BC-X-63

PROGRESS REPORT ON

Field Performance of Douglas-Fir & Western Hemlock Container Seedlings

ON VANCOUVER ISLAND, BRITISH COLUMBIA

J.T. ARNOTT
CANADIAN FORESTRY SERVICE

PROGRESS REPORT ON FIELD PERFORMANCE OF DOUGLAS-FIR AND WESTERN HEMLOCK CONTAINER SEEDLINGS ON VANCOUVER ISLAND, BRITISH COLUMBIA

by

J. T. ARNOTT

PACIFIC FOREST RESEARCH CENTRE

CANADIAN FORESTRY SERVICE

VICTORIA, BRITISH COLUMBIA

INFORMATION REPORT BC-X-63

Department of the Environment

December, 1971

TABLE OF CONTENTS

PREFACE

Four years have elapsed since the Canadian Forestry Service began large-scale testing of Walters' bullet system. With the invaluable cooperation of the British Columbia Forest Service, Forest Industries and The University of British Columbia Research Forest, simulated planting production trials, experimental stock comparison plantations, and various pilot-scale nursery methods are being studied. Scope of the project has broadened to include performance and planting productivity of several other containerized or "protected" seedling methods, as well as bare-root planting methods. Although growing and field testing of container trees is the foundation of the British Columbia Region's program, many aspects of containerization are being investigated simultaneously under a series of distinct tasks.

One of these primary tasks is a study of the field performance of container seedlings in the Coast Forest Region of British Columbia. This report covers the three-year establishment period of that task.

ABSTRACT

A series of experimental plantations were 'established over a variety of forest site types in southern Vancouver Island, British Columbia, to assess and compare the biological performance of the 4½-inch Walters' bullet, 4½-inch "plug" and bare-root reforestation systems. Plug seedlings were removed from the 44-inch bullet before planting. Douglas-fir and western hemlock container seedlings 'were grown in 4½-inch bullets in outdoor shadehouses for the full growing season before planting in the fall of the relevant year. The same stock was overwintered and outplanted at two dates in the same plantation during the spring, thus covering three planting seasons; fall, early-and late-spring. All plantations were replicated over a three-year period, beginning in the fall of 1967. Seedling performance was assessed annually. Because of the interim nature of the results, survival and height growth data over a three-year period are only available from the first-year replication. Data from subsequent replications cover a correspondingly shorter interval of time. Three years after planting, average survival of Douglas-fir plug, bare-root and bullet seedlings was 84, 80 and 68% respectively, at the medium elevation areas. For western hemlock, these respective figures were 66, 29 and 56%. Removal of the container from the tree at the time of planting thus resulted in significantly improved survival rates. This effect was limited to seedling survival as plug height growth was only slightly greater than that of bullet seedlings three years after planting. Season of planting had a highly significant effect on seedling survival, maximum survival usually resulting from fall or early-

spring planting. Data on container seedling performance at the high elevations only cover the two-year interval since planting. The trends were generally similar to the medium elevation results but, because of lower site quality and the shorter growing season, overall figures for survival and growth were lower.

INTRODUCTION

Planting of bare-root stock is the traditional system used for most artificial reforestation in the coastal forest region of British Columbia. Generally speaking, the biological performance of the system is satisfactory for certain tree species and under a favorable set of environmental and human factors. However, the overall cost per surviving seedling in the bare-root system is at least $0.07 per tree (Tunner, 1969, unpublished), whereas several container systems have indicated potential costs of $0.04 to $0.05 per tree. Furthermore, the bare-root system is labor intensive throughout, with much less potential for mechanization than is offered by several container systems.

A great many difficulties are encountered in bare-root planting when favorable conditions do not exist, and there is urgent need for improvement if reforestation targets are to be met, Recent innovations in the field of reforestation include the semi-rigid container or Ontario "tubeling" (Anon. 1967; MacKinnon, 1970), the rigid container or "bullet" (Walters, 1969), and the container-grown or styro-plug seedling presently being developed at the Pacific Forest Research Centre, Victoria, B.C. (Kinghorn, 1970; Vyse et al., 1971). This project is concerned with field testing of the "bullet", "plug" and bare-root systems over a range of forest site types in the Coast Forest Region of British Columbia. Testing of the "tubeling" system has been limited because this method is receiving adequate attention in other regions.

The "plug" seedling refers to a system wherein the tree is removed from the container in which it has been grown in the nursery and planted as a "plug" into a dibbled hole at the planting site. Once planted, no physical restriction is placed on the root system as is the case when the tree and container are planted intact. Planted alongside bullet seedlings, the plug seedling permits a valid biological appraisal of the container influence on survival, height growth and root development.

Plug seedlings in this report have been grown in the 4½-inch Walters' bullet and not in the more recent innovation of the BC/CFS Styroblock (Matthews, 1971).

STUDY OBJECTIVES

The project was originally designed to give the Walters' bullet system (2½ and 4½ inch) an objective test under realistic plantation stresses. Tubelings, 2+0 bare-root and plugs were also included tu provide a biological comparison. Early results led to a revision of the original objective, the new goals being as follows:

i) To establish a series of experimental plantations, replicated over a variety of forest site types of British Columbia coastal conditions, to assess and compare the biological performance of the "bullet", "plug" and bare-root reforestation systems. Plantations have been replicated for three successive years to cover annual weather variations. The principal study species are Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.).

ii) To assess the effect of the season of planting by employing three planting dates (fall, early-and late-spring) at each experimental plantation.

iii) To carry out yearly assessment of seedling performance in the experimental plantations over the initial three years following planting, with a final assessment in the fifth year. Factors to be assessed will be survival, cause of injury, cause of mortality, microsite, seedling quality and height growth.

iv) To establish a series of "satellite" plantations, supplementary to the above, wherein a variety of factors affecting container seedling performance will be studied. This objective is secondary to the preceding three and will only be covered briefly in this report.

SEEDLING CULTURE

Container seedlings required for field trials each year were grown at the Pacific Forest Research Centre's nurseries in Victoria. Although the methods used every year were similar, several basic changes were brought about through the need to improve stock size and quality. These changes were principally concerned with irrigation techniques and fertilization and will be discussed later.

Before seeding, the bullets were filled with California "C" soil mix (Matkin and Chandler, 1957), either manually or with an automated shaker. The latter led to mure uniform compaction of the soil mix. Depending on the germination capacity of the seedlot in use, one or two seeds were sown per container. The seeds were then covered by a layer of fine sand, which was supplanted at a later date by granite grit.

Following seeding, the container racks were either moved directly outside to the nursery facility or maintained indoors in a heated chamber supplied with a high level of humidity for a 4-to 8-day period to facilitate uniform germination of the seed. Sowing dates varied from year to year, ranging from mid-May in 1968 to early April in 7970.

It is within the area of the container nursery facility and cultural treatments employed within it that the greatest changes were realized between 1967 and 1970. The initial container nursery was a wooden frame structure covered with shadecloth yielding 46% shade. The bullets sat in subirrigation tanks that provided the water and nutrient tu the seedltngs (Appendix A-1). This basic system, together with a larger version (Appendix A-2), was used.to grow the seedlings required for all replications at the medium elevations and for the first and second replications at the high elevation areas. For the final replication at Meade Creek and Robertson River, the seedlings were grown on pallets in a shadehouse in which water and nutrient was supplied by a top-watering irrigation system (Appendix A-3). Previous tests have proven that the two basic systems provided identical stock quality. In this facility, shade was provided at the rate of 30% and 46% for Douglas-fir and western hemlock, respectively.

For the most part, containers were not watered on a fixed basis but as was required by the seedlings themselves. This usually meant irrigation with water containing nutrient twice a week. Occasionally, in late July and August, thrice-weekly watering was required. With minor variations, fertilizers used remained practically the same from one year to the next, the principal annual differences being the rates and frequencies of application and the time at which fertilization was begun.

During the first year's nursery culture in 1967, it was presumed that there was sufficient fertilizer in the California "C" soil mix to sustain satisfactory tree growth through the growing season. This was not the case, and led to the application of water soluble fertilizers to the seedlings in mid-summer. Trees grown in 1967 were very small. Tree size and quality were greatly improved in subsequent years through earlier and more frequent application of fertilizers.

All fertilizers were highly soluble and were fed to the seedlings through the irrigation system. The guiding principle was to supply the seedlings with high levels of nitrogen through mid-summer and to reduce nitrogen and increase potassium toward the end of the growing season. The two commercial fertilizers used almost exclusively for this purpose were the Plant Products Ltd.[1/] fertilizers 28-14-14 and 15-15-30. To reduce high salt accumulation which became apparent in 7968, these two fertilizers were usually alternated with ammonium nitrate (34-0-0) and ammonium sulphate (21-0-0). Build up of fertilizer tu any toxic level in the soil was avoided by heavy leaching with water at least once a month. Variations in the nursery techniques used have produced corresponding changes in the quality of stock grown each year. This point is stressed because over the three-year replication period, not only have climatic variations been encountered but stock quality has also varied. Such variation must be taken into account in the final analysis of the results. Many of the procedures used in the container nurseries over the past four years are in the preliminary manual prepared by R.G. Matthews (1971).

Photographic and dry-weight records were maintained of the seedlings produced each year for planting in the field trials. Representative photographs of stock grown between 1967 and 1969 are presented in Appendix 8. These illustrate the annual improvement in stock quality brought about by modification of the cultural techniques. Earlier germination and improved nutritional regimes have helped yield the larger

---

1/ Port Credit, Ontario.

and woodier plants. Color and bud set of Douglas-fir has been vastly improved.

Container seed sources were matched by locality and elevatton to their destined planting sites. This seed source was maintained for the full three-year replication period at each of the study areas. All seedlots are described in Table 1.

Table 1. Seedlots of container stock used in the experimental plantations.

Species	Experimental Area	B.C.F.S. Seedlot Registration No.	Source Description
Douglas-fir	Franklin River	92F6/B2/510/1.5	Great Central Lake
	Copper Canyon	92B13/B2/315/1.5	Mt. Prevost
	Meade and Robertson	92F1/B2/327/2.5	Mt. Benson
Western hemlock	Franklin River	92F4/B3/941/0.5	Tofino
	Copper Canyon	92K5/B3/960/0.5	Sayward
	Meade and Robertson	92L8/B3/959/2.3	Sayward

Bare-root stock was obtained from the British Columbia Forest Service nursery at Duncan. Where possible, seedlots were matched with those of container stock.

STUDY AREAS

Location

Experimental plantations have been replicated over a variety of forest site types of coastal British Columbia conditions and are principally located within the Douglas-fir and western hemlock zones of southern Vancouver Island. This falls within the Southern Pacific Coast Section, Coast Forest Region as described by Rowe (1959). The main centers of study are the medium elevation areas (500-1500 ft), at Franklin River and Copper Canyon situated on the west and east coasts of Vancouver Island, respectively, and the high elevation study areas (2,500-3,500 ft) of Meade Creek and Robertson River (Fig. 1).

Physiography, Geology and Soils

The typical land form throughout the study areas is one of small mountain ranges separated by deep, U-shaped valleys. The highest mountain peaks of this general area rise to approximately 5,000 ft above sea level. The mountain ranges themselves are generally 2,500 ft in the Franklin River area, rising to an average elevation of 4,000 ft above sea level in the Copper Canyon, Meade Creek and Robertson River areas.

Forest soils have been principally developed from glacial till and not from bedrock parent material. These well-drained, stony, sandy loam soils fall within the red-brown podzolic group which covers the east coast section of Vancouver Island, under study. In the cooler, mure humid climate of the west coast, true podzols occur (Anon., 1957). Generally soils at the high elevations have a continuous and distinct podzol development (Day et al., 1959). Soil depth varies from a few feet on the lower slopes to very thin stony soil at the high elevations where outcrops of basalt commonly occur.

Site Description

Sites selected for the experimental plantations were representative of each geographic location. Forest cover before logging was mostly even-aged Douglas-fir and western hemlock in the dry east and high elevation areas. Toward the west coast, with its increased precipitation and moister slopes, the predominance of Douglas-fir declines (Anon., 1957). Here uneven stands of western hemlock and western red cedar occur. Site index at 100 years ranges from 90 on the high elevations to 160 on the lower slopes. Almost all areas were logged and burned from one to three years before planting.

Although a few plantations are situated on level ground, the majority were established on hill slopes ranging from 10 tu 50%. Typical conditions selected are illustrated in Figure 2. Within each area, a range of aspects was chosen.

Competition from vegetation two to three years following fire is generally not severe. The principal competitive species at all areas is fireweed (*Epilobium angustifolium* L.) which is probably beneficial to the establishment of tree species on the exposed southern aspects. Sword fern (*Polystichum munitum* (Kaulf.) Presl.) and deer fern (*Blechnum spicant* (L.) Roth) occasionally compete to the detriment of tree seed-,

oist, lower slopes. Slash burning removes the shrub layer. Re-invasion occurs soon after, huwever, and the principal species which severely compete with container seedlings are Salal (*Gaultheria shallon* Pursh) and salmonberry (*Rubus spectabilis* Pursh).

Climate

The nearest approximation to the climate within the experimental areas from 1967-70 is outlined in Table 2.

Table 2. Precipitation and mean monthly temperature at two representative stations for the experimental areas on Vancouver Island.

Pachena Point Lat. 48°43'N Long. 125°06'W Elev. 150 ft.

Month	Precipitation (inches) 1967	1968	1969	1970	Mean Monthly Temp. (°F.) 1967	1968	1969	1970
Jan.	25.0	19.5	12.9	11.3	42	40	33	40
Feb.	15.8	12.6	11.1	5.3	42	43	39	44
Mar.	14.1	15.5	14.9	8.5	41	44	42	43
Apr.	4.8	7.0	10.7	11.3	44	44	46	44
May	3.9	3.2	4.8	3.8	49	51	52	48
June	1.0	4.4	1.6	1.0	54	53	56	53
Jul.	2.0	2.8	1.3	3.2	57	57	55	54
Aug.	0.9	6.8	6.6	1.1	57	56	55	55
Sept.	4.6	9.6	13.0	8.9	57	54	54	52
Oct.	33.3	24.1	8.0	10.2	51	49	49	48
Nov.	9.6	15.3	16.6	14.6	46	46	46	44
Dec.	19.3	18.5	16.8	21.6	40	38	44	39
Total pptn.	134.3	139.3	118.3	100.8				

Cowichan take Lat. 48°49'N Long. 124°08'W Elev. 580 ft.

Month	Precipitation (inches) 1967	1968	1969	1970	Mean Monthly Temp. (oF.) 1967	1968	1969	1970
Jan.	20.9	22.6	13.6	9.9	38	36	36	37
Feb.	7.9	12.2	9.1	4.7	40	42	36	43
Mar.	12.5	12.0	8.9	6.2	39	44	42	43
Apr.	2.9	3.2	9.0	11.3	45	46	45	45
May	1.4	1.9	2.9	0.9	55	54	56	52
June	0.1	2.5	0.7	0.4	64	59	65	62
Jul.	1.0	1.3	0.6	1.1	65	66	65	65
Aug.	0.1	3.1	1.6	0.6	71	63	60	65
Sept.	3.6	3.4	7.6	3.7	62	59	59	56
Oct.	19.8	14.6	4.2	6.7	50	48	50	49
Nov.	6.6	13.4	6.0	10.6	44	43	43	42
Dec.	16.9	16.6	14.9	18.1	37	33	40	36
Total pptn.	93.7	106.8	79.1	74.2				

Franklin River study area is about 18 miles northeast of Pachena Point. Cowichan take is the nearest meteorological station for the Copper Canyon and high elevation areas at Meade Creek and Robertson River. It must be stressed that these meteorological records only approximate the local conditions at the experimental areas, which cover a wide altitudinal range. The high elevation areas at Robertson River and Meade Creek are approximately 2,000 and 3,000 ft above Lake Cowichan, respectively. Nevertheless, the data of Table 2 serve to illustrate the annual climatic variations encountered, together with the distinctive precipitation gradient from the west to the east coast of Vancouver Island.

