FIELD PERFORMANCE OF CONTAINERIZED SEEDLINGS IN INTERIOR BRITISH COLUMBIA

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Abstract.--Seedlings of white spruce *(Picea glauca* [Moench] Voss), lodgepole pine *(Pinus contorta* var. l Engelm.) and Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco) were grown in Walters bullets and BC/CFS styroblocks and outplanted in 1970 in the bullets, as bullet plugs, and as styroplugs. Bare-root seedlings of each species were planted as controls. Plantings were carried out in June, July, August and September of the same year to test the effect of extending the planting season. Survival and height growth results 10 years after planting are presented.

Résumé.--On a cultivé des semis d'épinette blanche *(Picea glauca* [Moench] Voss), de pin tordu latifolié *(Pinus contorta* var. *latifolia* Engelm.) et de Douglas taxifolié *(Pseudotsuga menziesii* [Mirb.] Franco) dans des cartouches de Walters et des BC/CFS styroblocks et on les a transplantés en 1970, dans leurs contenants. À titre de témoins, on a planté des semis 2-0 à racines nues de chacune des essences. Afin de vérifier les effets de la prolongation de la saison de plantation, on a réparti les dates de plantation en juin, juillet, août et septembre de la même année. On présente les résultats obtenus en dix ans après la plantation relativement à la survie et à la croissance en hauteur.

INTRODUCTION

Field testing of container reforestation systems over a wide range of site types in coastal and interior British Columbia began in 1967 with the initiation of the cooperative container planting research and development program of the Pacific Forest Research Centre (PFRC) and the British Columbia Forest Service (Kinghorn 1972). The trial reported here was established in 1970 near Prince George in the central interior of British Columbia and formed part of the second phase of the container program, which involved continued development of container systems and pilot production. The objectives of the trial were to study height growth and survival of seedlings grown in two container types, the Walters bullet (Walters 1969) and the BC/CFS styroblock (Sjoberg 1974), and to investigate the feasibility of extending the planting season throughout the June to September growing period.

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SEEDLING PRODUCTION

All container stock for the trial was grown at the Pacific Forest Research Centre in Victoria, B.C. Seed of Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco), white spruce *(Picea glauca* [Moench] Voss) and lodgepole pine *(Pinus contorta* var. l Engelm.), obtained from provenances local to the test area, were sown into 11-cm Walters bullets (22 cm^3) and BC/CFS styroblock-2 (40 cm^3) containers in early March 1969. The growing medium consisted of a peat-vermiculite mix (3:1 by volume) to which 3 kg of dolomitic limestone (12 mesh and finer) had been added. The seeds were covered with #2 granite grit and misted daily. Seedlings were retained in the greenhouse for approximately 12 weeks after germination was completed and were transferred to outdoor shade-houses which provided 30% shade for lodgepole pine and Douglas-fir and 46% shade for white spruce.

Fertilization consisted principally of biweekly applications of 28-14-14 at 187-374 g/kl throughout the peak height growth period (late March to mid-July). This was supplemented with three applications of 21-0-0 (lodgepole pine and white spruce) and 34-0-0 (Douglas-fir) at 374 g/kl. Thereafter each crop received two applications of 0-0-60 at 78-94 g/kl, one application of 15-15-30 at 312 g/kl, followed by a single application of 34-0-0 at 312 g/kl. All fertilizers were water soluble and applied concurrently with irrigation, using fixed sprinklers.

Bare-root stock, used for controls in the trial, was obtained from the British Columbia Forest Service nursery at Red Rock, B.C. Morphological characteristics of all planting stock are given in Table 1.

PLANTATION ESTABLISHMENT AND ASSESSMENT

Study Area

The study area is located approximately 120 km north of Prince George near the south end of McLeod Lake (lat. 54°52', long. 122°58') in the central interior of British Columbia, at an elevation of 855 m. The site falls within the SA.2 interior subalpine forest section (Rowe 1972) and previously supported a mixed stand of white spruce, subalpine fir (*Abies lasiocarpa* [Hook.] Nutt.) and lodgepole pine. The area was logged between 1964 and 1966 and slash was burned in 1967.

