PERFORMANCE IN BRITISH COLUMBIA 1/

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Abstract.--Compares field survival and growth of bullet, bullet-plug and styro-plug seedlings with bareroot planting stock for commercially-important tree species in British Columbia. Plug seedlings survive as well as, or better than, bareroot stock, and they grow at comparable rates. Survival of container-grown stock falls when the seedlings are planted in progressively harsher growing conditions.

INTRODUCTION

Container seedling trials in British Columbia have centered principally around Walters' bullets (Walters 1969), bullet-plugs (Arnott 1971) and styro-plugs (Kinghorn 1970; Cayford 1972). Bareroot seedlings were used as the 'control' component in each of these field experiments. The bullet trials of the 1960's led to development of the plug concept which has evolved into the fully operational BC/CFS Styroblock Reforestation System, presently being used throughout the province (Arnott (1973).

My review will be in two parts. The first section will deal with bullet, bullet-plug and bareroot trials which were tested prior to 1970; the second section will concentrate on styro-plug and bareroot trials which were established in the 70's. The reason for this separation is that long-term results are now available from the early bullet-plug field trials, whereas only second-year data are available from the more recently established styro-plug experiments. Although the latter exhibit similar, or improved performance compared to the original bullet-plug trials, the styro-plug data are for two seasons' growth only; this fact should be taken into consideration when interpreting the results.

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British Columbia is characterized by two broad climatic zones - the maritime Pacific Coast and the continental Interior east of the Coast Mountains. Not only does the climate differ between these regions, the tree species indigenous to them also are quite distinct. I shall deal with each region separately.

BULLETS, BULLET-PLUGS AND BAREROOT

Coastal British Columbia

A series of field trials was initiated in 1967 on Vancouver Island to assess the relative survival and growth of Walters' 4½-inch bullets and bullet-plugs and 2-0 bareroot stock. Douglas-fir and western hemlock were used in the trial. Three planting seasons were selected each year — fall, early spring and late spring — and the whole series was replicated over a three-year period from 1967/68 to 1969/70. Third-year results of these trials on the west coast of Vancouver Island are outlined in Tables 1 and 2. Clearly, the container is of no use to the tree after it has been planted. Indeed, comparison of bullet and bullet-plug results show the container to be detrimental to seedling survival; although, in most instances, the container did not significantly affect seedling growth.

Initial size difference of 10-15 cm between the 1-0 container seedlings and the 2-0 bareroot stock account for the large height differences between these two categories in Tables 1 and 2. Nevertheless, Douglas-fir bullet-plug survival compares favorably with bareroot stock in two out of three years. The situation is quite different for hemlock, where bullet-plug seedlings had survival rates

Table 1.--Percent survival and average height[1/] of Douglas-fir bullet, bullet-plug and 2-0 bareroot seedlings three years after planting on the west coast of Vancouver Island

Replication/ Year Planted	Bullet	Bullet-plug	Bareroot
		Survival (%)	
I - 1967/68	66	81	88
II - 1968/69	48	51	79
III - 1969/70	60	73	79
Average	58	68	82
		Height (cm)	
I - 1967/68	37	38	84
II - 1968/69	25	27	72
III - 1969/70	33	37	55
Average	32	34	70

1/ Means based on 5000 seedlings planted on a range of sites and planting dates.

Table 2.--Percent survival and average height[1/] of western hemlock bullet, bullet-plug and 2-0 bareroot seedlings three years after planting on the west coast of Vancouver Island

Replication/ Year Planted	Bullet	Bullet-plug	Bareroot
		Survival (%)	
I - 1967/68	52	60	25
II - 1968/69	41	52	43
III - 1969/70	53	64	38
Average	49	59	35
		Height (cm)	
I - 1967/68	48	55	76
II - 1968/69	41	43	66
III - 1969/70	48	51	53
Average	46	50	65

1/ Means based on 4000 seedlings planted on a range of sites and planting dates.

significantly superior to the bareroot 'control', clearly demonstrating the biological advantage of planting hemlock as plugs on these Pacific Coastal sites of Vancouver Island.

Despite substantial initial size differences between 1-0 bullet-plug and 2-0 bareroot seedlings mentioned above, their respective growth rates are similar over the first three years after planting. Where vegetative competition is severe, growth rate of the smaller plug seedling is less than bareroot. On drier sites with less competition, plug seedling growth parallels or exceeds that of bareroot stock (Arnott 1974)3/.