The low precipitation and warmer summer temperatures of Cowichan lake are characteristic of the Douglas-fir region, whfle the much wetter and cooler summer climate of Pachena Point is representative of the western hemlock zone (Table 3). These differences occur because the rain-bearing winds come from the Pacific Ocean, placing areas to the lee of the mountainous west coast of Vancouver Island under the influence of a rain shadow effect (Chapman, 1952). The location of the shadow appears to be quite variable, however, being displaced to the west during the summer months (McMinn, 1960). This author indicates that the Nitinat Camp area, although receiving almost the same total precipitation as Pachena Point, lies within the summer rain shadow whereby the June, July and August precipitation is half that of the west coast. With Franklin River lying between these two points, it can be assumed that this experimental area will be subject to a mixture of coastal and

Table 3. Selected climatic data from the two stations covering the summer and winter months.

Station	Year	Precipitation (inches)		Summer[1] Temp. (°F.)		Winter[2] Temp. (°F.)	
		Total Summer	Diff. from normal	Mean	Diff. from normal	Mean	Diff. from normal
Pachena Point	1968	14.0	+4.1	55	0	41	0
	1969	9.4	-0.5	56	+1	37	-4
	1970	5.3	-4.6	54	-1	43	+2
Cowichan Lake	1968	6.9	+1.9	63	+2	39	+3
	1969	2.8	-2.2	63	+2	32	-4
	1970	2.1	-2.9	64	+3	40	+4

1/ Summer: June, July, August

2/ Winter: December, January, February.

rain shadow influences over the summer period. Summer fogs are also common at Franklin River and can add considerably to the amount of precipitation reaching the ground during the dry summer months (Anon. 1957). Fog, being associated with reduced sunshine and high humidity, cuts down the transpiration and evaporation losses from the soil.

Snow does not lie on the ground for extensive periods of time an the west coast and occurs intermittently during the winter at Franklin River. Winter temperatures are usually low enough in the Copper Canyon area from December to March for the precipitation to fall as snow (McMinn, 1960). At the high elevation areas, snow cover is usually on the ground by early November and can remain on the north aspects until mid-June, although it has usually disappeared from the south slopes by the middle of May. As a result of this snow cover, the soil is insulated against frost.

The mean monthly temperatures and total monthly precipitation encountered within the experimental area are outlined in Table 2.

Temperature extremes during the period under study, 1968-70, range from a minimum of 14 F to a maximum of 79 F on the west coast. Similar data for the Lake Cowichan area are 3 F and 93 F. Again elevational differences must be taken into account when using these figures. The frost-free growing season at Franklin River, Copper Canyon and the high elevation areas is approximately 200, 160 and 100-120 days, respectively (Anon., 1957).

FIELD TRIALS

Main Experiment

At each of the main study locations of Franklin River, Copper Canyon, Meade Creek and Robertson River, a set of experimental plantations have been established and replicated annually over a three-year period. The first replication of plantations at Franklin River and Copper Canyon included several container categories; namely, the 2½- and 4½-inch Walters' bullet, the 4½-inch plug, plus the ½-inch Ontario tube. However, in line with the revised objectives, only 4½-inch bullets and plugs, together with the 2+0 bare-root stock, were included in the subsequent replications during 1968 and 1969. As the high elevation areas were initiated in 1968, the experimental replicates include only bullets, plugs and bare-root. The numbers of plantations and trees planted per area per year are shown in Table 4.

Within each annual replication, three planting seasons were tested: fall, early-and late-spring. The approximate dates of the actual planting are given in Table 5, although it should be noted that replicates at any given area were not all established on that given day.

Since the first of the plantations were established in the autumn of 1967, three basic designs have been employed. In the first replication, a completely random design was used (Appendix C-1). The following year a split plot design was introduced (Appendix C-2), this being modified at the third replication, as illustrated in Appendix C-3. The latter is basically a split plot design, although the subplots (containers) have not been theoretically randomized. These changes in the design throughout the three-year period were necessary to reduce

Table 4. Total numbers of trees planted per area per year in the main experimental plantations.

Area	Year	Replication	No. of Plantations	Total No. Trees
Franklin River	1967-68	I	16	12,800
Copper Canyon			14	11,200
Sub-total			30	24,000
Franklin River	1968-69	II	8	3,000
Copper Canyon			8	3,000
Meade Creek		I	4	1,500
Robertson River			4	1,500
Sub-total			24	9,000
Franklin River	1969-70	III	8	3,600
Copper Canyon			8	3,600
Meade Creek		II	4	1,800
Robertson River			4	1,800
Sub-total			24	10,800
Meade Creek	1970-71	111	4	1,800
Robertson River			4	1,800
Sub-total			8	3,600
GRAND TOTAL			86	47,400

Table 5. Dates selected for fall, early-and late-spring plantings in the experimental plantations.

Area	Fall	Early Spring	Late Spring
		1967-68	
Franklin River	16 October	13 March	5 June
Copper Canyon	23 October	25 March	28 June
		1968-69	
Franklin River	21 November	9 April	8 July
Copper Canyon	18 November	30 April	30 June
Meade Creek	13 November	25 June	7 July
Robertson River	14 November	29 May	16 July
		1969-70	
Franklin River	28 October	14 April	27 May
Copper Canyon	6 November	26 March	14 May
Meade Creek	29 October	4 June	2 July
Robertson River	27 October	27 May	1 July
		1970-71	
Meade Creek	4 November	23 June	8 July
Robertson River	3 November	26 May	7 July

the sire of the' experimental plot (plantation) from the large, extensive design of the 67/68 series tu the more practical dimensions of the field design used in 1969 and 1970. Such changes have improved the homogeneity of the plots and greatly reduced the input required in plot establishment, without impairing subsequent analyses of the data.

Throughout the four-year planting period, three basic planting tools have been used:

a) Guns - for bullets

b) Dibbles - for plugs and tubes

c) Mattocks - for bare-root stock

Several modifications have been made in the design of the initial gun used, which was the 'Step Pedal' type developed by J. Walters (1969). This model had no ripper for splitting the bullet as it was pushed into the ground. To overcome this limitation, a "walking stick" gun was developed by the Canadian Forestry Service which incorporated a bullet-ripper. More recently, bullets have been planted with the single-bullet Walters' gun, which is of a telescopic design and has cutting wheels for splitting the bullet as it is planted (Vyse, 1970). With the sole exception of the 'Step Pedal' Walters' gun, no specific differences in planting quality of bullet seedlings are to be found despite variations in the planting equipment employed. A chronological record of the planting guns used is outlined in Table 6.

Table 6. Guns used for bullet-planting in experimental and operational trials - 1967-71

Year	Planting Seasons	Bullet Gun Used
1967	Fall	Step-pedal Walters (no ripper)
1968	Spring and Fall	CFS Walking Stick
1969	Spring	CFS Walking Stick
1969	Fall	Telescopic - Walters
1970	Spring and Fall	" "
1971	Spring	" "

Supplemental Studies

Every year, in accordance with objective (iv), supplemental studies have been established to investigate various aspects outside the sphere of reference of the main experiment. These were established within a series of "satellite" plantations which cover a much broader range of the Southern Pacific Coast Section, Coast Forest Region (Rowe, 1959), than does the main experiment. The plantations are located at Haney, Victoria Water Board, Muir Creek, Port Renfrew and Nootka Island (Fig. 1).

Within these 44 experimental plantations containing a total of 25,700 trees, the following factors are being studied:

a) effect of stuck quality and size of container seedlings on subsequent survival and growth;

b) fertilization of container seedlings at planting.

c) effects of cold-hardening container seedlings on subsequent survival through cultural techniques in the nursery;

d) survival and growth of Sitka spruce container seedlings on Nootka Island;

e) effects of deer browsing on the survival and growth of container seedlings, and

f) root development of container seedlings 3 to 5 years after planting.

All these studies yield information pertinent to the total container program for the region. However, as they are not contained within the main experiment, the results of these separate investigations, with the exception of study 'a', will be reported at a later date.

Within the first replications at Franklin River and Copper Canyon, "small" stock was planted in paired comparison with the "regular" 4½-inch bullet stock. The objective of this study (a) was to obtain information on the effect stock size and quality would ultimately have on tree survival. The "small" stock was grown during 1967 at the University of British Columbia Research Forest at Haney. These seedlings did not receive additional fertilizer through the irrigation system and were grown under too much shade. The "regular" stock was raised in the Victoria shadehouse, which provided adequate light, and water-soluble fertilizers were added through the irrigation system from mid-July onward. At planting, mean heights of these "small" and "regular" stock in the 4½-inch bullets were 6 and 9 cm, respectively, for Douglas-fir and 3 and 7 cm, respectively, for western hemlock.

Not only did the "regular" stock have greater height and dry matter production, but the seedlings also had greater needle-length and better color, indicating superior quality to the "small" stock from Haney.

Simulated Production Planting

As part of the original study objective, large numbers of containerized trees were planted by experienced contract planting crews under simulated production conditions during 1967 and 1968. The primary purpose of these trials was to examine container planting productivity, to test planting tools and container handling logistics. A secondary, but important, objective was to compare the survival and growth performance of these operationally-planted trees with those planted by research personnel in the adjacent experimental plantations of the main experiment, Fur this purpose, 10,600 trees from the simulated production planting were staked fur assessment.

Findings from this secondary trial are reported herein. Results from the investigations of container planting productivity and handling will be reported separately. Preliminary results have already been.reported (Arnott and Vyse, unpublished).

FIELD ASSESSMENT

Since the fall of 1968, survival and height growth measurements have been made at the end of each growing season on all seedlings planted. In a certain number of plantations, trees planted in the autumn have been assessed the following spring to evaluate overwintering effects.

In addition to survival and height growth data, the following variables have been noted per seedling: cause of mortality or injury, degree of frost heaving, microsite, seedling vigor and degree of shade. These data are transcribed to computer tapes for processing and analyses. The initial print-out provides percentage survival and mean height per line per plantation, together with a complete record of the assessment data for every seedling. Data from the main experiment, which has been replicated over a three-year period at Franklin River, Copper Canyon, Meade Creek and Robertson River, have been subjected to analyses of variance tu determine the significance of differences obtained among container types, planting seasons and plantations by species fur each year's replication at all four locations. Due to the wide range in percentage survival, arcsin$\sqrt{\text{percentage}}$ transformation was used for all analyses.

RESULTS

Main Experiment

For the medium elevation areas at Franklin River and Copper Canyon, survival by specific planting season fur the 4½-inch bullet, the 4½-inch plug and 2+0 bare-root seedlings is presented for Douglas-fir and western hemlock in Figures 3 and 4, respectively. These data are based on replications over three years and, for those plantations which were established in 1967, the results encompass tree survival over the three subsequent years of assessment. Those plantations established in 1968 and 1969 have only been assessed twice and once, respectively.

Following analyses of variance, Duncan's multiple range tests of survival means for each year are incorporated in Figures 3 to 8, where applicable. These tests are indicated symbolically and apply tu the most recent survival data available from each replication. Thus for replicate I at Franklin River (Fig. 3), the range test is indicating the significance of differences in survival among the three categories, three years after planting. For replicates II and III, the range test indicates significant survival differences among the three categories two years and one year after planting, respectively.

Survival of Douglas-fir container seedlings at the medium elevations compared favorably with bare-root stock (Fig. 3). The overall trend has been plugs > bare-root > bullets. Three years after planting, average survival of Douglas-fir plug, bare-root and bullet seedlings was 84, 80 and 68%, respectively. For western hemlock, these respective figures fur the fall and early spring plantings only, were 66, 29 and 56%. Overall performance of both species was greater at Franklin River where site was more favorable to tree survival and growth. Removal of the container from the Douglas-fir seedling at the time of planting resulted in significantly higher survival rates for plug seedlings over those planted in bullets, particularly at Copper Canyon where site conditions were mure limiting. Western hemlock plug seedling survival was consistently greater than that of bullets, although the difference was usually insignificant. Mortality of bullet and plug seedlings has continued into the third year after planting.

Survival data for the high elevation areas at Meade Creek and Reobertson River are presented in Figures 5 and 6. Due to the fact that elevation, climate and soil type are common to both locations, survival and height data for the two areas have been combined. No results are available for the third-year replication at Meade and Robertson as this was only completed in July, 1971. Bullet and plug seedling survival trends were similar to the medium elevation areas but, because of much lower site quality at Meade and Robertson, overall figures were lower. Plug seedling survival has been significantly greater than that of bullets for both species.

The influence that the planting season has had on the subsequent survival of bullet, plug and bare-root stock is illustrated in Figures 7 and 8. Data are not shown for the fall planting of western hemlock in 1968 because container stock was not available. Maximum survival for Douglas-fir and western hemlock generally resulted from fall or early-spring planting at all experimental areas.

The relationship between seedling survival and aspect is provided by Tables 7 and 8, where combined survival of bullet, plug and bare-root seedlings is presented for each plantation. Although sites were not always homogeneous within each annual replication, northern and eastern slopes generally produced significantly higher survival rates than south and west aspects at most locations, except Franklin River. Reasons for this will be discussed in a later section. No Duncan's multiple range test of plantation means was conducted in the first replication for bullet, plug and bare-root seedling survival as other container categories were included in these plantations.

Mean height growth has been averaged from the three planting seasons at Franklin River and Copper Canyon where three-year data are available and this information is presented graphically in Figure 9.

Table 7. Combined survival of Douglas-fir bullet, plug and bare-root seedlings by plantation as related to aspect (1970 Assessment).

Area	Replication-Year Established	No. of Plantations	% survival by Plantation (letter indicates aspect)							
Franklin River	I-67	8	73N	77SE	77NE	77S	78N	79SE	80E	84W 1/
	II-68	4	55N	56S	61N	62S 2/				
	III-69	4	76S	78S	87N	88N				
Copper Canyon	I-67	7	67W	70N	70N	77N	79N	79N	81N 1/	
	II-68	4	50S	56S	61E	62E				
	III-69	4	53S	58S	67N	69NE				
Meade and Robertson	I-68	4	74N	74S	75S	86N				
	II-69	4	45S	50NW	51S	71N				

1/ No Duncan's Multiple Range Test available.

2/ Means underscored by same line are not significantly different at the 5% level.

Table 8. Combined survival of western hemlock bullet, plug and bare-root seedlings by plantation as related to aspect (1970 Assessment).

Area	Replication-Year Established	No. of Plantations	% survival by plantation ('letter indicates aspect)							
Franklin River	1-67	8	36E	37W	37NE	41E	44N	47W	50E	50S 1/
	11-68	4	47s	54s	54s	54S 2/				
	I11-69	4	68N	72N	76S	79S				
Copper Canyon	1-67	7	36N	39W	50N	51N	57N	57N	67N 1/	
	II-68	4	24S	25S	31E	53E				
	II1-69	4	48E	48S	52S	65N				
Meade and Robertson	1-68	4	36S	52W	60NE	62E				
	11-69	4.	30S	36NW	44S	57N				

1/ No Duncan's Multiple Range Test available.

2/ Means underscored by same line are not significantly different at the 5% level.