Predominant vegetation includes thimbleberry (*Rebus parviflora* Nutt.), black twinberry (*Lonicera involucrata* [Richards] Banks), *Vaccinium* spp., red elderberry (*Sambucus pubens* Michx.), pine grass (*Calamagrostis rubescens* Buckl.), *SaZix* spp. and trembling aspen (*Populus tremuloides* Michx.). Soils are variable, ranging from a coarse textured, well drained, degraded, dystric brunisol over glacial outwash to fine textured, moderately well drained to poorly drained orthic gray and bisqua gray luvisols[2]. The climate consists of relatively cool, moist summers and long, cold winters. The mean annual temperature is 3.5°C, with a May to September average of 12°C. Annual precipitation is up to 63 cm, a third of which is snow. Table 2 gives a June-September monthly temperature and precipitation summary for the duration of the trial.

Planting, Experimental Design and Assessment

Seedlings (1-0) of each species grown in the bullets and styroblocks were outplanted 1) in the bullets, 2) as bullet-plugs (Arnott 1971), and 3) as styroplugs. Cold-stored (2-0) and fresh-lifted (2-1) bare-root stock

[2]Soils description taken from project record compiled by E. Van Eerden (unpublished data).

Table 1. Morphological characteristics of container and bare-root stock at time of planting

Species and seedlot	Stock type	Shoot length (cm)	Root collar diam. (mm)	Dry weight (g)			Shoot:root ratio
				Shoot	Root	Total	
Douglas-fir 590[a]	bullet	9.1	1.6	0.30	0.17	0.47	1.8
	styroplug	18.9	2.1	0.83	0.43	1.26	1.9
	bare-root	17.1	3.3	1.65	0.86	2.51	1.9
Lodgepole pine 55	bullet	8.4	1.8	0.62	0.27	0.89	2.6
	styroplug	11.6	2.3	1.02	0.53	1.55	2.0
	bare-root	14.7	4.3	3.80	1.02	3.82	3.8
White spruce 779	bullet	10.2	1.9	0.50	0.30	0.80	1.7
	styroplug	15.9	2.0	0.66	0.33	0.99	2.0
	bare-root	16.7	3.9	2.54	0.98	3.52	2.7

[a]B.C. Ministry of Forests registered seedlot numbers.

Table 2. Mean monthly temperature (°C) and precipitation (mm) for June, July, August and September at Prince George, B.C., for the period 1970-1980a

Year	June temp.	Precip.	July temp.	Precip.	August temp.	Precip.	September temp.	Precip.
1970	14.3	74.7	14.5	73.4	14.2	46.9	8.5	55.6
1971	12.7	73.9	14.7	84.1	16.0	32.8	8.2	61.2
1972	12.9	107.7	14.1	94.1	14.4	43.7	7.7	24.1
1973	11.7	90.2	14.5	50.0	12.5	48.7	9.0	63.2
1974	12.6	41.9	13.7	97.5	15.4	23.6	11.1	45.7
1975	12.1	88.1	17.1	43.4	12.6	86.4	10.4	22.7
1976	10.9	122.1	13.8	80.8	14.4	58.7	10.9	41.4
1977	13.0	54.3	14.1	109.5	15.6	52.2	8.6	65.8
1978	13.0	37.0	17.0	37.9	14.2	62.8	9.3	52.4
1979	12.5	72.6	16.0	24.6	16.1	31.7	11.9	50.2
1980	13.5	84.4	14.3	83.4	12.7	106.2	9.8	85.3
Average[b]	13.0	58.2	14.9	57.9	13.7	73.4	9.8	54.9

[a]Source: Monthly meteorological observations Canada, Department of the Environment, 1970-1980.
[b]Average monthly temperature and precipitation for the period 1970-1980.

of each species was planted as a control. Planting was carried out four times throughout the summer of 1970: on 23 and 24 June (container stock and 2-0 cold-stored bare-root stock), on 25 and 26 July, on 20 August and from 15 to 21 September (container stock and 2-1 fresh-lifted bare-root stock). Bullet plugs and styroplugs were extracted from their containers on site and were dibble planted. Bullet seedlings were planted with a "gun" (Walters 1969) and bare-root seedlings were mattock planted.