Best bullet-plug survival and growth was obtained from fall or early spring planting dates (Arnott 1971). There was a distinct reduction in plug seedling survival when the stock was outplanted in the harsher growing conditions typical of late spring in Coastal British Columbia.

Although morphological characteristics of the bullet-grown seedlings were improved from 1967 to 1969 (Table 3), these gains were not reflected in the field results reported in Tables 1 and 2 where survival and height of the seedlings planted in 1969/70 was not consistently better than that of seedlings planted in 1967/68. The positive effect of stock quality improvement between these two years may have been masked by the harsher growing conditions experienced in 1970, a factor that could also account for the much lower average heights of the bareroot stock planted in 1969/70.

Table 3.--Characteristics of fall-planted 4½-inch bullet seedlings

Year	Ht. (cm)	Shoot Wt. (mg)	Root Wt. (mg)	Shoot/ Root
		DOUGLAS-FIR		
1967	9	221	127	1.7
1968	7	165	101	1.6
1969	14	530	217	2.4
		WESTERN HEMLOCK		
1967	9	192	94	2.0
1968	--	--	--[1/]	--
1969	10	378	199	1.9

1/ No hemlock seedlings fall-planted in 1968.

That a correlation does exist between the size of seedling planted and its subsequent field performance is exhibited by the Douglas-fir bullet seedlings grown in 1968 (Table 3) and planted in the second replicate (Table 1). These smaller trees gave significantly poorer field results. Further evidence of such

3/Arnott, J.T. 1974. Field performance of container-grown trees in Coastal British Columbia. Unpublished manuscript.

correlation was produced in the first of our field trials, where 'small' and 'large' bullet seedlings were paired for comparisons. Differences were immediately apparent and continued to be significant to the fifth-year assessment (Table 4).

Table 4.—Effect of initial seedling size on field performance of 4½-inch bullet seedlings, five years after planting

Initial size	Ht. (cm)	Shoot Wt. (mg)	Root Wt. (mg)	Survival[1/] (%)	Ht.[1/] (cm)
		DOUGLAS-FIR			
Small	6	68	82	40	62
Large	9	221	127	61	84
		WESTERN HEMLOCK			
Small	3	15	8	23	69
Large	9	192	94	49	96

1/Means based on a total of 1575 Douglas-fir and 1050 western hemlock seedlings, respectively.

Drought is the most important single cause of container-grown seedling mortality in the field, accounting for most seedling deaths over the first three years after planting. Seedling losses from smothering do not occur in significant amounts until the third year and then are usually restricted to poor-quality seedlings that have had low vigor since planting (Arnott 1974).3/

Plug seedling losses due to frost heaving are insignificant from sea level to the medium elevations (500 m) on Vancouver Island. Such losses as do occur are usually restricted to bullet-planted trees.

Browsing of Douglas-fir seedlings is prevalent throughout coastal British Columbia; however, it rarely can be cited as the sole cause of seedling failure.

Interior British Columbia

Similar trials were simultaneously conducted on Interior Douglas-fir, lodgepole pine and white spruce in the montane and subalpine forest regions of the Prince George District (Van Eerden 1972). Irrespective of site, age and size of stock and planting season, removal of the container improved seedling survival. Survival and average height/ of bullet, bullet-plug and bareroot seedlings five years after planting was as follows:

Seedling Category	Douglas-fir	Lodgepole pine	White Spruce
		Survival (%)	
Bullet	65	88	65
Bullet-plug	75	95	87
2-0 bareroot	72	83	62
		Height (cm)	
Bullet	29	60	36
Bullet-plug	36	73	43
2-0 bareroot	45	110	43

White spruce bareroot survival was significantly lower than bullet-plugs. Survival of Douglas-fir and lodgepole pine bullet-plugs was bett er than bareroot stock although average seedling height was less, primarily due to size differences at planting.

These plantations convincingly illustrate the influence of size and age of planting stock on seedling establishment (Table 5).

Table 5.--Survival and average height[1/] of two two age classes of bullet seedlings near Prince George, B.C., five years after planting.[2/]

Young	Old	Young	Old
Survival (%)		Height (cm)	
	DOUGLAS-FIR		
62	67	25	32
	LODGEPOLE PINE		
78	85	54	63
	WHITE SPRUCE		
58	69	23	36

1/Means of three planting dates and two sites with 630 trees/age category/species.
2/Source: Van Eerden.

Respective initial heights for these young- and old-age categories were: Douglas-fir, 5 and 7 cm; lodgepole pine, 5 and 12 cm and white spruce, 3 and 6 cm. The effect of seedling age, and thus size, on field establishment is particularly evident for white spruce and lodgepole pine; the differences are less striking for Douglas-fir, perhaps because it is near the northern limit of its natural range.

