cm. Slopes ranged from steep at Robertson (50%) to moderate at Leech (30%). Prior to logging, the areas had supported mature stands of Douglas fir and western hemlock admixed with amabilis fir (*Abies amabilis* (Dougl.) Forbes) and western red cedar (*Thuja plicata* Donn). Slash burning after logging reduced the surface organic layers to 3–4 cm and resulted in a dense vegetative cover of fireweed (*Epilobium angustifolium*).

Study Areas: Interior Region

White spruce and lodgepole pine were outplanted from 1970 to 1972 at three test sites within a 100 km radius of Prince George (Lat. 53°55'N; Long. 122°45'W). All areas fell within the Sub-Boreal-Spruce biogeoclimatic zone (Meidinger *et al.*, 1984) with elevation above sea level ranging from 670 to 915 m. The climate of this region is continental, with long, cold winters and cool, moist summers. Mean annual temperature in the study areas is 2–3 °C with a seasonal mean temperature (May–September) of 11.5 °C. Growing degree days greater than 5 °C are 970. Mean annual precipitation ranges from 600 to 900 mm with 300 mm falling within the growing season. Unlike the coastal climate, precipitation here is fairly evenly distributed throughout the growing season. Average soil depth to glacial till at the planting sites was 80 cm. Other characteristics of the sites are summarized in Table 2.

Planting, Experimental Design and Seedling Appraisal

The coastal plantations were established in early March 1973. Those in the interior were established in late June to early July, from 1970 to 1972. Styroplug seedlings were extracted from the styroblocks on site and dibble-planted without interim cold storage. Bare-root stock was planted using mattocks; the white spruce and lodgepole pine bare-root stock, which had been stored at –2 °C, was removed from the storage units several days before outplanting and held in a cool, shaded environment to allow the stock to thaw out.

The field trials used a randomised block design. In the coastal trials, a series of three and six randomised blocks were set out at Robertson and Leech Rivers, respectively per species. In each block, 50 seedlings per stock type

TABLE 2 – Site characteristics of the interior plantations

Area Lat. Long.	Soils[1]	Previous Stand[2]	Logging, Site Prep. and Planting
McLeod Lake 54°52' N, 122°58' W	Brunisolic Gray Luvisol, Fine texture, Poor to imperfect drainage	Sw, B1, P1	Log 1964; Burn 1967; Plant 1970
Clucultz Lake 53°53' N, 123°34' W	Brunisolic Gray Luvisol, Coarse texture, Moderately well drained	P1, Sw	Log 1969; Scarify 1969; Plant 1971
North Purden 54°00' N, 121°57' W	Orthic Gleyed Gray Luvisol, Fine texture, Poor to imperfect drainage	Sw, B1, Df	Log 1971; Burn 1972; Plant 1972

[1] Canada Department Agriculture (1970).

[2] Tree species' symbols: Sw = white spruce; P1 = lodgepole pine; Df = Douglas fir; B1 = subalpine fir (*Abies asiocarpa* (Hook.) Nutt.).

were planted at 2 x 1 m for each species for a total of 450 trees per stock type per species. The interior trials used a similar design of three randomised blocks per species at each of the three test sites. Fifty seedlings per stock type were planted at 2 x 2 m spacing in each of the blocks in all areas except at McLeod Lake where the total per stock type was 35. Thus, a total of 405 seedlings per stock type per species were outplanted in the interior plantations. No weeding or brushing was done in the plantations throughout the study period.

Seedling survival and height growth measurements were made after the first, second, third and fifth growing seasons at all locations. Subsequent remeasurements were made after the 10th and 11th growing seasons on the interior and coastal plantations, respectively. Analysis of variance and Tukey's mean separation test were used to determine treatment differences within a species (Steele and Torrie, 1980). Arcsin transformation was done on the percent survival data.

RESULTS

Coastal Region

Douglas fir seedling survival 5 and 11 years after planting was not significantly different between stock types or among areas (Table 3). As there were no significant interactions between areas and stock types for percent survival and seedling height in the statistical analyses, results were averaged by area and stock type in Table 3. Styroplug seedling survival was usually slightly less than that of bare-root stock over the 11-year study period (Fig. 2A). Although Leech South had taller trees at the end of 11 years, there were no significant differences in seedling heights between styroplug and bare-root stock (Table 3). The older 2-0 bare-root stock were taller at the time of planting and a significant differential remained throughout the first 5 years after planting. Subsequently, greater variation in growth among both stock types reduced the difference to a non-significant level (Table 3; Fig. 2B).