The trial was arranged in a randomized block design with a block consisting of three plantations, each of 16 rows. Each species was assigned to a plantation and each stock type was assigned four rows within a plantation. A row contained 35 trees for the bullet, styroplug and bare-root stock types, but only eight trees for the bullet-plug type. Styroplugs were planted in a single line by themselves at a 2 m spacing, whereas the bullet, bullet-plug and bare-root types were planted in cluster plots consisting of a central stake with a bullet seedling in front, a bare-root seedling to the right and a bullet-plug to the rear, all within a 0.5 m^2 area. Bullet-plugs were located at the first plot and at every fifth plot thereafter, including the last plot. There were three replications of the blocks, for a total of 4068 trees.

The trial was assessed for survival and height growth annually until 1975 and again in 1980. For brevity, only the first, third, fifth and tenth year assessments are reported here.

The data were subjected to analysis of variance and multiple range tests for determination of significant effects.

RESULTS AND DISCUSSION

Survival data by species and container types up to 10 years following outplanting are given in Table 3.

There were no statistically significant differences in survival among container types for white spruce or lodgepole pine over the duration of the trial.

Douglas-fir survival stabilized following the third growing season. Survival of styroplug and bare-root seedlings was significantly higher than that of bullet and

Table 3. Summary of survival of Douglas-fir, white spruce and lodgepole pine by stock type (%)

Species	Years from planting	Stock type			
		Styroplug	Bullet	Bullet-plug	Bare-root
Douglas-fir	1	89.5[a]	77.3[b]	82.3[ab]	80.9[ab]
	3	83.3[a]	63.5[c]	69.7[bc]	75.7[ab]
	5	80.2[a]	59.7[b]	64.5[b]	74.0[a]
	10	74.7[a]	52.8[b]	52.0[b]	66.1[a]
White spruce	1	96.9[a]	91.1[a]	95.8[a]	93.3[a]
	3	93.3[a]	88.9[a]	95.8[a]	91.4[a]
	5	91.4[a]	87.7[a]	94.7[a]	90.3[a]
	10	87.6[a]	80.7[a]	81.2[a]	87.4[a]
Lodgepole pine	1	96.6[a]	86.9[a]	89.5[a]	87.6[a]
	3	94.7[a]	85.0[a]	84.3[a]	85.3[a]
	5	94.0[a]	84.7[a]	84.3[a]	84.4[a]
	10	89.5[a]	80.9[a]	78.1[a]	82.1[a]

Note: Within each row, means followed by the same letters are not significantly different ($p \leqslant .05$).

bullet-plug seedlings. Climatic data in Table 2 indicate that the establishment year of planting (1970) was generally warmer and wetter than normal, except for a moisture deficit in August and a slight drop in temperature in September. It is probable that conditions for establishment of the seedlings were better than normal, and this may explain the relatively high survival rates encountered.

Styroplugs invariably produced the best survival rates by the tenth year, followed by bare-root seedlings and then by bullets and bullet-plugs (for Douglas-fir and lodgepole pine) or bullet-plugs and bullets (for white spruce). Data in Table 1 show that seedlings grown in bullets were physically smaller than bare-root or styroplug stock. This may have put them at a disadvantage when outplanted in terms of their ability to resist vegetative competition. Such competition was a common cause of mortality among all species in the first growing season.

Survival of Douglas-fir was considerably lower than that of lodgepole pine or white spruce, regardless of container type. It was noted by Van Eerden (1972) that this location approaches the northern limit of the range of Douglas-fir and consequently this species may have had difficulty in adapting to the site.