4/Means of four planting dates on two sites with 192 trees/category/species.

As with the coastal situation, survival of container grown stock fell when the seedlings were planted in progressively harsher growing conditions. In these 1968 plantings, there was a general and steady decline in survival of bullet-planted seedlings for each progressively later planting date from June to August, with an occasional slight upswing in September (Table 6). 1968 was a year with adequate precipitation throughout the summer. In subsequent years with a June-July drought, survival from June-planted stock was severely reduced (Van Eerden 1972). As Van Eerden stated, "the issue is not by how much we can stretch the planting season, but rather to what degree we can compress it." With high planting productivity of container systems, large numbers of high-quality stock can be planted during short periods of favorable weather and soil moisture conditions with increased probability of success. Although survival of spring plantings is highest in years with adequate summer precipitation, stock quality and size, rather than the season, should govern the time of planting in the B.C. Interior. Survival reductions from late planting dates will be minimal if stock quality standards are met.

Table 6.--Survival[1/] of Douglas-fir, lodgepole pine and white spruce bullet and 2-0 bareroot seedlings planted at monthly intervals from June to September, five years after planting[2/]

Species	Seedling Type	Planting Date			
		June	July	Aug.	Sept.
		Survival (%)			
Douglas-fir	Bullet	78	75	61	64
	Bareroot	--[3/]	55	71	85
Lodgepole pine	Bullet	95	88	81	85
	Bareroot	--	81	81	83
White spruce	Bullet	83	74	73	69
	Bareroot	--	80	64	61

1/Means from two sites with 210 trees/species/seedling type/planting date

2/Source: Van Eerden.

3/No bareroot planted in June.

Although the data presented in this paper are averages of several selected sites in the Prince George area, the favorable effects of properly matching species to site has been reported by Van Eerden (1972). Although growth rates are highest for all species on the high quality wet sites, survival of lodgepole pine and Douglas-fir have been significantly greater on drier, poorer-quality sites. Under the temperature extremes of the B.C. Interior, container-planted seedlings are prone to serious frost heaving on bare mineral soil. Such losses can be markedly reduced by planting on soils with some organic or vegetative cover.

Rabbit browsing of lodgepole pine has been severe on several of the test sites, greatly reducing survival and retarding growth. Plug seedlings appear to recover from this setback more readily than bullet-planted trees.

STYRO-PLUGS AND BAREROOT

Coastal British Columbia

Vancouver Island

Field trials of Douglas-fir, western hemlock and Sitka spruce plug seedlings grown in BC/CFS Styroblocks 2 (40 cm^3) and 8 (125 cm3) have been established over the past two years on Vancouver Island's west coast. All container stock was grown in a shelterhouse for one year, overwintered and outplanted early in the following spring on a freshly burned cutover which had formerly supported a stand of western hemlock and western red cedar.

Mortality through the first two growing seasons was low for both sizes of styro-plugs (Table 7). The large styro-plug 8 Douglas-fir and Sitka spruce seedlings gave improved results over the styro-2's in the field, particularly Sitka spruce, which was not browsed by deer. Western hemlock styro-8's did not, because they were not much larger than the styro-2's at planting. This stock had been grown in the outdoor environment of a shelterhouse and had not had time to fully utilize the cavity volume of the Styroblock-8 in one growing season, as evidenced by equal root weights for both styro-2 and styro-8 seedlings (Table 7). Earlier sowing and propagation in a greenhouse from February to May, followed by outdoor growing, is one means of fully utilizing the potential of this container size for western hemlock.

It is too soon to predict the long-term performance of these styro-plug 2 seedlings. Some indication, however, can be obtained by comparing the second-year data from these styro-plug trials with that of the earlier experiments with bullet-plugs on similar sites.

Table 7.--Survival and height growth[1/] of styro-plug 2 and styro-plug 8 Douglas-fir, western hemlock and Sitka spruce seedlings planted Spring 1972 on the west coast of Vancouver Island

Species	Container	Planting Stock Characteristics			Field Performance			
		Ht. (cm)	Shoot Wt. (mg)	Root Wt. (mg)	Fall 1972		Fall 1973	
					Surv.(%)	Ht.(cm)	Surv.(%)	Ht.(cm)
Douglas-fir	Styro-2	18	1082	489	86	22	83	27
	Styro-8	24	2040	1300	91	29	86	35
Western hemlock	Styro-2	12	632	375	82	26	80	44
	Styro-8	16	735	430	82	30	70	46
Sitka spruce	Styro-2	13	1081	555	96	18	84	38
	Styro-8	21	1995	1057	95	30	96	55

[1/] Based on 150 seedlings/container type/species.