Significantly higher survival rates were obtained for western hemlock using styroplug seedlings (Table 3; Fig. 3A). There were differences among the test areas with significantly lower survival and seedling heights on the Leech South and Leech North test sites, respectively. The species survived much better on the cooler, north aspects typical of Robertson and Leech North but it did not grow well on the drier range of sites of the Leech north plantations (Table 3). Although the styroplug seedlings were significantly taller than the bare-root stock 5 years after planting, these relatively small differences had become insignificant by the 11th year after planting (Table 3).

Interior Region

White spruce and lodgepole pine styroplug seedlings had significantly higher survival than bare-root stock within the first growing season and this pattern continued throughout the 10-year study period (Figures 4A and 5A). As was the case in the coastal region, there were no significant interactions between area and stock type for seedling survival of both species. Therefore, results are averaged by area and stock type in Table 4. Five years

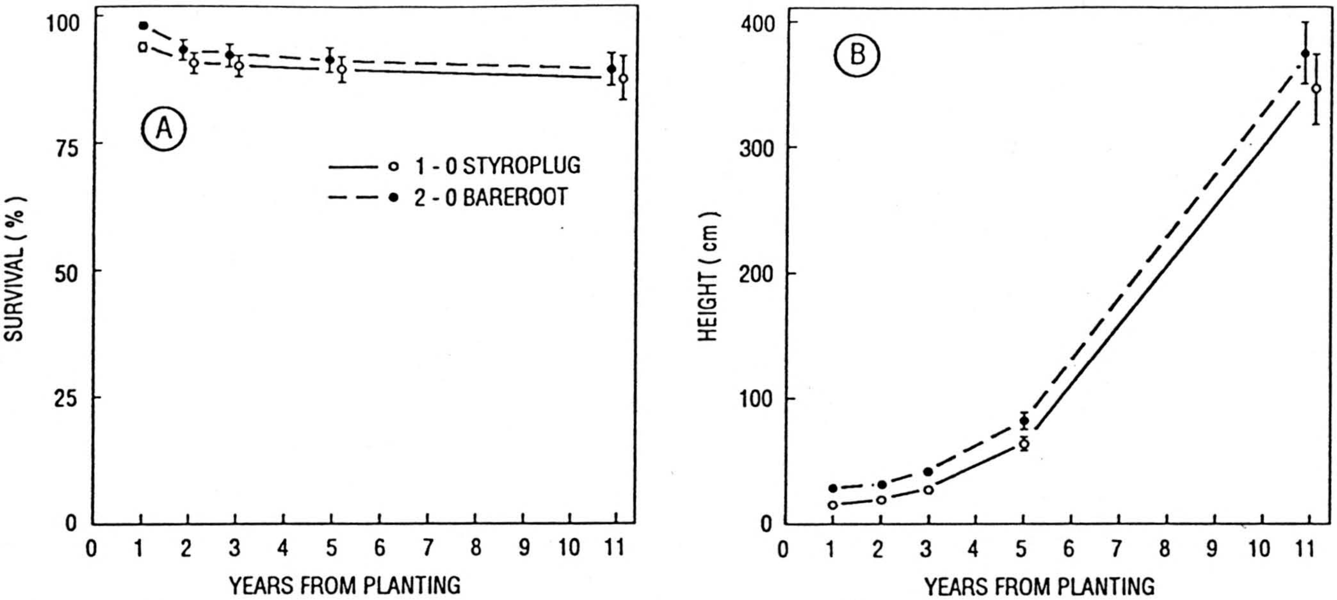

FIGURE 2 - Percent survival (A) and height (B) of Douglas fir styroplug and bare-root seedlings. Vertical bars represent ± 1 SE.