Although this simply underlines the obvious fact that the 2+0 bare-root stock initially had an additional year's growth over the container categories included in the comparison, the histograms do illustrate the fact that growth rates of bullet and plug seedlings compared favorably with bare-root stock. Average height of plug seedlings was always greater than that of bullets. Height growth of all categories at Franklin River was almost twice that of Copper Canyon, reflecting the more favorable growing conditions of the west coast of Vancouver Island. Seedling growth at the high elevations was less than that of Copper Canyon, the graph clearly indicating the site gradient between the main study areas.

Details of percentage survival and average heights for the two container categories and 2+0 bare-root stuck are given by location, species, year of establishment (i.e., replication) and planting season in Appendix D.

In the foregoing, no mention has been made of the factors causing injury and seedling mortality and the effect that microsite has on survival and growth. These investigations will be the subject of later reports.

Supplemental Study

The effect that stock quality and size differences have had on bullet survival is shown in Table 9. Although these results illustrate the effect three years after planting, the trend was evident from the beginning of the trial. For Douglas-fir at both east and west coast locations, survival of the "small" stock was two-thirds that of the "regular" category. Survival of "regular" western hemlock stock was two to six times greater than the smaller category.

Table 9. Fer cent survival of Douglas-fir and western hemlock three years after planting in 4½-inch bullets using two sizes of stock.

(i) West Coast (Franklin River)

Stock Size	PLANTING SEASONS					
	Fall - 1967		Early Spring - 1968		Late Spring - 1968	
	Douglas-fir	Western hemlock	Douglas-fir	Western hemlock	Douglas-fir	Western hemlock
Small	46	22	44	27	40	19
Regular	68	48	71	56	58	7

(ii) East Coast (Copper Canyon)

Small	47	9	29	14	58	29
Regular	74	59	71	59	66	17

The trend reversal for late spring planted western hemlock was due to the combination of "regular" stock deterioration and "small" stock improvement in the nursery before the late spring planting in 1968.

Simulated Production Planting

Three-year survival data for Douglas-fir and western hemlock production trials at the medium elevations are shown in Figures 10 and 11, respectively. In every instance, survival of the production-planted stock has been compared with its equivalent container category in the adjacent experimental plantations. The difference is presented below each histogram.

One of the more encouraging aspects of the Copper Canyon results has been the low mortality of the 4½-inch Douglas-fir bullet seedlings which was 10, 7 and 2%, respectively, over the first three years after planting (Fig. 10). The fact that the Copper Canyon Douglas-fir has had better survival from production rather than experimental plantings is a reflection of site, rather than planting crew differences.

The opposite effect at Franklin River is also site-induced and not due to the diligence of research personnel at plantation establishment. Although adjacent to the experimental plots, the production plantings cover extensive areas. Site differences are encountered, yielding the responses indicated in Figures 10 and 11.

Two distinct areas were chosen for the fall and spring production plantings at both areas. At Franklin River, the experimental and operational fall planting sites were in such close proximity that large survival differences did not exist. However, the spring-planted experimental plots were predominantly on fresh, lower slopes with the production plantings covering the much drier slopes above. This has resulted in poorer survival from the production planting in this instance. The fall production trials at Copper Canyon were located much further uphill than the experimental plantations. Thus, they tended to avoid the severe erosion that affected the research plots and also benefitted from the edge effect of the standing timber on the upper slopes.

This relationship between production and experimental results was not solely restricted to the medium elevation areas. Comparisons at Meade Creek and Robertson River indicated a similar situation at the high elevations (Table 10). Any wide differences that arose resulted from site and not from differences in planting quality.

Table 10. Comparison of survival and height of Douglas-fir seedlings planted in 4½-inch bullets in simulated production and experimental plantations at the high elevation areas.

Area		Simulated Production		Experimental Plantations	
		1969	1970	1969	1970
Meade Creek	% Survival	81	73	77	68
	Average Ht. (cm)	7.1	10.0	8.5	11.2
Robertson River	% Survival	75	50	68	63
	Average Ht. (cm)	7.1	8.8	8.5	11.9

Considering that site has created the respective negative and positive difference at the medium and high elevation areas, it can be concluded that no major differences should result in the survival of bullet-planted trees whether planted by research personnel or regular contract crews. This is a very important point as it adds credence to the results from all experimental plots covered in this report when they are taken as guidelines for container planting programs in the British Columbia Coastal Region.

DISCUSSION

Only the results of the main experiment will be discussed as data from the supplemental study and simulated production trials have already been adequately covered.

The discussion will be divided into four sections to cover the two tree species at the two elevations. Each section will consist of four parts. The first, headed "Containers and bare-root" deals with the survival differences encountered among the bullet, plug and bare-root categories. The second discusses the influence that the three planting seasons have had on seedling survival. The third covers the effect of aspect on seedling survival, and the fourth compares height growth of the bullet, plug and bare-root seedlings, three years after planting.

Douglas-fir - Medium Elevation

Containers and Bare-root

Discounting the low bullet and plug seedling survival in the second replication, plugs have almost consistently out-performed both bare-root and bullet categories at Copper Canyon over the three annual replications (Fig. 3). These differences are not nearly so well defined at Franklin River where conditions are more favorable for tree growth. Here bare-root has generally proven equal to or better than the container categories. This suggests that, where site and climatical conditions are more limiting, such as at Copper Canyon, root protection through containerization has helped yield better survival. To elaborate, bullet and plug seedlings do not have their root systems appreciably disturbed at planting, which is markedly different from the bare-.root planting method. As a result, the container trees suffer less planting check and, it is assumed that this factor, on somewhat more limiting sites within the medium-elevation range, results in better container seedling survival over 2+0 bare-root stock.

Where such site limitations do not exist, such as at Franklin River, the larger 2+0 stock survive favorably with plug seedlings, although this difference may not always be statistically significant, as indicated in Figure 3. Verification of this assumption can be found by studying the mortality trend of bullet, plug and bare-root seedlings over the three-year period within the first replicate at Franklin River and Copper Canyon. Initial bare-root mortality at Franklin River was low and had almost ceased three years after planting, giving the 2+0 stock a superior performance rating over the plug system. However, at Copper Canyon, the plug seedling, with its undisturbed root system has proven superior to the bare-root category that was initially subject to higher mortality.

As the survival of bullet seedlings has usually been lower than that of plugs, it can be concluded that the restriction placed on the root system by the bullet has been detrimental to survival.

The general survival pattern of container-grown trees in relation to 2+0 stock at the medium elevations has been plugs > bare-root > bullets. Three years after establishment, average survival of Douglas-fir plug seedlings from the three planting seasons at both east and west coast locations was 84%. This compared favorably with the survival average of 80% fur 2+0 stock.

Reference was initially made to low survival of Douglas-fir bullet and plug seedlings in the second replication at the medium elevations (Fig. 3). This did not result from particularly adverse climatic conditions immediately following planting, but was due to root dieback of Douglas-fir container seedlings in the nursery during the winter of 1968-69. The severe nature of the actual dieback was not noticed in the seedlings at the time of planting and was only detected by the unusually high mortality registered at the first assessment. In the interim, between early-and late-spring planting of that year, sufficient root regeneration had taken place in the trees remaining in the container nursery so that survival rates were remarkably high in face of conditions of heat and drought stress encountered at the later planting date of mid-June.

This is not an isolated occurrence of winter root dieback of container-grown Douglas-fir. It has arisen under similar circumstances at the British Columbia Forest Service container nursery at Duncan (Matthews, 1971). Research is currently underway to identify the causes of the problem.

Season

Although an analysis of variance has not been conducted on the bullet, plug and bare-root survival data alone from the first year's replication at Franklin River and Copper Canyon, the means from all three planting dates did not differ greatly from one another (Fig. 7).

From the second and third years' replications, significant differences occurred. However, with the exception of Copper Canyon, survival from fall and late-spring plantings do not appear to be too divergent. Had it not been for the moribund state of the bullet seedling's root system in the early spring of 1969 and the severe'drought conditions of the 1970 growing season (Table 3), it is probable that the survival from the secund and third years' replications would have been quite similar to that of replicate I.

Aspect

Although sites were not necessarily homogeneous within each annual replication, the variable that did have a noticeable effect on seedling survival was aspect. Northern and eastern slopes did provide significantly higher survival rates than south and west aspects at Copper Canyon (Table 7). . Where climatic conditions were less limiting at Franklin River, aspect differences were not significant. Due to experimental design, no analyses have been conducted on the first replication at both areas. Although the plantation. means indicate differences at Franklin River, they result more from topographic and site variability than aspect alone. The majority of the plantations in the first replication at Copper Canyon were established on north-facing slopes so no meaningful comparisons are available.

Height Growth

Height growth after three growing seasons at Franklin River is almost twice that attained at Copper Canyon for all three categories -

bullet, plug and bare-root (Fig. 9). This reflects the more favorable growing conditions of the west coast. The average height of plug seedlings was greater than that of bullets at both locations, Of interest is the fact that plug seedling height growth during the third year at Copper Canyon equals that of bare-root stock. This may be an indication of one advantage that plugs have over the bare-root stock.

Douglas-fir - High Elevation

Containers and Bare-Root

Survival at the high elevation areas has been low, particularly within the late-spring planting of the second-year replication (Fig. 5). Poor performance of both spring plantings for that year resulted from the severe drought of 1970. Plug seedlings planted in the fall of 1968 at the high elevations survived fairly well over the two-year period (785%) but their survival was significantly lower than bare-root stock at the spring-planting dates.

Winter root dieback of Douglas-fir container seedlings did not occur among the high elevation provenances in 1968 when the Franklin River and Copper Canyon stock was affected. Maximum survival of bullet seedlings at Meade and Robertson was obtained from the early-spring planting that year (Fig. 5).

Season

As the full three-year study period at the high elevations is not complete, it is premature tu state which season is the most preferable choice for the planting of bullet or plug seedlings. With much drier, shallower soils, it would appear from the results obtained to date that fall planting offers the greatest potential for success of plantation establishment (Fig. 7). Clearly climate plays a very significant role at the higher elevations, particularly if spring plantings are extended well into late May and June as a result of heavy winter snows and a late-spring thaw. Spring plantings in the second replicate were on average a month later than in the previous year. This, in association with the hot dry conditions of June and July of 1970, created very significant seasonal differences in the second replicate (Fig. 7).

Aspect

In the first-year replication of Douglas-fir at the higher elevations, seedling survival was generally lower on the south-facing slopes than on the north but this difference was not significant (Table 7). At both high elevation locations in the second-year replication, survival on the south-facing slopes was significantly lower than on the northern aspects. Aspect plays a more significant role above the 3,000 ft level than it does on the lower slopes. Southern aspects, with their extremes of temperature, drier soils and sparser vegetative cover offer a poor chance for successful regeneration at the high elevation areas covered in this study. Aspect differences appear to be at a minimum during fall planting and progressively increase through the early- and late-spring planting dates. If south-facing slopes are to be planted with container stock, this would best be done in the fall.

Height Growth

In the year after planting, there were no substantial height differences between the three categories at the high elevation areas and Copper Canyon (Fig. 9). The site limitations at Meade and Robertson created by the shallower soils, the greater extremes of temperature and the shorter growing season were reflected in the second year's growth, which was much less than at the medium elevations. There was little difference between the average heights of bullet and plug seedlings two years after planting.

Western hemlock - Medium Elevation

Containers and Bare-root

Survival of western hemlock bullet and plug seedlings has been generally poorer than the results obtained with Douglas-fir. However, one outstanding difference between the two species is the fact that hemlock container seedling survival is much superior to that of bare-root stock. With the exception of one instance, bare-root mortality has exceeded that of bullet and plug seedlings (Fig. 4). Results to date indicate that three years after planting, the average seedling survival from the fall and early-spring planting dates for plug, bullet and bare-root categories was 66, 56 and 26%, respectively. Container systems minimize root disturbance at the time of planting, and it would appear that this protection has produced the much lower mortality figures among the western hemlock bullet and plug categories.

At Franklin River, bullet and plug seedling survival over the three annual replications were not significantly different, although plugs showed a trend toward higher survival rates. At Copper Canyon, these same differences also occurred but they were significant only in the third-year replication. The outstanding feature of this last replication at Franklin River was the 83-87% survival figures obtained for bullet and plug seedlings from the fall and early-spring planting dates. The Copper Canyon data parallel the Franklin River results. However, these drier, eastern slopes of Vancouver Island are not as favorable for western hemlock as the wetter west coast and so survival was lower.

The increase in bullet and plug seedling survival from the third planting at Franklin River may well have been brought about by improvement in western hemlock stock quality through annual amendments to plant cultural techniques in the container nursery. The photographs of Appendix B illustrate how substantial these annual improvements were to western hemlock stock quality. However, the better quality stock did not realize a corresponding trend of annually improved survival rates at Copper Canyon due to the more limiting site conditions for the species at this location.

Season

Establishment of western hemlock in relation to planting season has been significant, although not necessarily in every year (Fig. 8). Despite annual variability, late-spring planting has usually resulted in the highest mortality. An exception was the late-spring planting of the second replication where mortality rates were lower. The weather records indicate that the summer months that year (1969) were much hotter and drier than normal (Table 3) and one can conclude that improvements in stock quality could have somehow reduced the mortality from the late-spring planting in this second replication.

The point should again be made that the extremely low survival from late-spring planting at Franklin River and Copper Canyon was not entirely the result of seasonal variation. As was mentioned previously, western hemlock container stock deteriorated in the nursery before the late-spring planting that year. The low survival, therefore, was more a result of this poor quality stock than seasonal influences.

Aspect

Aspect has played a significant role at the medium elevations where site conditions have been more limiting for western hemlock survival; namely, at Copper Canyon. As most of the first-year replication was planted on north-facing slopes, aspect comparisons are only available from the second and third year's planting. Survival generally was very poor in the second replication. Nevertheless, significantly higher survival rates appeared on the eastern slopes as opposed to the south. North slopes yielded significantly higher survival in the third year (Table 8).

The situation was quite different at Franklin River. There were no significant differences in seedling survival between north and south aspects in the third year where higher survival figures were actually obtained on the south slopes. It is unfortunate that no information is available from the second replication where all hemlock plantations were replicated on southern aspects. In the first-year planting at Franklin, although differences did exist, they, as with Douglas-fir, were due more to topographic and site changes than just aspect alone.

Height Growth

Differences in western hemlock height growth between Franklin River and Copper Canyon parallel those of Douglas-fir (Fig. 9). This again reflects the significant climatic differences between these west and east coast locations. The average total height after three years for each category at Franklin River was twice that of Copper Canyon. For bare-root stock, these average heights fur the west and east coast locations were 76 and 33 cm, respectively. Similar data for the combined container categories was 43 and 24 cm.

At both medium elevation locations, total height growth of the bullet seedlings after three years was less than that of plugs. On the west coast, bullet and plug seedlings doubled their height annually. A slower growth rate was evident at Copper Canyon, but the third-year height increments of both container categories was much greater than bare-root stock. It will be interesting to see if this trend continues.

The data discussed above pertain to the first-year replication as this was the only one where height growth over the three-year period could be studied. Similar growth patterns were apparent in the second year's replicate (Appendix D-2,5). Continuation of this trend will be verified at the end of the five-year period covered by the investigation.

Western hemlock - High Elevation

Containers and Bare-root

As with Douglas-fir, western hemlock survival at the high elevations is much lower than that of Franklin River and Copper Canyon. The second-year spring plantings, in particular, have had high mortality rates. Survival differences have been significant (Fig. 6). Although the pattern has not remained constant from year to year, the general order has been plugs > bare-root > bullets. First-year plug seedling survival of 83% from the 1969 fall planting is quite impressive. However, insufficient information is available from the high elevation areas to predict survival patterns of plug seedlings over the next few years.