It is evident that the styro-plug seedling survives better, and grows faster than its predecessor.

Species	Seedling Type	Second-year	
		Surv. (%)	Ht.(cm)
Douglas-fir	Bullet-plug	72	22
	Styro-plug 2	83	27
Western hemlock	Bullet-plug	74	30
	Styro-plug 2	80	44

Such improved performance arises from the better quality and size of seedling that was grown in the Styroblock 2, as opposed to the 4 1/2-inch bullet (Table 8). The improvement in stock size did not derive solely from differences in container configuration or cavity volume. It was also the result of improvements in our container cultural practices over the past four years.

Bareroot comparisons are only available for Douglas-fir styro-plug 8 and 1-2 bareroot stock which have been tested on high site bottom-land on Vancouver Island's west coast. Large 1-2 bareroot trees, 45 cm tall with a root collar diameter of 7 mm, is the traditional type of planting stock used on these alluvial soils where brush competition poses a serious threat to successful plantation establishment. The tests were established in the early spring of 1972 to determine the potential of 1-0 styro-plug 8 Douglas-fir seedlings on such areas which, through past logging practices, had developed a cover of pure alder. Two test sites were selected. Area 1 was scarified with a bulldozer blade in the fall of 1971, and the remaining alder was poisoned with 2,4-D amine, applied to basal cuts, in June, 1972. Area 2 was not scarified but the heavy undergrowth of salmonberry was cleared by hand and the alder overstory was poisoned as in Area 1.

Test stock was planted during March and April, 1972. Results of field performance, assessed in September, 1972 and April and September, 1973, are summarized in Table 9. At both locations, the styro-plug seedlings showed little signs of planting check when compared with first-year growth of the bareroot stock, but they suffered greater mortality, primarily during the winter of 1972/73. Also, second-year growth rate of styro-plug (35%) was less than bareroot (52%) as a result of severe weed competition on the smaller styro-plug seedling. It is still too soon to determine what ultimate potential the styro-plug 8 Douglas-fir has for use on these high site bottomlands of the coastal forest region of British Columbia.

Table 8.--Comparative sizes of 1-0 4½-inch bullet-plug and styro-plug 2 seedlings at planting

Seedling Type	Ht. (cm)	Shoot Wt. (mg)	Root Wt. (mg)	Shoot/Root
		DOUGLAS-FIR		
Bullet-plug	14	530	217	2.4
Styro-plug	18	1082	489	2.2
		WESTERN HEMLOCK		
Bullet-plug	10	378	199	1.9
Styro-plug	12	632	375	1.7

Table 9.--Survival and height growth[1] of styro-plug 8 and 1-2 bareroot Douglas-fir seedlings near Port Renfrew, B.C.

Area	Seedling Type	Spring '72	Fall '72	Spring '73	Fall '73
			Survival (%)		
1	Styro-8	–	95	85	79
	Bareroot	–	100	98	98
2	Styro-8	–	95	88	83
	Bareroot	–	94	94	94
			Average Height (cm)		
1	Styro-8	24	33	–	48
	Bareroot	45	50	–	81
2	Styro-8	24	35	–	44
	Bareroot	44	47	–	66

1/ Based on a mean of 120 styro-plug 8 and 50 bareroot seedlings at each area.

Lower Mainland

Extensive field comparisons of styro-plug 2 seedlings and 2-0 bareroot stock were initiated by the B.C. Forest Service in the fall/spring of 1970/71. Three locations in the Vancouver Forest District were selected: Squamish, Alta Lake and Pemberton. Eight plots were established at each location on a range of sites, slopes and aspects which had been logged and burned three years before planting. Elevations were generally within the 500-700 m range; a few of the plots at Alta Lake were at 1000 meters. Within each plot, eight planting dates were selected, ranging from August 24, 1970 to August 2, 1971. Fifty styro-plug and bareroot seedlings were planted on each date in each plot. Second-year results of the trial, assessed in the fall of 1972, are shown in Table 10.

As with the earlier bullet-plug trials on Vancouver Island, styro-plug seedlings planted in late fall exhibited highest survival. However, the same stock planted in September still had second-year survival in excess of 70 percent, which was significantly greater than bareroot planted during that month (Table 10). As seedlings were planted in progressively harsher growing conditions, probability of high survival fell. However, at any given planting date, styro-plug seedling survival was better than bareroot. Unfortunately, these trials do not provide an early spring counterpart to the earlier bullet-plug trials on Vancouver Island. Most of the 1971 planting dates constitute a late spring — summer planting season and, as happened in the early bullet-plug trials on Vancouver Island, survival figures fell off sharply as a result of mid-June or later planting dates.