TABLE 3 – Douglas fir and western hemlock: 5 and 11 year survival and height, by area (R = Robertson; LN = Leech North; LS = Leech South) and stock type

Species	Area			Stock type	
	R	LN	LS	Styroplug	Bare-root
5-YEAR					
			Survival (%)		
Douglas fir	90a	94a	85a	89c	91c
Western hemlock	94a	90a	55b	88c	71d
			Height (cm)		
Douglas fir	61a	65a	92b	63c	81d
Western hemlock	73a	44b	71a	67c	56d
11-YEAR					
			Survival (%)		
Douglas fir	85a	93a	85a	87c	89c
Western hemlock	92a	87a	52b	84c	70d
			Height (cm)		
Douglas fir	319a	300a	454b	343c	372c
Western hemlock	273a	135b	275a	234c	221c

NOTE: Reading across, within species by area and stock type, means followed by the same letter are not significantly different at the 5% level. Analyses based on a total of 900 trees per species.

after planting, the difference in survival between these two stock types was 18% for white spruce and 11% for lodgepole pine (Table 4). While the 2-year-old bare-root stock was taller than the 1-year-old styroplug seedlings at the time of planting for both species, these differences soon became insignificant. The relatively faster growth rate of the styroplug stock in the initial years following planting, as was also found by Vyse (1981) for many pine and spruce plantations, accounted for the early convergence in the height growth curves (Figures 4B and 5B). However, white spruce seedlings showed divergence in height growth beyond the fifth growing season. There were significant growth and survival differences for both species among the three test sites as would be expected from their inherent

TABLE 4 – White spruce and lodgepole pine: 5 and 10 year survival and height, by area (ML = McLeod Lake; CLU = Clucultz; NP = North Purden) and stock type

Species	Area			Stock type	
	ML	CLU	NP	Styroplug	Bare-root
5-YEAR					
			Survival (%)		
White spruce	86a	64b	74ab	84c	66d
Lodgepole pine	82a	84a	69a	84c	73d
			Height (cm)		
White spruce	35a	38a	66b	45c	47c
Lodgepole pine	63a	76a	128b	87c	92d
11-YEAR					
			Survival (%)		
White spruce	84a	60b	72a	81c	63d
Lodgepole pine	81a	77ab	66b	79c	70d
			Height (cm)		
White spruce	128a	122a	188b	139c	153c
Lodgepole pine	283a	305a	469b	356c	348c

NOTE: Reading across, within species by area and stock type, means followed by the same letter are not significantly different at the 5% level. Analyses based on a total of 810 trees per species.