Season

The highly significant seasonal differences of the second-year replication result from the prolonged drought during the summer of 1970 (Fig. 8). Parallel patterns of seasonal trends in the 1969 plantings between Copper Canyon and the high elevation areas are striking. The progressive mortality of the late-spring planting data ranging from high at Copper Canyon to severe at Meade and Robertson illustrates the point that when western hemlock is to be planted as bullets or plugs on sites which are marginal for the species, selection of the correct planting season is very important.

Aspect

Significant survival differences arose between plantations on north and south slopes. In the first replication, highest survival was obtained on the northern and eastern slopes with much poorer results on the southern aspects. These results were repeated in the second replication. At this second planting, the influence that aspect had on survival became more pronounced as the planting date was extended into the late spring. Thus, if hemlock must be planted on south aspects at the high elevations, it should be done in the fall.

Height Growth

Total heights of all three categories in the first year after planting differed little from those of Copper Canyon (Fig. 9). Subsequent differences reflected the much shorter growing season and poorer sites of the high elevation areas. Bullet and plug seedling height growth differences were insignificant. Second-year growth of these trees almost equalled that of bare-root stock. Based as a percentage of the original height, this indicated faster growth rates for bullet and plug categories. As the Meade Creek and Robertson River data are only inclusive to the second year after planting, these results are somewhat tentative. One will have to wait until the fifth year for conclusive evidence on growth rate differentiation between bullet, plug and bare-root stock.

SUMMARY

Due to the interim nature of the results of this study, many of the conclusions to be drawn are somewhat tentative, Nevertheless, they are listed as follows:

Douglas-fir

1. Survival of bullet and plug seedlings at the medium elevations compared favorably with bare-root stock. The overall trend, encompassing three years of replication, was plugs > bare-root > bullets.

2. Three years after establishment, average survival of plug, bare-root and bullet seedlings at the medium elevations was 84, 80 and 68%, respectively.
3. Two years after planting at the high elevation areas, maximum plug survival (85%) compared favorably with that of bare-root stock (97%).
4. Season of planting had a highly significant, although variable, effect on Douglas-fir surviva . Generally, maximum survival resulted from fall or early-spr ng planting.
5. Container stock, which was of poor quality and small at the time of planting (6 cm), was subject to greater mortality than healthier trees that were 9 cm in height.
6. Improvement in container seedling quality over the three consecutive years did not correspondingly improve Douglas-fir survival from the spring planting dates between 1967 and 1970. Quality improvement did improve survival when the trees were fall-planted.
7. Three years after planting, average height of plug seedlings was greater than that of bullets although the difference was insignificant.
8. Mortality of bullet and plug seedlings continued into the third year after planting.

Western hemlock

1. Survival of bullet and plug seedlings at the medium elevations was greater than bare-root stock, the order being plugs > bullets > bare-root.
2. Results to date indicate that three years after planting, average seedling survival from the fall and early-spring planting dates for

plug, bullet and bare-root categories was 66, 56 and 29%, respectively. These data illustrate the advantages to be realized through the use of a container reforestation system for western hemlock as opposed tu conventional 2+0 bare-root stock.

3. At the high elevations, similar survival differences existed between plug and bare-root seedlings but, because of lower site quality, the overall figures were lower, In contrast to the medium elevations, bullet seedling survival was generally less than that of bare-root stuck.

4. Survival of western hemlock was highly dependent on the planting season, late spring generally proving to be the least favorable.

5. Container stock, small at the time of planting (2-3 cm), was subject to much greater mortality than stock that was 7 cm in height.

6. Improvement of container stock quality in the nursery resulted in correspondingly increased survival for western hemlock.

7. As with Douglas-fir, average heights of western hemlock bullet and plug seedlings were not significantly different three years after planting although height of plug stock was always greater.

8. Mortality of western hemlock bullet and plug seedlings continued into the third year after planting.

9. There was no real evidence tu support the assumption that the survival rates of bullet-planted Douglas-fir and western hemlock obtained from these experimental plantations would have been any lower had the trees been planted operationally by regular planting crews.

ADDENDUM

Much of the discussion on container planting has been focused. on a comparison between the container-planted tree, the 4½-inch bullet, and its counterpart, the 4½-inch plug which has had the container removed from the tree at the time of planting. The general conclusion is that removal of the container has resulted in significantly improved survival rates.

The biologically acceptable results obtained from these trials with the 4½-inch plug seedling has led to the development of a plug system which utilizes the BC/CFS Styroblock for growing the seedlings in the nursery (Kinghorn, 1970; Matthews, 1971). These blocks contain tapered rounded cavities for protecting and shaping the roots. Although 4½ inches deep, their larger diameter produces a soil capacity of 2.4 cubic inches, almost twice that of the 4½-inch Walters' bullet. This cavity-size difference yields a larger, better developed styro-plug seedling than was possible in the 4½-inch Walters' bullet.

Despite its larger size, the styro-plug seedling is the same biological entity as the 4½-inch plug which has been extensively tested in field trials reported herein. Therefore, it can be forecast that styro-plug field performance will be at least as good as plug seedlings which have been removed from a 4½-inch bullet. If anything, survival and height growth will improve due to the quality and size of tree produced in the styroblock. Conclusive evidence to support these assumptions will be obtained from the results of field trials currently being conducted by the British Columbia Forest Service.

ACKNOWLEDGMENTS

Appreciation is expressed to the following cooperators on whose limits these experiments were conducted:

1. B. C. Forest Products Ltd.
2. Greater Victoria Water Board.
3. MacMillan Bloedel Ltd.
4. Pacific Logging Ltd.
5. Rayonier Canada Ltd.
6. Tahsis Ltd.
7. University of British Columbia.

The author also wishes to thank *the* British Columbia Forest Service for providing the necessary tree seed and 2+0 bare-root nursery stock used in all plantations.

Particular acknowledgment is made of the major role played by Mr. C. P. Brett who directed this project from 1967-69 and to Mr. J. M. Kinghorn who has directed the section dealing with the simulated production planting.

All members of the Liaison and Development section have been involved in the coastal container planting program and the assistance provided by the following individuals is gratefully acknowledged: E. Van Eerden, R. G. Matthews, G. D. Nixon, D. G. Lund and 8. J. Downing.

Finally, the author would like to thank Mr. J. C. Wiens for preparing the figures in this report.

REFERENCES

Anon. 1957. An introduction to forest soils of the Douglas-fir region of the Pacific Northwest. Forest Soils Committee, Western Forestry and Conservation Association. Portland, Oregon.

Anon. 1967. Provisional instructions for growing and planting seedlings in tubes. Research and Timber Branches, Ont. Dept. Lands and Forests. Manual for restricted distribution.

Chapman, J. D. 1952. The climate of British Columbia. In Trans. 5th B. C. Nat. Res. Conf., Victoria.

Day, J. H., L. Farstad and D. G. Laird. 1959, Soil survey of southeast Vancouver Island and Gulf Islands, British Columbia. Res. Br., Canada Dept. Agric., Rept. No. 6, British Columbia Soil Survey.

Kinghorn, J. M. 1970. The status of container planting in western Canada, For. Chron. 46: 466-469.

MacKinnon, G. E. 1970. Container planting in Ontario. For. Chron. 46: 470-472.

Matthews, R. G. 1971. Container seedling production - a provisional manual. Dept. of the Environment, Pacific Forest Research Centre, Canadian Forestry Service, Victoria, B.C. Information Report, BC-X-58.

Matkin, O. A. and P. A. Chandler. 1957. The U.C.-type soil mixes. In the U. C. System for producing healthy container-grown plants. University of California, Division of Agricultural Sciences. Manual 23.

McMinn, R. G. 1960. Water relations and forest distribution in the Douglas-fir region on Vancouver Island. for. Biol. Div., Canada Dept. Agric. Publ. 1091.

Rowe, J. S. 1959. Forest regions of Canada. Can. Dept. Northern Affairs and Nat. Res. , For. Br. Bull, No. 123.

Vyse, A. 1971. Planting rates increased in British Columbia with new planting gun and bullets. Tree Plant, Notes. 22(1): 1.

Vyse, A,, G. A. Birchfield and E. Van Eerden. 1971. An operational trial of the styro-plug reforestation system in British Columbia, Dept. of the Environment, Pacific forest Research Centre. Canadian Forestry Service, Victoria, B.C. Information Report BC-X-59.

Walters, J. 1969. Container planting of Douglas fir, For. Prod. J. 19(10): 10-14.

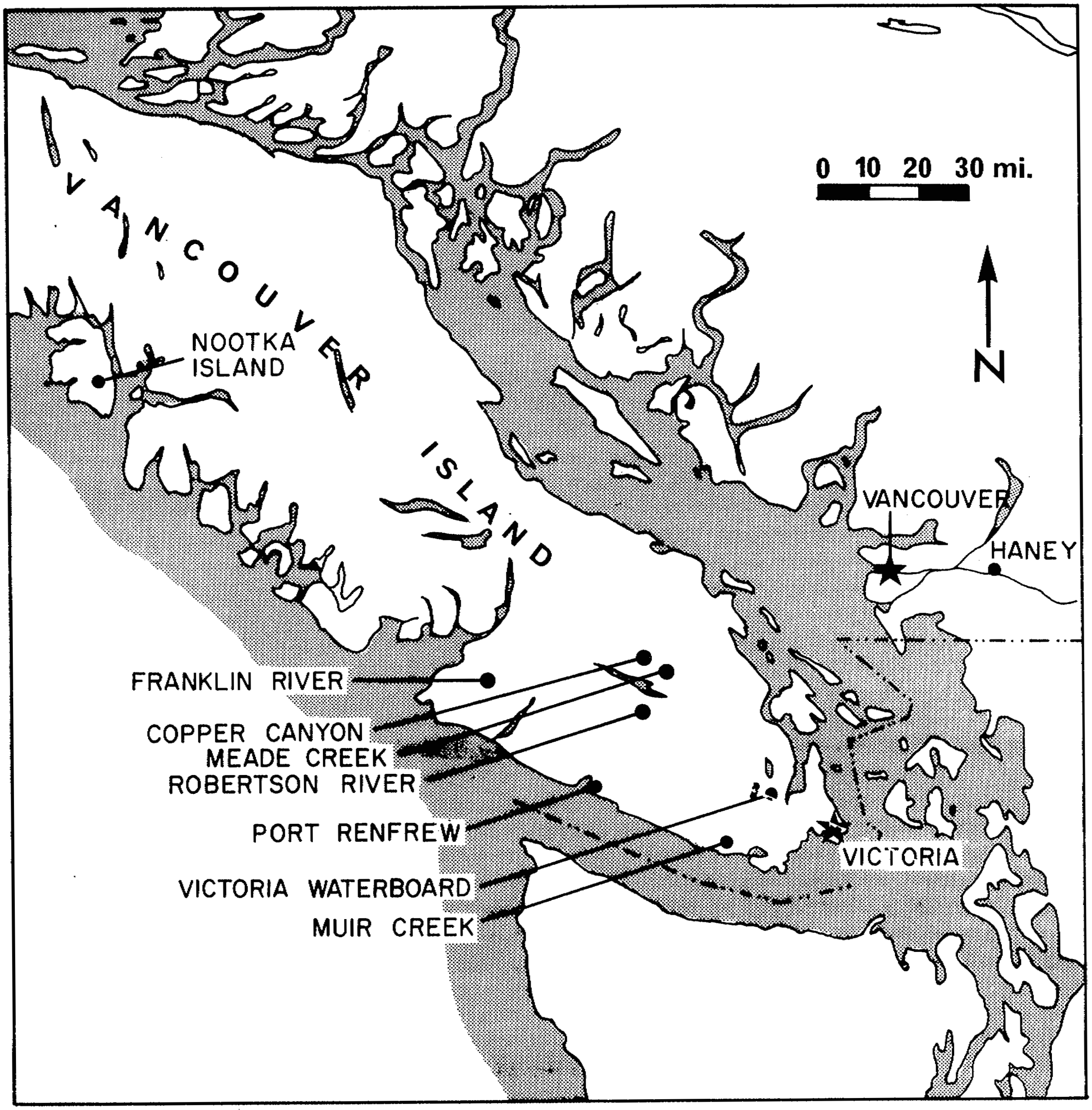


Figure 1. Location of plantations on Vancouver Island and the lower mainland, British Columbia.

FRANKLIN RIVER   COPPER CANYON   OBERTSON RIVER

Figure 2. Representative site conditions at three of the main experimental areas.

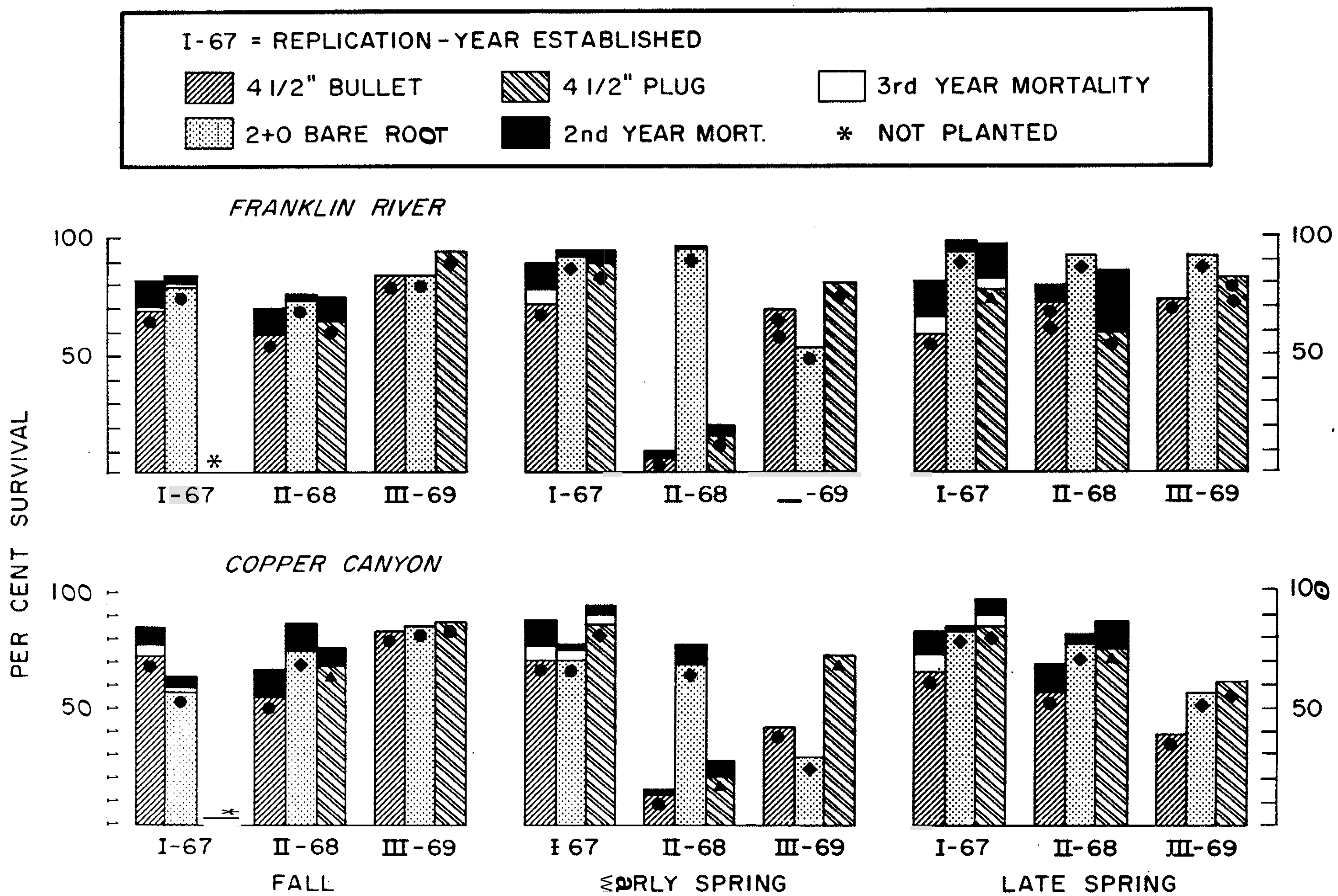


Figure 3. Survival of Douglas-fir bullet, plug and bare-root seedlings planted at three seasons over a three-year period at two medium-elevation areas. (Means underscribed by the same symbol are not significantly different at the 5% level).