Early indications are that the growth rates of these two stock types are similar. These early findings therefore suggest that styro-plug Douglas-fir seedlings may be potentially superior to conventional bareroot planting stock in the Lower Mainland coastal region of British Columbia.

Interior British Columbia

Extensive styro-plug and bareroot comparative studies were established by the B.C. Forest Service in the Nelson and Kamloops Forest Districts of the Southern Interior during 1972. Interior Douglas-fir, lodgepole pine and white spruce were outplanted at three dates from early June to mid July, at a variety of sites and elevations. Similar field trials were established by the Canadian Forestry Service that same year, to the north in the

Table 10.--Second-year survival of styro-plug 2 and 2-0 bareroot Douglas-fir seedlings planted in the Pemberton-Alta Lake-Squamish region of B.C.[1]

Seedling	1970 — Planting Dates —				1971			
	Aug. 24	Sep. 14	Oct. 5	Oct. 19	June 1	June 22	July 12	Aug. 2
				Survival (%)[2]				
Styro-plug	71	75	82	78	68	60	48	39
Bareroot	45	58	61	58	65	60	34	5

1/ Source: B.C. Forest Service.
2/ Based on a mean from three areas with a total of 9,200 styro-plug and 8,000 bareroot seedlings.

Prince George Forest District. In this trial, only one planting date was selected - early July. Second-year results show no significant differences between planting dates in the Southern Interior, so the data have been combined in Table 11.

Table 11.--Second-year survival of styro-plug 2 and 2-0 bareroot seedlings in the Nelson[1/], Kamloops[1/] and Prince George[2/] Forest Districts

Seedling Type	Douglas-fir	Lodgepole pine	White/Engelmann spruce
		Survival (%)[3/]	
		NELSON - KAMLOOPS	
Styro-plug	28	75	86
Bareroot	4	44	69
		PRINCE GEORGE	
Styro-plug	52	77	92
Bareroot	19	71	64

[1/]Source: B.C. Forest Service
[2/]Source: Van Eerden
[3/]Means/seedling type based on following totals; Douglas-fir - 1350, lodgepole pine - 1350; spruce - 1950.

Again, the data indicate the potential biological superiority of the styro-plug planting system over traditional bareroot methods for lodgepole pine and spruce in the British Columbia Interior. However, Douglas-fir performance was unacceptably low for both seedling types. The styro-plug Douglas-fir planted in the Nelson and Kamloops Districts likely had root deterioration from over-wintering in the nursery, and bareroot stock quality was also poor at planting in both regions, with resulting poor field performance.

Over the past two years, considerable interest has been expressed in transferring 1-0 styro-plug seedlings from the Styroblock 2 to nursery transplant beds, thus providing a plug-1 seedling for outplanting. This has been tried on an experimental basis for white spruce. Results, two years after planting 1-0 styroplug, plug-1 transplant and 2-0 bareroot white spruce in the Prince George Forest District, are shown in Table 12.

Initial field performance of the transplanted styro-plug is only intermediate between styro-plugs and bareroot and further demonstrates the advantages to be gained by planting the styro-plug seedling directly in the field from the styroblock.

Table 12.--Survival and growth of styro-plug, plug transplant and bareroot seedlings two years after planting

1-0 styro-plug	Plug-1 transplant	2-0 bareroot
	Survival %	
92	74	53
	Initial Height (cm)	
12	18	11
	Height after 2 yrs(cm)	
22	25	14

CONCLUSION

Field performance of bullet-plugs has been emphasized because early trials now have yielded substantial results over a five-year study period, whereas styro-plug data are still rather limited. The basic biological similarity between bullet-plugs and styro-plugs led us to conclude as early as 1971 that styro-plug seedlings would perform as well as, if not better than, bullet-plugs in the field. Incoming styro-plug data substantiate this conclusion and these data, plus the proven field performance of bullet-plug seedlings, have formed the biological base on which decisions have been made to expand styro-plug seedling production in British Columbia.

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Question: Do you have any data comparing nursery-extracted plugs versus taking the plugs to the field and extracting them there? Do the plugs begin to disintegrate in packing and what effect does that have on survival?

Arnott: No, we don't have comparative data, because all plug stock now going to the field is extracted at the nursery.