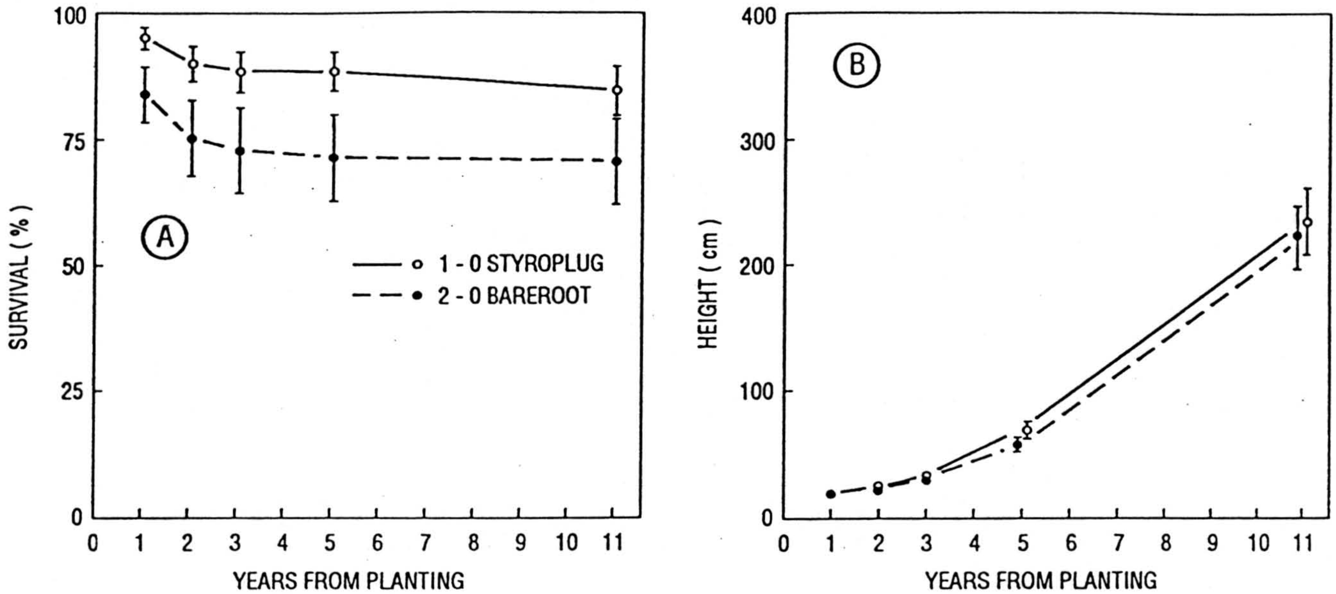

FIGURE 3 - Percent survival (A) and height (B) of western hemlock styroplug and bare-root seedlings. Vertical bars represent ± 1 SE.

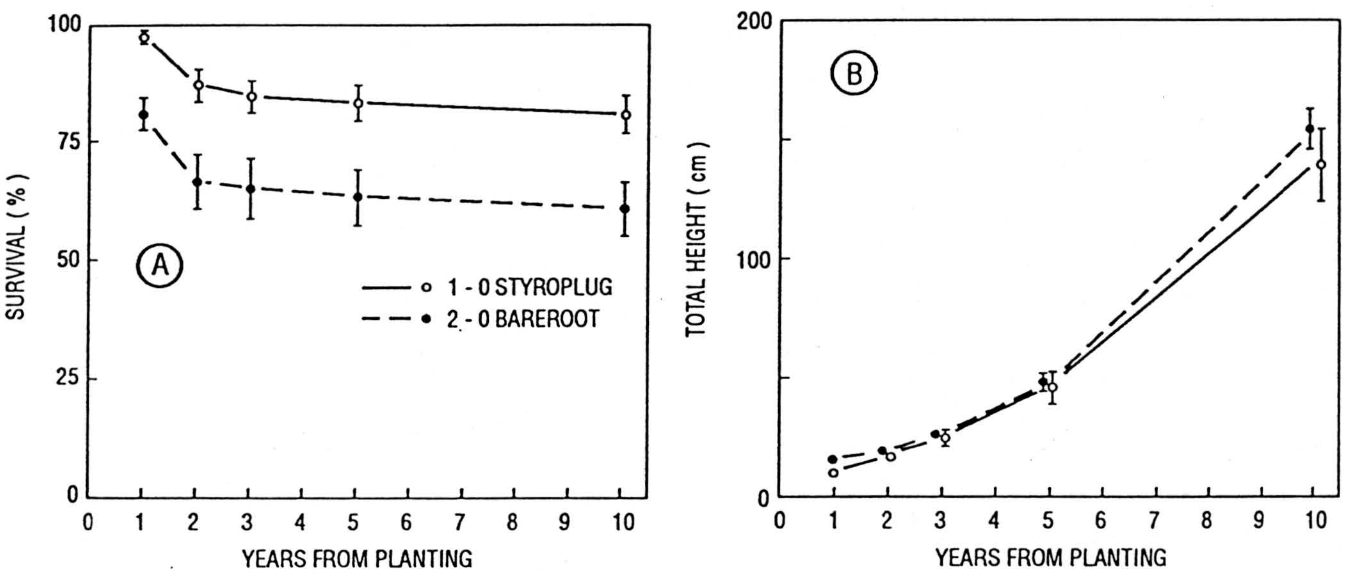

FIGURE 4 - Percent survival (A) and height (B) of white spruce styroplug and bare-root seedlings. Vertical bars represent ± 1 SE.

ecological variation. The tallest trees of both species were found at North Purden area where soils and climate favoured faster growth rates. There were no significant growth differences in either species between the other two areas.

ECONOMICS

In order to maximise financial return from a stand of trees, the objective must be to maximise the net present value (NPV) of the anticipated value of wood products from the stand, less the NPV of all management costs, such as seedling production, planting, brushing, thinning and fertilisation. The results presented here have shown that tree growth 10 to 11 years after planting is not significantly affected by the stock type selected. The analysis can thus be restricted to determining the most cost effective means of producing and planting a desired number of surviving seedlings, with the assumption that the surviving seedlings will grow similarly thereafter regardless of which nursery system was selected to grow the planting stock.