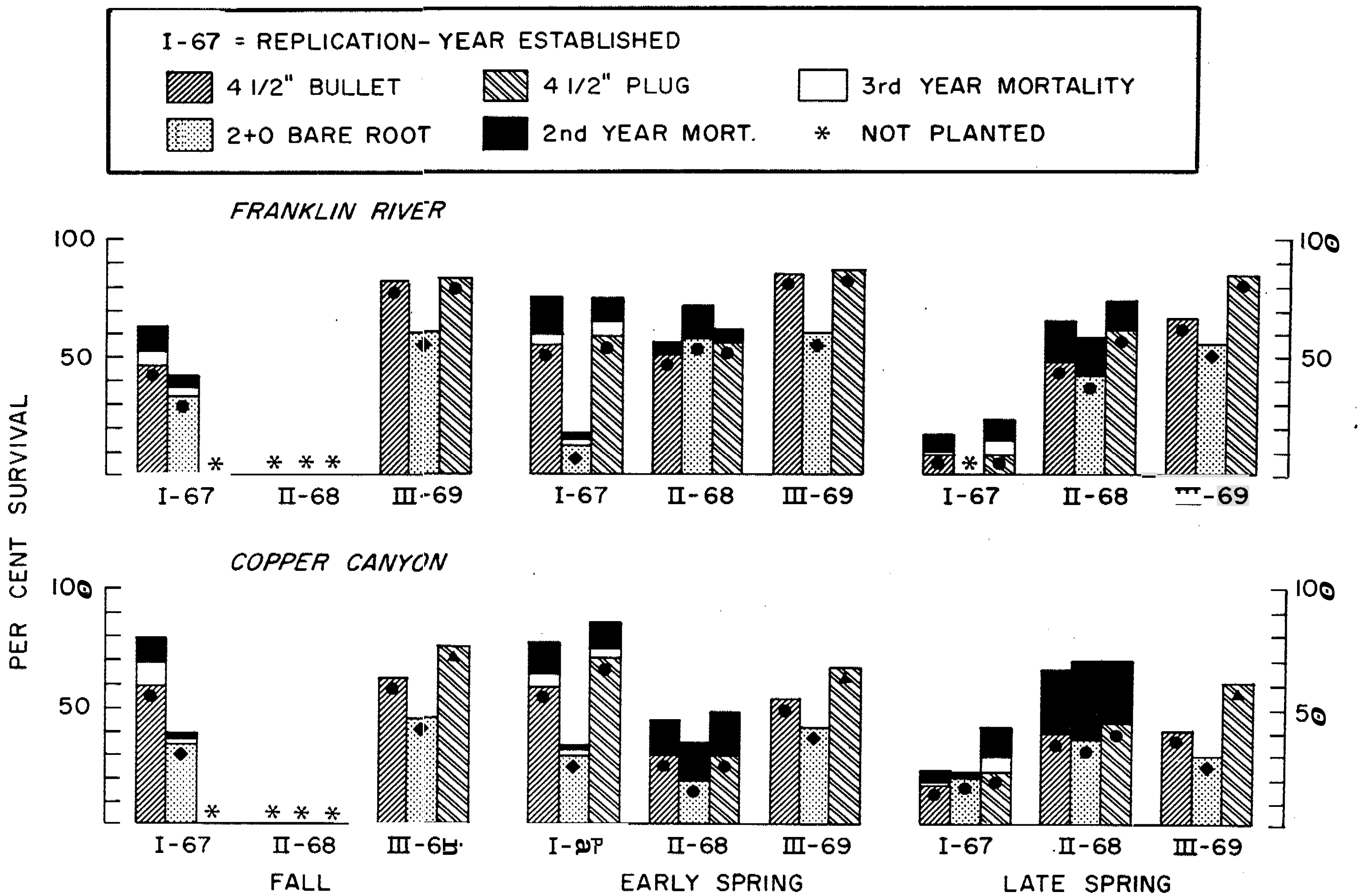


Figure 4. Survival of western hemlock bullet, plug and bare-root seedlings planted at three seasons over a three-year period at two medium-elevation areas. (Means underscribed by the same symbol are not significantly different at the 5% level).

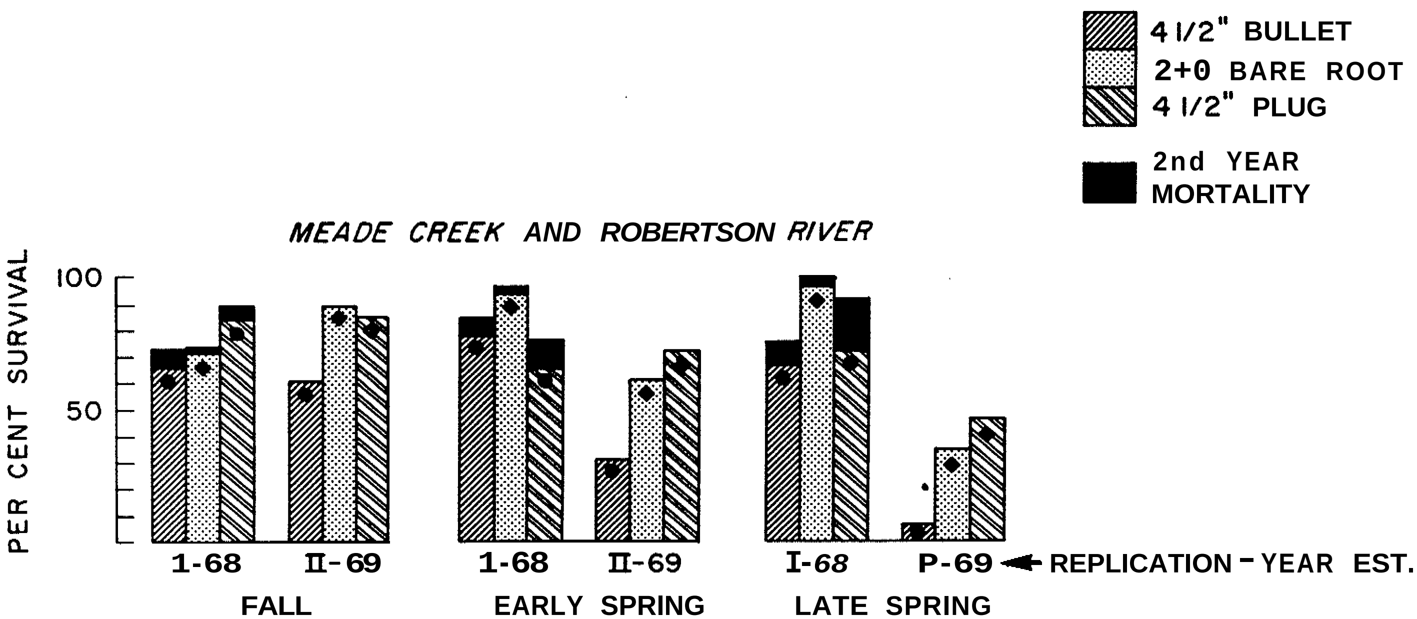


Figure 5. Survival of Douglas-fir bullet, plug and bare-root seedlings planted at three seasons over a two-year period at two high-elevation areas. (Means underscribed by the same symbol are not significantly different at the 5% level).

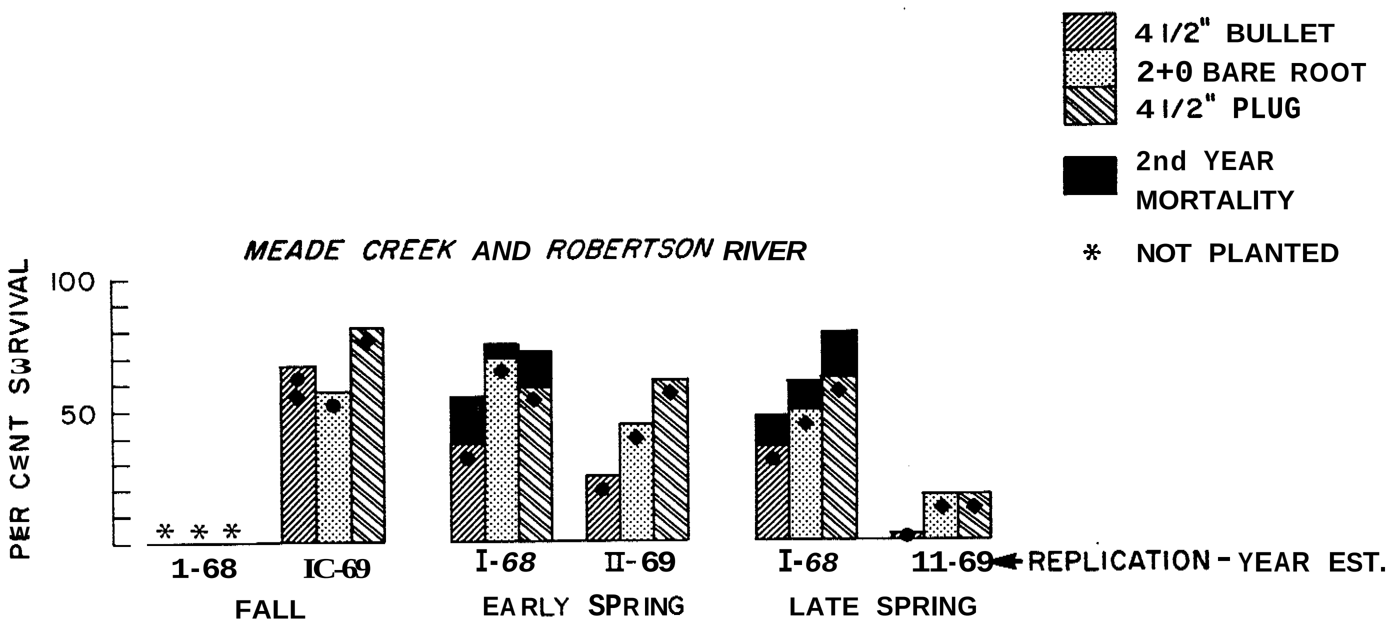
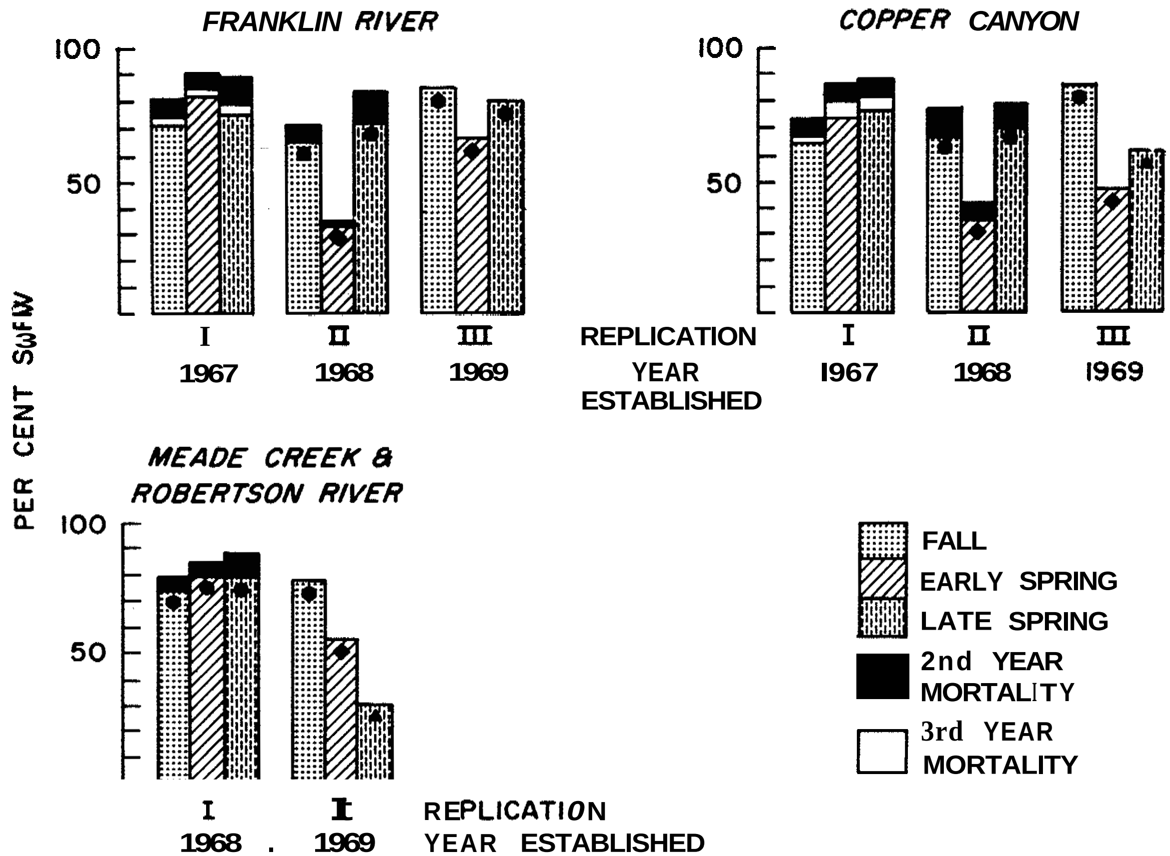


Figure 6. **Survival** of **western hemlock bullet, plug and bare-root seedlings planted** at three seasons **over a two-year period** at two high-elevation **areas. (Means underscribed by** the **same** symbol are not significantly different at the 5% level).



'Figure 7. Survival of Douglas-fir by planting season at the four experimental areas. (No ANOVA for I-1967 at Franklin River and Copper Canyon. Otherwise means underscribed by the same symbol are not significantly different at the 5% level).