Table 4 summarizes height growth by species and container type. Bare-root seedlings generally had faster growth rates and were the tallest seedlings by the tenth year. There were two exceptions. Douglas-fir styroplug seedlings outgrew their bare-root counterparts by the first assessment. This result was likely due to the initial size difference between the stock types, as indicated in Table 1. Thereafter the bare-root seedlings assumed dominance over styroplugs in terms of height growth. Between the fifth and tenth years, lodgepole pine styroplugs grew faster than the bare-root seedlings, but by year 10 there was no significant difference in height between these stock types (Table 4). Bare-root seedlings maintained a consistently significant height advantage over bullets and bullet-plug seedlings except in the case of Douglas-fir, where the average height of bullet-plug seedlings by year 10 was not significantly different from that of bare-root seedlings.

Bullet-plugs invariably exhibited faster growth rates and produced taller seedlings than bullets, although differences were rarely significant. Styroplugs, initially larger than bullet grown stock, continually outgrew both bullet and bullet-plug seedlings of all species. However, lodgepole pine was the only species in which the average height of

Table 4. Summary of height growth (cm) of Douglas-fir, white spruce and lodgepole pine by stock type

Species	Years from planting	Stock type			
		Styroplug	Bullet	Bullet-plug	Bare-root
Douglas-fir	1	18.9[a]	10.8[b]	11.5[b]	17.1[a]
	3	25.5[a]	14.8[b]	16.3[b]	28.9[a]
	5	36.7[ab]	21.7[c]	26.0[bc]	44.0[a]
	10	103.6[ab]	81.8[b]	92.6[ab]	130.9[a]
White spruce	1	16.7[b]	12.6[c]	13.0[c]	20.2[a]
	3	27.1[b]	19.2[c]	23.6[b]	36.6[a]
	5	39.3[b]	28.5[b]	34.9[b]	54.6[a]
	10	113.6[b]	88.1[b]	99.2[b]	150.0[a]
Lodgepole pine	1	17.7[a]	14.2[b]	14.0[b]	18.3[a]
	3	41.3[b]	30.3[c]	32.6[c]	52.0[a]
	5	82.4[b]	62.3[d]	71.8[c]	99.9[a]
	10	297.1[a]	248.2[b]	265.7[b]	302.0[a]

Note: Within each row, means followed by the same letters are not significantly different ($p \leqslant .05$).

styroplugs was significantly higher by year 10 than that of bullet and bullet-plug seedlings.

Table 5 presents a summary of first-year survival of all species by container type and planting date. Planting date produced little significant variation in survival within species. Seedlings planted in June tended to have a somewhat higher mortality rate than seedlings planted later in the season. The author suggests that June-planted stock underwent the dual stress of having to establish root-soil contact at the same time that it was initiating shoot activity. Tinus (1974) states that it is preferable for shoots of seedlings to be dormant during the initial establishment phase because if shoots are actively flushing, food reserves within a seedling are generally utilized to support the flush, and root extension, critical to successful seedling establishment, is minimal. Stock planted Later in the season would not likely have flushed that year, thereby allowing for better root establishment prior to the next shoot extension period.

Arnott (1972) states that, for container-grown trees, the single most important factor affecting seedling mortality and early growth rate in similar trials under coastal conditions was the removal of the container at the time of planting. The results of this study tend to substantiate this, though perhaps not as definitively. Styroplug seedlings consistently, though not significantly, achieved the highest survival rates coupled with the second best growth rates, regardless of species. On the other hand, bullet seedlings exhibited the poorest growth rates together with either third best or lowest survival. The data also indicate that the styroblock container produced a better seedling for planting purposes than did the bullets. Simple removal of the container at planting, as was done to create bullet-plug seedlings, did not necessarily achieve greater performance. Survival of bullet plugs was never significantly greater than that of bullets, and for Douglas-fir and lodgepole pine it was lower than that of the bullets by year 10. Bullet-plugs maintained growth rates superior to those of bullet seedlings throughout the trial, but the differences were rarely significant and, by the tenth year, were not statistically significant for any species.