Costs to be considered in site establishment include seedling production, transportation, storage, site prepara-

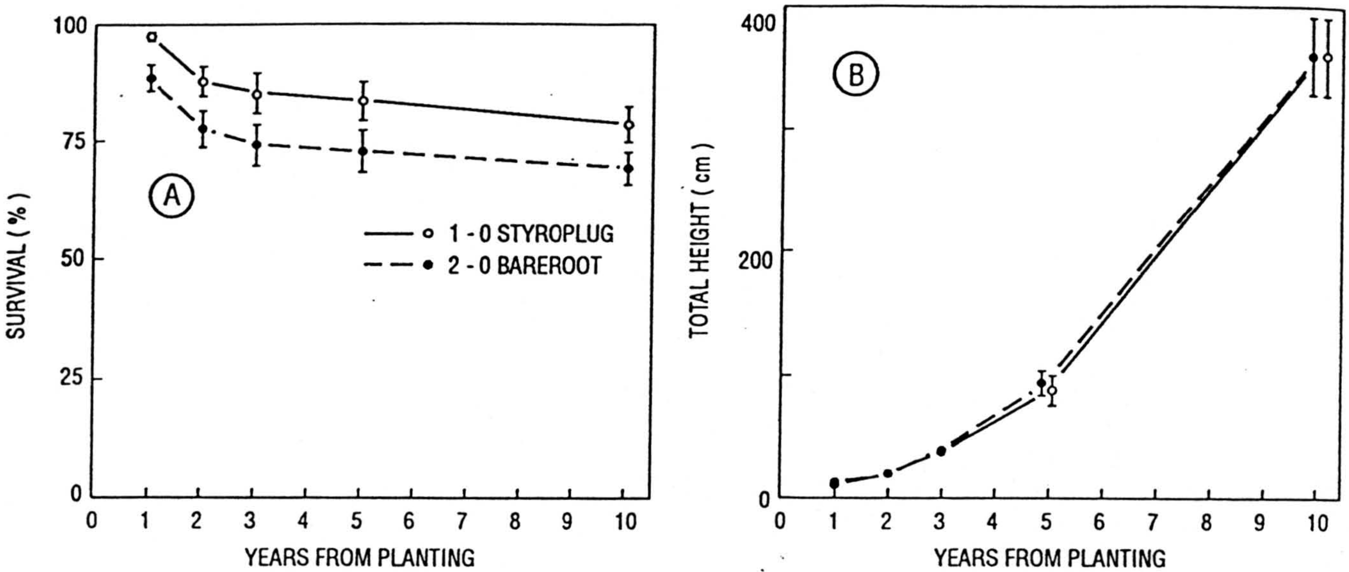

FIGURE 5 - Percent survival (A) and height (B) of lodgepole pine styroplug and bare-root seedlings. Vertical bars represent ± 1 SE.

tion and planting (R.S. Danielson, unpublished report).

The other key variable in the analysis is the survival rate. Higher survival rates mean fewer seedlings would have to be handled, thus reducing the total cost of site establishment. Table 5 shows the cost of producing, storing, transporting, site preparing and planting 1000 bare-root and styroplug seedlings for each of the four species covered in this study. Throughout British Columbia, 1000 trees per

TABLE 5 – Relative cost in Canadian dollars of establishing a site with 1000 surviving seedlings after 5 years using bare-root (BR) and styroplug (SP) seedlings

Type of Cost[1]	Cost per thousand seedlings							
	Douglas fir		Western hemlock		White spruce		Lodgepole pine	
	BR	SP	BR[2]	SP	BR	SP	BR	SP
Production	135	175	135	163	135	154	135	146
Transportation and Storage	15	15	15	15	15	15	15	15
Site preparation	344	344	344	344	222	222	222	222
Planting	370	370	370	370	287	287	287	287
Total cost	864	904	864	892	659	678	659	670
Survival rate (%)[3]	91	89	71	88	66	84	73	84
Adjusted cost per 1000 surviving seedlings	949	1016	1217	1014	998	807	903	798

[1] Source: Production and planting costs (1988-89) from Ralph Winter and Kathy Mitchell, Silviculture Branch, B.C. Ministry of Forests (BCMOF), Victoria, B.C. Site preparation costs from 1986-87 Annual Report, BCMOF, Victoria, B.C. Transportation and storage costs from R.S. Danielson, unpublished report .