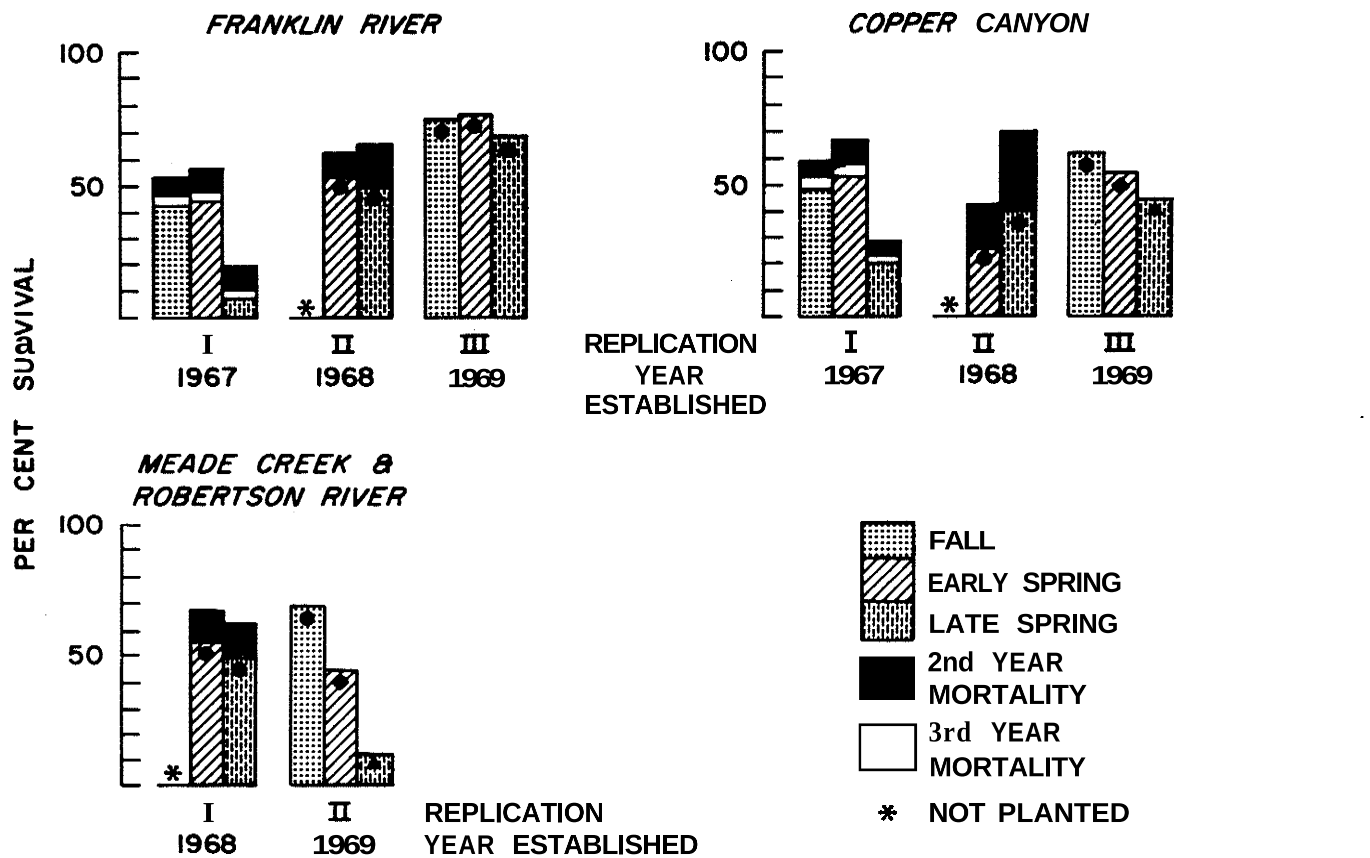


Figure 8. Survival of **western hemlock by planting season** at the **four experimental areas.** (No ANOVA for 1-1967 at Franklin River and Copper Canyon. Otherwise mans underscribed by the same symbol are not significantly different at the 5% level).

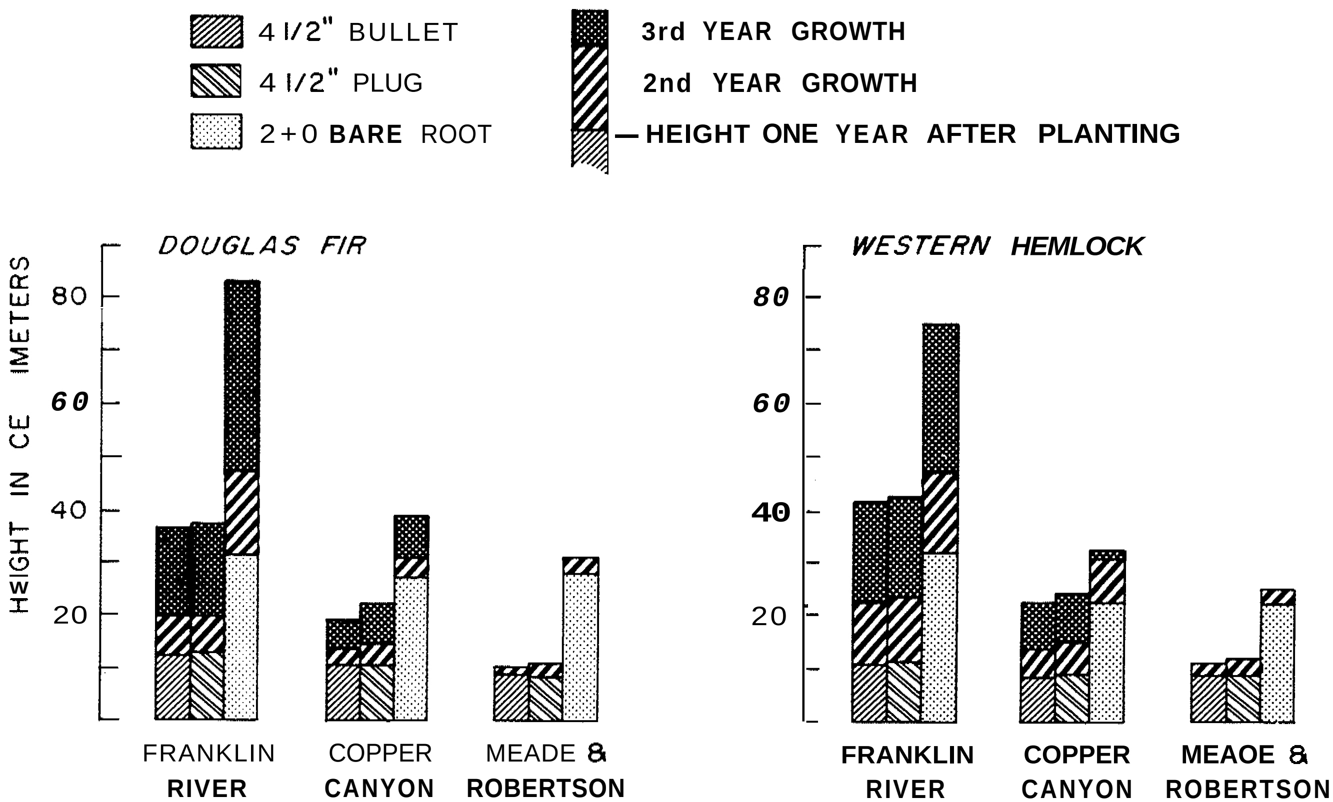


Figure 9. Height growth of Douglas-fir and western hemlock bullet, plug and bare-root seedlings at medium- and high-elevation areas.

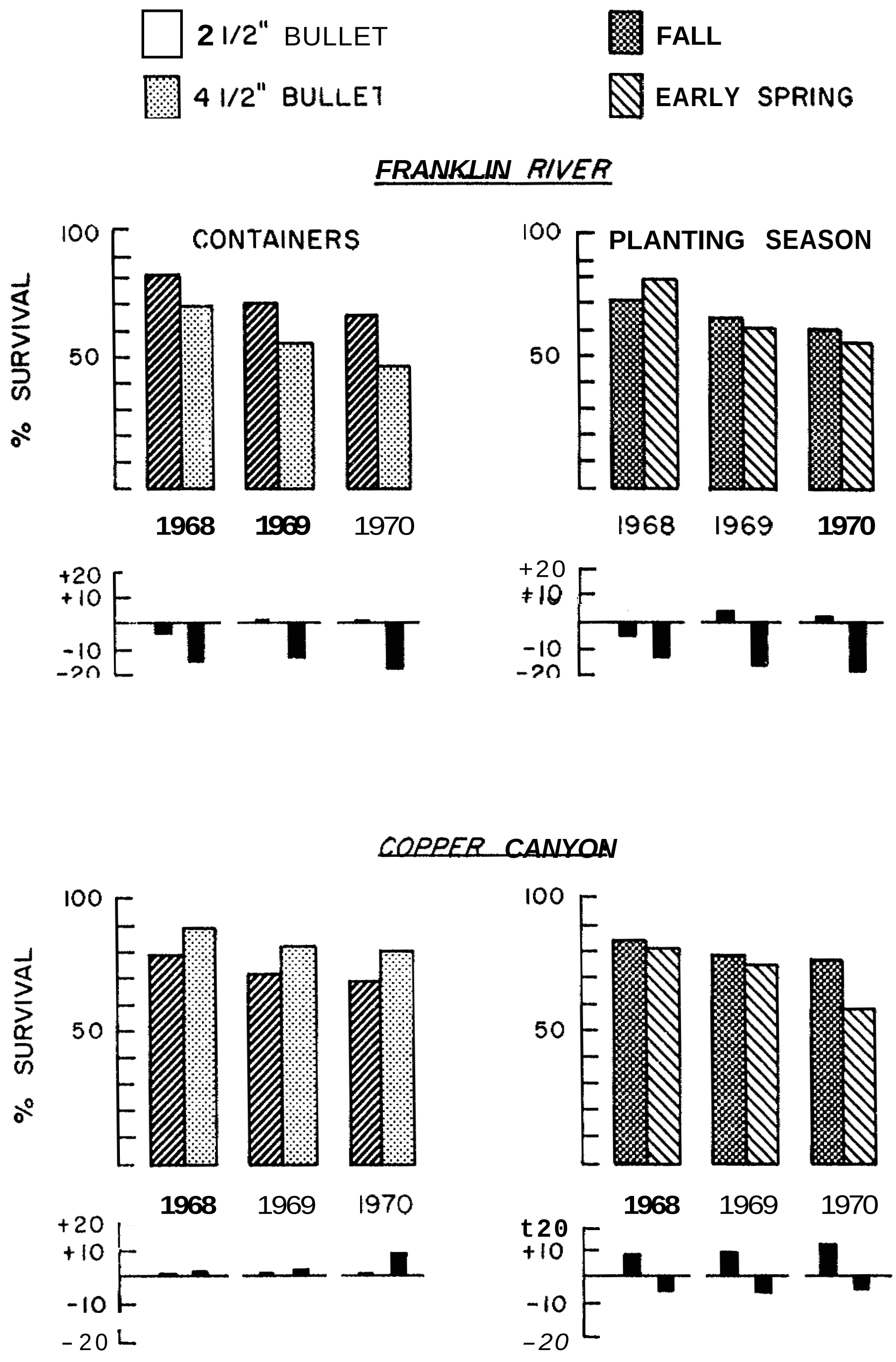


Figure 10. Three-year survival data for Douglas-fir in the simulated production trials at Franklin River and Copper Canyon. (Differences from experimental plantations are indicated below each histogram).

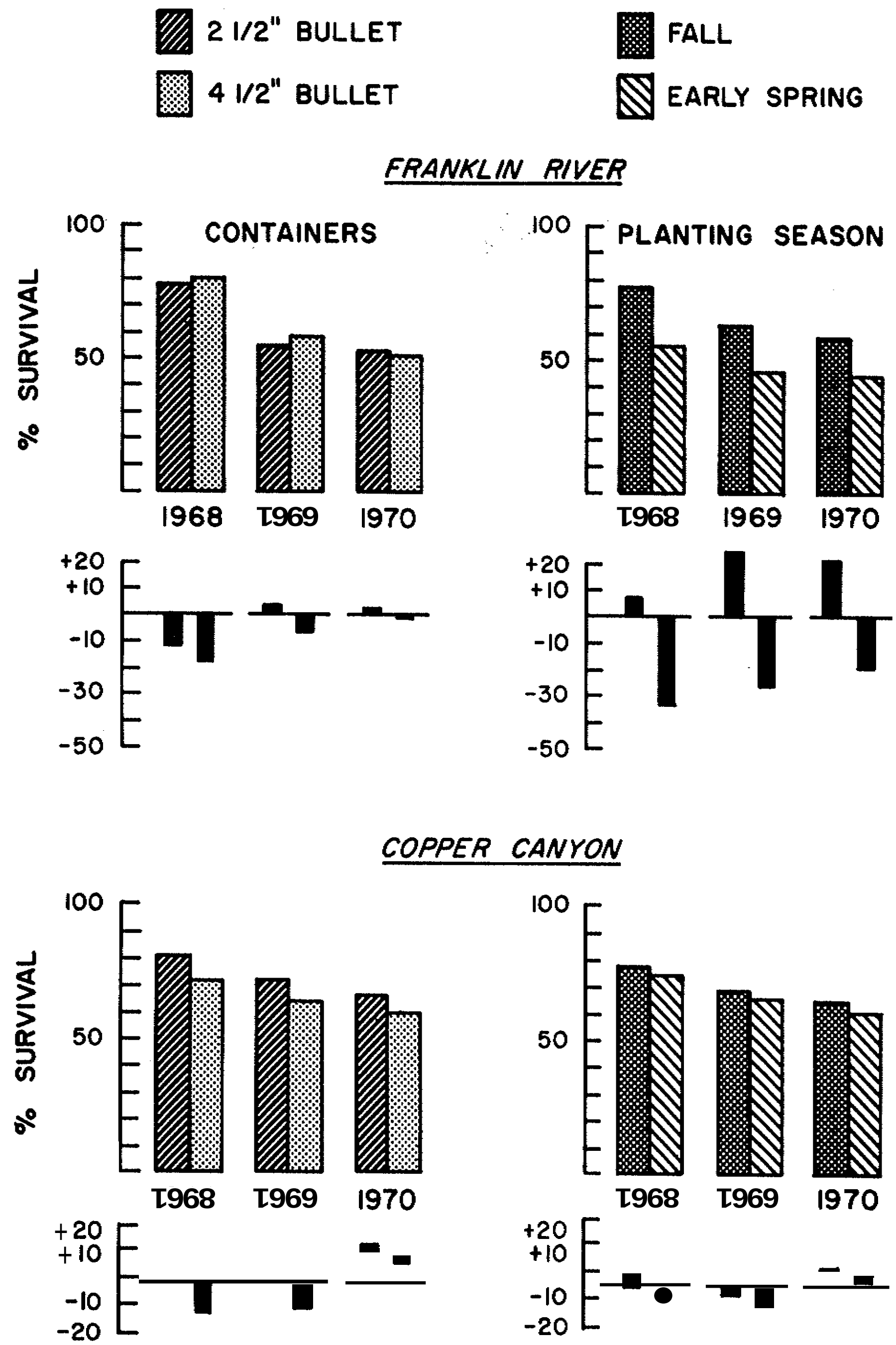
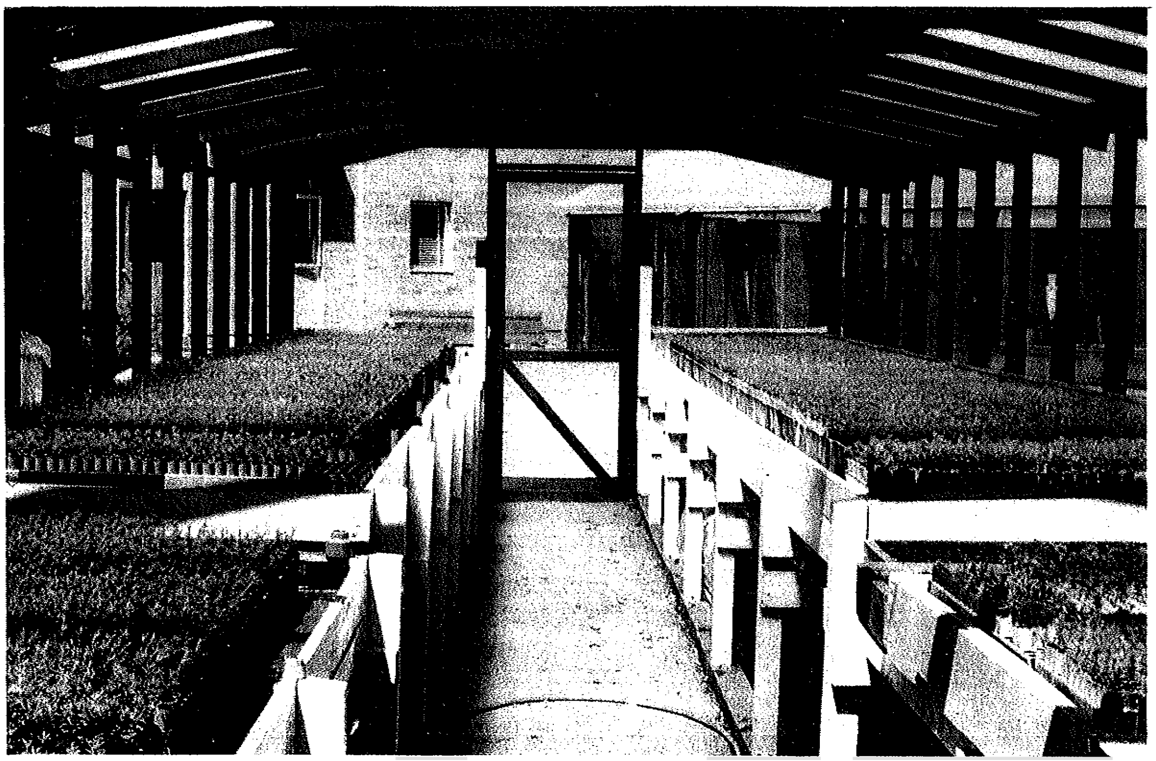