Reforestation systems such as the styroblock and bare-root systems were designed partly to produce seedlings with root systems which would quickly establish contact with,

Table 5. First-year survival of Douglas-fir, white spruce and lodgepole pine by planting date and stock type (%)

Species	Stock type	Time of planting			
		June	July	August	September
Douglas-fir	styroplug	85.7[ab]	85.7[ab]	91.4[a]	95.2[a]
	bullet	73.3[ab]	82.8[ab]	78.1[ab]	75.3[ab]
	bullet-plug	79.1[ab]	79.1[ab]	79.1[ab]	91.7[a]
	bare-root	64.3[b]	93.1[a]	76.2[ab]	89.5[a]
White spruce	styroplug	92.3[a]	99.0[a]	96.1[a]	100.0[a]
	bullet	75.8[a]	97.1[a]	93.3[a]	98.1[a]
	bullet-plug	91.7[a]	91.7[a]	100.0[a]	100.0[a]
	bare-root	82.8[a]	94.3[a]	96.1[a]	100.0[a]
Lodgepole pine	styroplug	93.3[a]	98.0[a]	97.1[a]	98.1[a]
	bullet	75.2[a]	96.1[a]	83.8[a]	92.4[a]
	bullet-plug	87.5[a]	87.5[a]	83.3[a]	100.0[a]
	bare-root	82.8[a]	89.5[a]	85.7[a]	92.4[a]

Note: Within each row, means followed by the same letters are not significantly different ($p \leqslant .05$).

and extend into, the soil. The generally slower growth rates and lower survival of bullet seedlings may be due, in part, to the fact that the roots of these plants are almost totally encapsulated by the container at planting and have little initial contact with the soil (Van Eerden 1978). Subsequent root egress into the soil may occur only from the side slits or drainage holes at the base of the container. Roots of container-free seedlings have immediate contact with the soil and experience less restriction of root extension into the surrounding soil.

Long (1978) and Arnott (1978) concluded that reforestation systems influence survival and growth for a relatively short time following planting. Data from this study indicate that the influence of containers on survival does not generally last beyond the first growing season, except for Douglas-fir, where final relationships between stock types were not determined until after the third growing season. It must be stressed, however, that survival of Douglas-fir in this study may have been influenced by other ecological factors resulting from the fact that the study area is close to the northern limit for this species.

Height relationships between container types (excluding bare-root stock) tended to stabilize after three growing seasons; however, early differences in height may be related as much to differences in initial size at planting as to container influence (Arnott 1978). Given this and the observation that stock type had no significant influence on survival of lodgepole pine and white spruce, it may be concluded that all reforestation systems employed in the study were successful in facilitating adaptation of the seedlings to the environment in which they were planted. In view of the fact that the bare-root seedlings used in the study were one or two years older than the containerized stock, and always larger, it may also be concluded that container-grown seedlings (especially the styroplugs) are capable of survival and height growth rates comparable with or superior to those of bare-root seedlings.

It should be noted that neither container type studied here is currently in use. The unribbed BC/CFS styroblock-2 has been replaced by the ribbed model 2A, and the 11 cm Walters bullet model used in the study has not been in general use for several years. This study is important as a contribution to the development of container systems and should be looked upon as an affirmation of the concept of containerization as a workable reforestation alternative, rather than as a statement of superiority of one system over another.

SUMMARY

1. Styroplug seedlings produced the highest survival rates of any of the stock types tested.

2. Bare-root stock produced the tallest seedlings of the study, but styroplug seedlings achieved comparable average heights despite the initial size advantage of the former.

3. Seedlings planted with container removed tended to achieve higher survival and faster growth rates than those planted

with the container still encasing the roots.

4. Container influence on survival and growth does not appear to last beyond the third growing season.

5. Planting container-grown seedlings and bare-root seedlings (using a mixture of cold-stored and fresh-lifted stock) throughout the growing season proved feasible for the Prince George region, provided that moisture conditions were near or above normal.

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