[2] There is no longer any western hemlock bare-root stock production. For comparison, it was assumed that production cost would be similar to that of the other species.

[3] Five years after planting.

hectare is an approximate target for many plantations over a wide range of ecosystems and regions. The adjusted cost per 1000 surviving seedlings 5 years after planting was obtained by incorporating the variable survival rates of the species by stock type to obtain an expected cost per surviving seedling. The cost per surviving seedling was then multiplied by 1000 to obtain the expected cost of achieving 1000 surviving seedlings on the site. For all species except Douglas fir, styroplug seedlings are the most cost effective means of plantation establishment despite higher production costs (12 to 19% less expensive per 1000 surviving seedlings). Reasons for the continued use of styroplug seedlings for Douglas fir are provided in the discussion. Western hemlock bare-root seedlings are no longer produced in British Columbia.

For the purpose of comparison it was assumed that the production cost of bare-root hemlock stock would be the same as that for all other species.

DISCUSSION

All of the 1-0 styroplug seedling stock used in this study were grown in the Styroblock 2, commonly known as PSB 211* stock in British Columbia.

Since our field trials were established in the early 1970s, container technology has continued to evolve. Styroblocks with different physical dimensions have been developed to grow a bigger seedling. All four tree species are now grown in the Styroblock 4 (PSB 313A) which has a larger cavity (top diameter 27 mm; volume 57 cm^3) and lower spacial density of 932 cavities/m^2 compared to the original Styroblock 2. Douglas fir, western hemlock, white spruce and lodgepole pine are all now grown in the Styroblock 4 because the greater media volume and reduced seedling density produces a larger, sturdier seedling for outplanting. This, in turn, produces better survival and growth in the field. This point is made to substantiate the conclusion that the survival advantages documented in this study are conservative when compared to today's standards of container stock production.

To paraphrase Vyse and Ketcheson (1974), foresters in British Columbia have looked for a reforestation system that will yield the greatest net benefit in most situations. We firmly believe that the Styroblock Reforestation System meets these goals. Results from the field trials reported here represent a realistic sample of what is possible with this reforestation system in both the coastal and interior ecosystems of British Columbia. Furthermore, for reasons given in the preceding paragraph, the reported survival gains with styroplug seedlings, and hence the economic benefits calculated, are conservative. Also, we feel that the results of these trials are strengthened by the fact that they are reported over a 10- to 11-year period, and are not taken from the more traditional 3- to 5-year window.

Although percent survival and seedling production costs have been the main variables used in the economic analysis, the real success of any reforestation program is its ability to quickly and cost-effectively establish a well-stocked, free-to-grow stand of trees. The styroplug provides a significant gain in survival over conventional bare-root stock for most species in British Columbia and these plug seedlings can reach a free-to-grow stage just as rapidly as the older 2-0 bare-root seedlings. Matched against the bare-root system, our results indicate that the cost advantage of the Styroblock Reforestation System for most species is primarily due to the savings made in significantly improved survival rates at the planting site. However, there are other advantages of this container reforestation system.

Greenhouses are used extensively to grow styroplug seedlings as they provide a much greater degree of environmental control over seed germination and initial growth than is possible with conventional bare-root seed beds. Styroplug seedlings also greatly extend the available planting season in the field by providing consistently higher survival rates throughout a wider planting season than is possible with bare-root stock (Arnott 1974; Gardner 1981). They are ready for planting after 1 year instead of the 2 years that are required to produce bare-root stock. Finally, one of the most important benefits of container reforestation systems is the reduced time it takes to construct a nursery when compared with a conventional bare-root unit. Guldin (1984) has estimated that the extra time required to expand bare-root nurseries rewards every additional dollar spent on a container nursery with $5.90 in present worth benefits. The ease with which container nurseries can be constructed to meet the rapid expansion in British Columbia's reforestation program has contributed much to their success. Without this flexibility of expansion that containerised systems provide, it is doubtful if the nursery production targets outlined in Figure 1 would have been met.