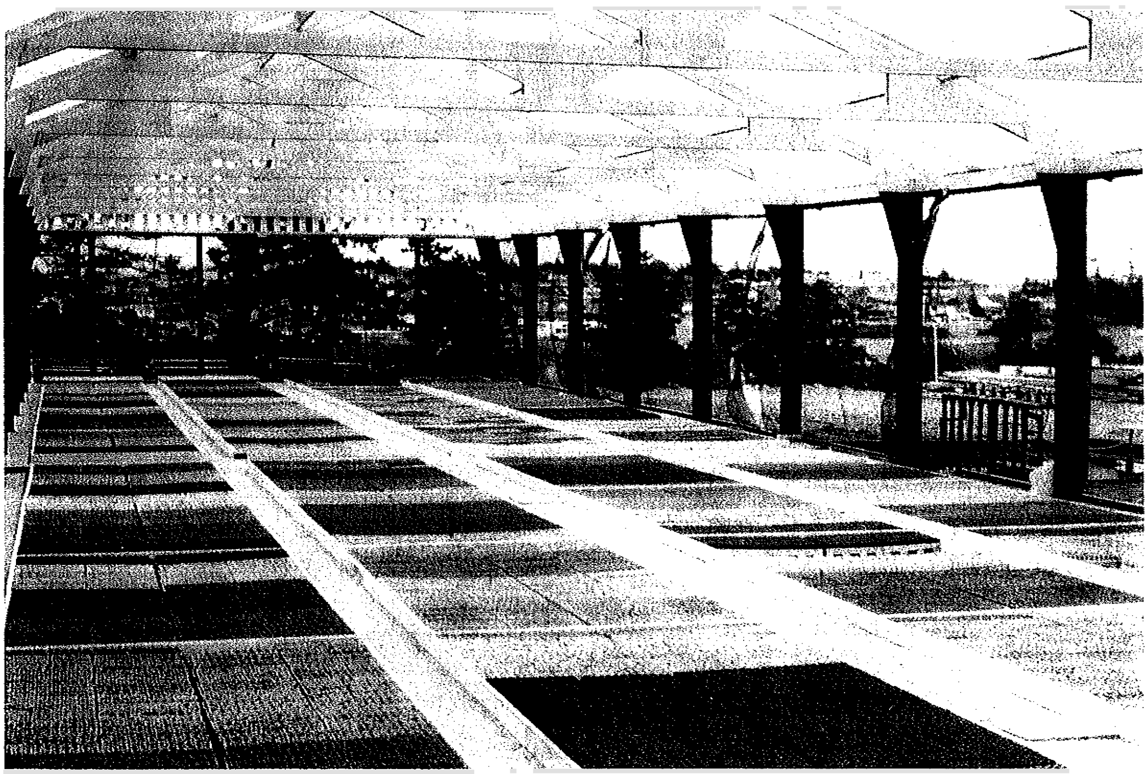
Figure 11. Three-year survival data for western hemlock in the simulated production trials at Franklin River and Copper Canyon. (Differences from experimental plantations are indicated below each histogram).

APPENDIX A

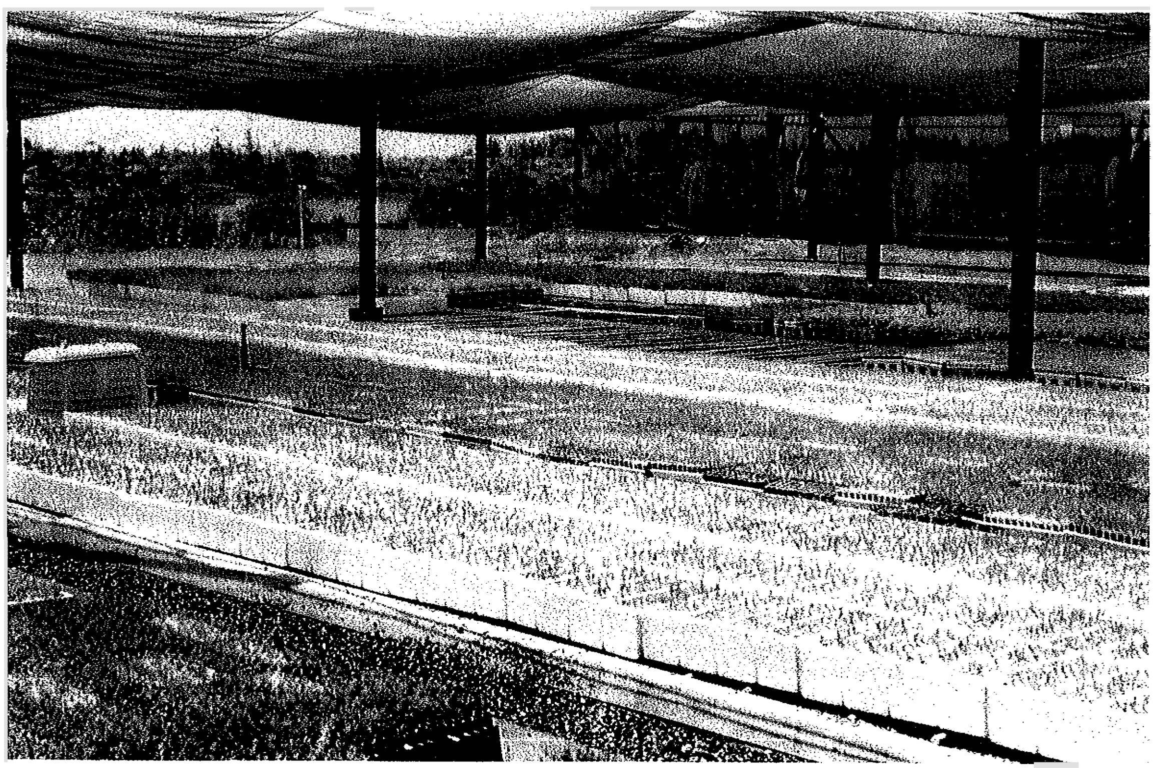
Shadehouses used from 1967-71 for growing container stuck for the coastal field trials



Subirrigation unit with a capacity of 30,000 bullets; 1967-70



Subirrigation unit with a capacity of 176,000 bullets; 1969

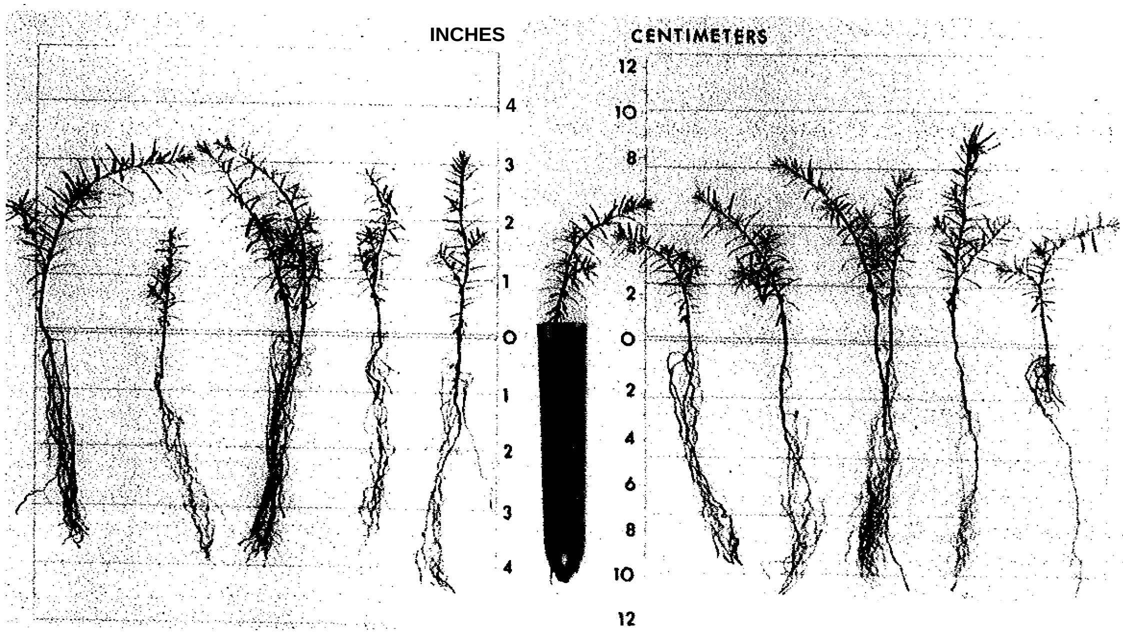


Low-cost, top watering **facility** with a capacity of 225,000 trees in BC/CFS Styroblocks; 1970-71.

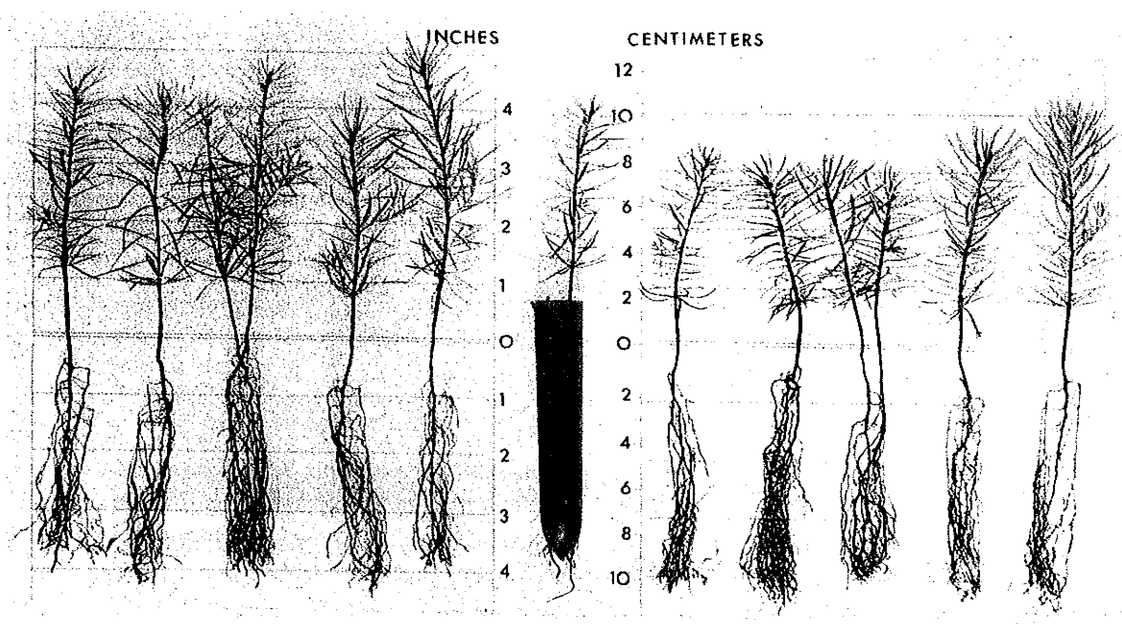
APPENDIX B

Representative samples of container stock planted in the coastal field trials between 1967 and 1969