The cost advantage (19%) of a container reforestation system for spruce, and reduction in risk realized by growing trees in a controlled environment, is reflected in the fact that 89% of all white spruce planting stock is grown in container nurseries (Table 6). At present, 78% of all bare-root production in British Columbia is lodgepole pine and although bare-root nurseries produce good quality lodge-

* PSB = Plug StyroBlock; 211 refers to the approximate diameter (2) and depth (11) of the container cavity, expresed in centimetres

TABLE 6 – Proportion of white spruce, lodgepole pine, Douglas fir and western hemlocksown as container seedlings in 1989 in British Columbia nurseries

Species	Total	2-0 Bare-root	Transplants	Container	% Container
White spruce	87,954,200	28,000	10,741,100	77,185,100	88.8
Lodgepole pine	107,470,200	20,414,400	700,000	86,355,800	80.4
Douglas fir	10,399,700	1,770,000	162,900	8,466,800	81.0
Western hemlock	7,296,400	–	–	7,296,400	100.0

Source: Ms P. Kagawa, Silviculture Branch, B.C. Ministry of Forests, Victoria, B.C.; data from sowing allocation reports of the Ministry.

pole pine seedlings that survive well, our analysis indicates that there is about a 12% cost advantage favouring a container reforestation system for this species. Furthermore, 81% of the coastal Douglas fir stock is grown in containers even though the economic analysis favours the bare-root system by about 7%. This clearly shows the value imputed to the additional benefits of container reforestation noted in the paragraph above. The performance of western hemlock bare-root stock was so poor in the past (Arnott 1975) that bare-root stock production of this species stopped in the mid 1970s. Since that time, all western hemlock plantations have been established using container-grown stock. Similarly, poor performance of white spruce bare-root stock is the reason behind the current trend towards 100% container or container-transplant stock production of this species (Table 6).

CONCLUSIONS

The Styroblock Reforestation System is now used for over 90% of British Columbia's reforestation program. The styroplug seedling has virtually replaced the 2-0 bare-root stock type for most species because it significantly improves seedling survival rate in the critical early years after establishment. While bare-root stock is larger when planted, growth differences between these two stock types 10 years after planting were insignificant. Therefore, although styroplug seedlings are more expensive to produce, their superior survival rates result in a net saving in cost of plantation establishment in the range of 12 to 19%.

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DISCUSSION

Ray – Why was there inferior survival in bare-root stock?

Arnott– We feel it is the reduced amount of root disturbance, from seed to field, in containers. Furthermore, our nurseries tend to be in milder climates at long distances from the planting sites and container stock travel better than bare-root seedlings.

Mason – Is it also because of a superior root/shoot ratio in the containers?

Arnott–Yes, it may well be that.

Porada – When do you plant?

Arnott– Coastal regions are planted in the fall or the stock is held in cold storage for 4 months and planted in the spring, January to March. The central interior regions (north) are planted in the first 4 months of summer (mid-May till August).

Berg – What spacing do you use in the nursery?

Arnott–Containers are placed at 930 /m^2 and bare-root stock at 120/m^2.

Nelson– Does bare-root Douglas fir survive better than container-grown stock?

Arnott– The difference is minute, virtually no difference.

M. Wilcox– How do you harden off the seedlings?

Arnott– Covers are taken off the greenhouse after 16 weeks. Hardening off occurs naturally after this, at about weeks 25–27.

Trewin– Have you done any studies on root form comparing bare-root stock with container stock?

Arnott– Yes, we studied root development and we see no reasons to indicate a difference in stability. Better studies were done in Scandinavia related to problems with paper pots; as a consequence they have got away from those. A root-pruning chemical is also available for use in the styro container.

Porada– Have you considered control of root/shoot ratio by mechanical toppling of bare-root stock?

Arnott– No, we haven't, multi-leadering is a concern.

Porada– Why not increase root growth?

Arnott– We need larger shoots to have a head start on weeds.

Cazalet– What was the medium for the styro block?

Arnott– Vermiculite and sphagnum peat at a ratio of 1:3.

Saunders– Have you encountered planter resistance by using containerised stock?

Arnott– No, it is probably easier to plant containersised stock.

Berg– Later papers by Scandinavians deal with containerised stock, for instance 85% of Sweden's planting stock of 500 million is containerised.

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