1967

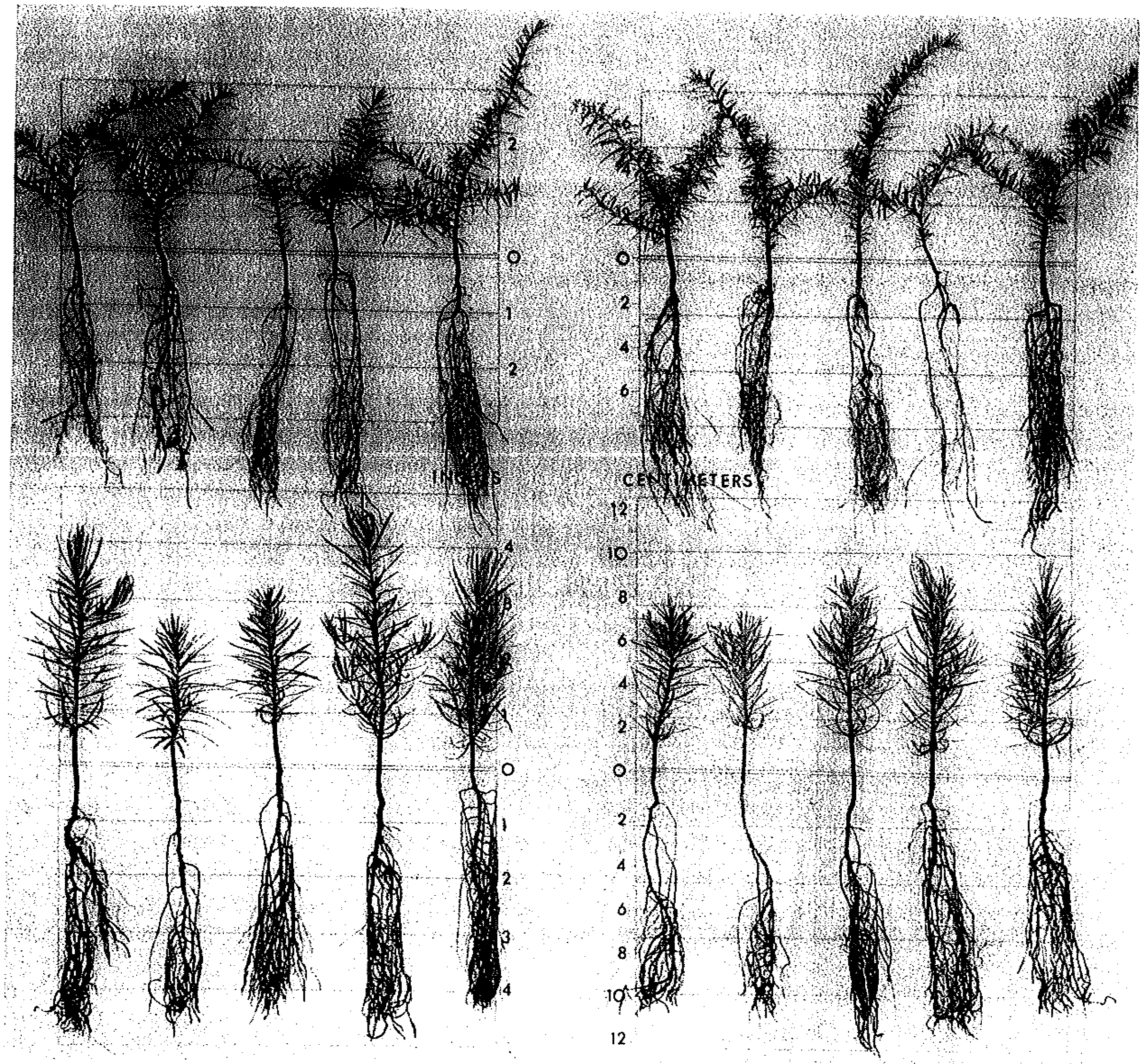


Western hemlock



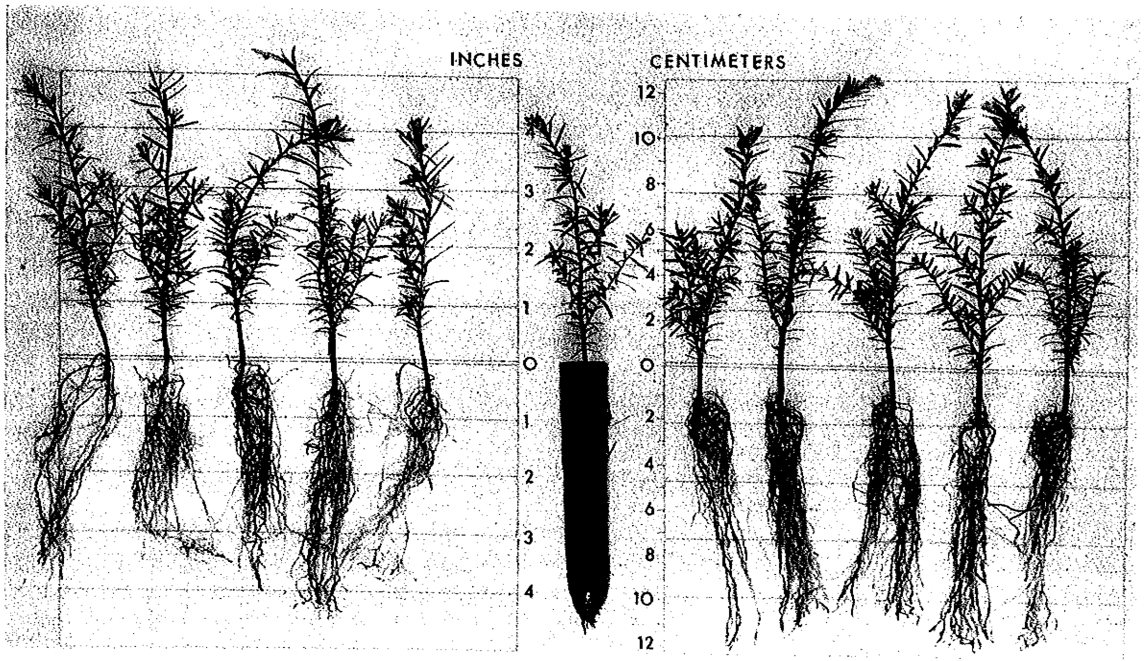
Douglas-fir

1968

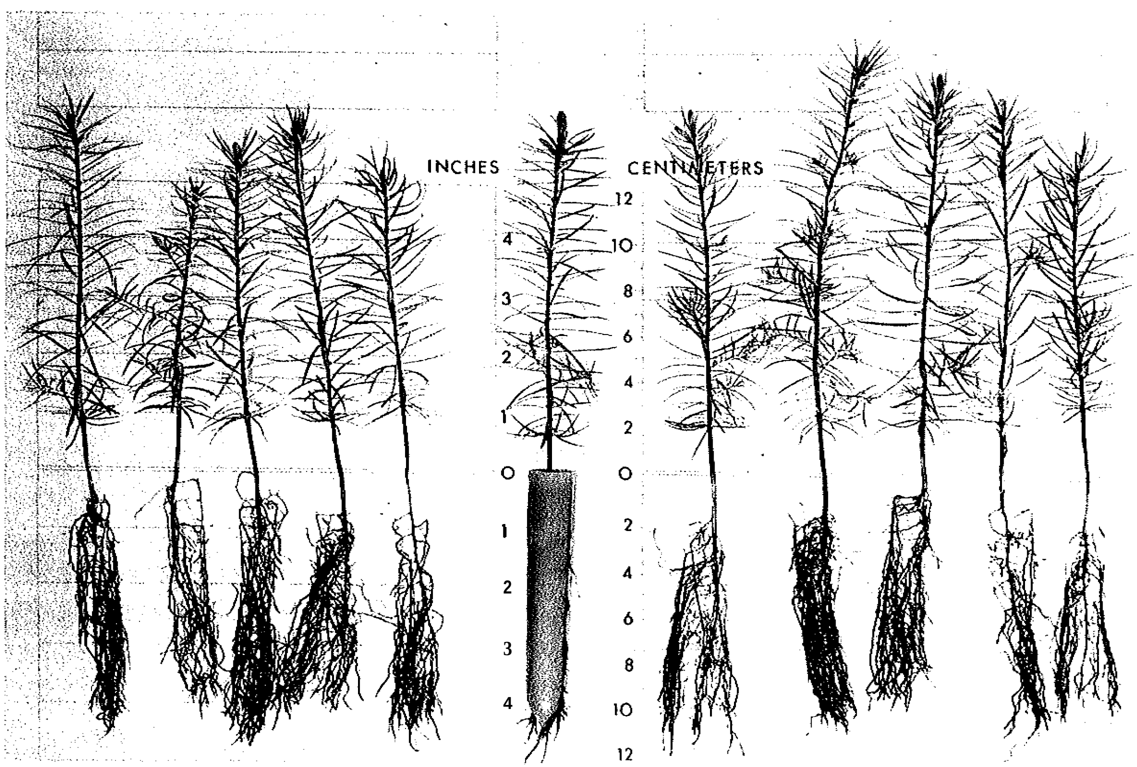


Western hemlock and Douglas-fir

1969



Western hemlock

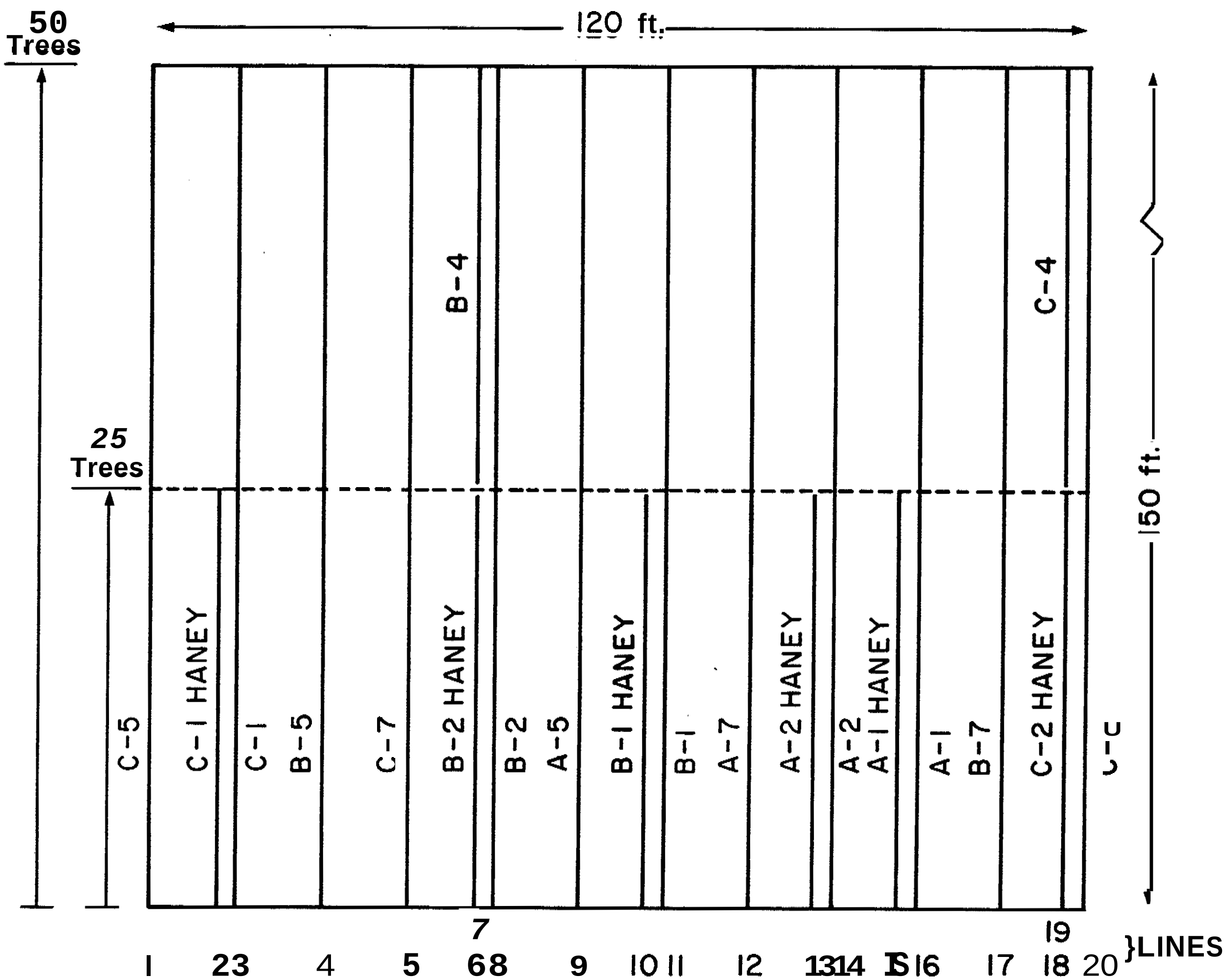


Douglas-fir

APPENDIX C

Plot design in the experimental plantations

SAMPLE OF PLOT LAYOUT, SERIES I (1967-68)



Completely Rondom Design

TREATMENT CODE

SEASONS

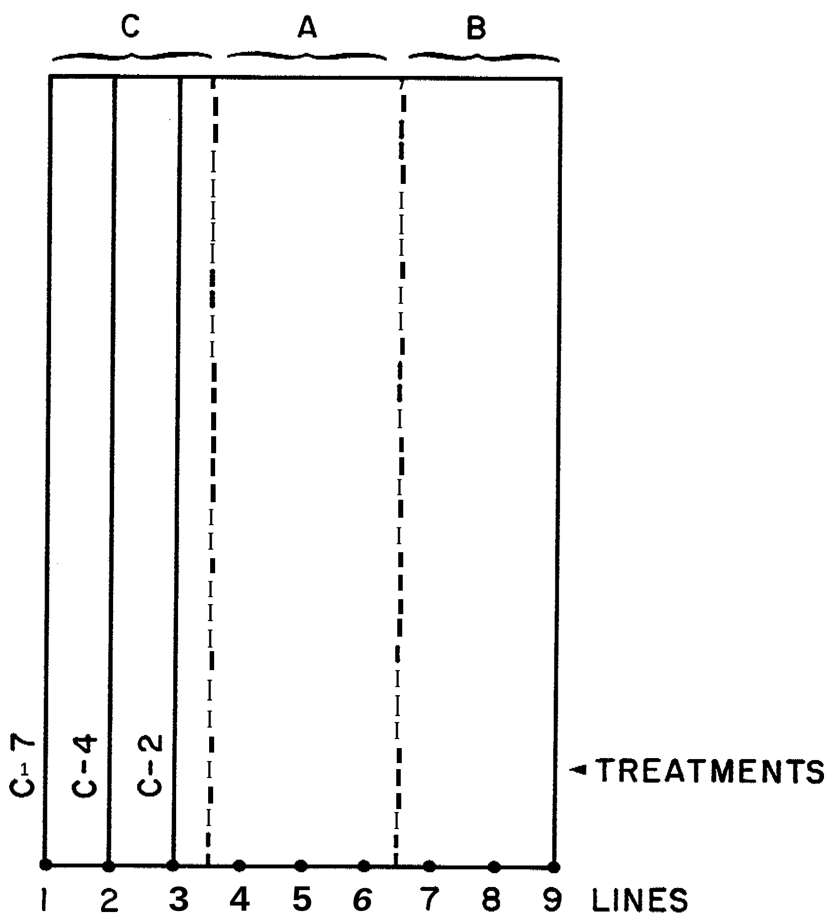
A - FALL
B - EARLY SPRING
C - LATE SPRING

CONTAINERS

1 - 2 1/2" BULLET
2 - 4 1/2" BULLET
4 - 4 1/2" PLUG
5 - 1/2" TUBE
7 - 2+0 BARE-ROOT

HANEY - Stock grown at U.B.C. research forest
- Remainder grown at P.F.R.C., Victoria

SAMPLE OF PLOT LAYOUT, SERIES II (1968-69)



TREATMENT CODE

SEASONS

A - FALL
B - EARLY SPRING
C - LATE SPRING

CONTAINERS

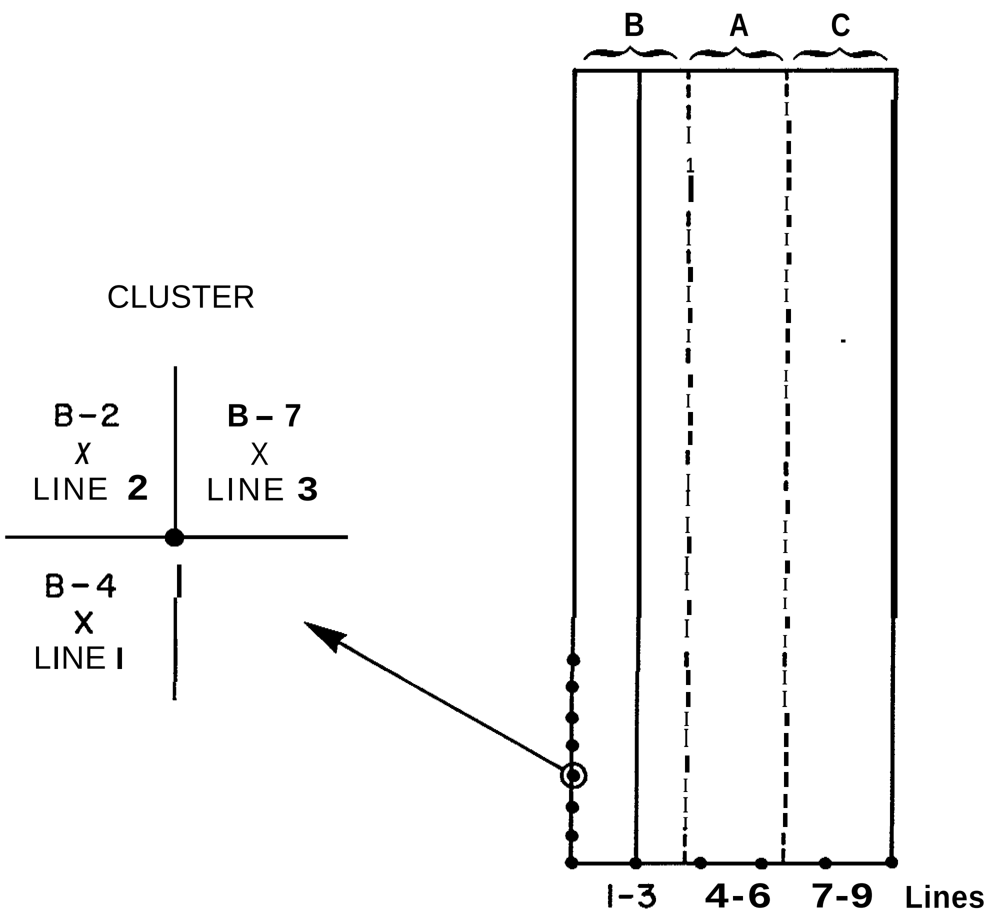
2 - 41/2" BULLET
4 - 41/2" PLUG
7 - 2+0 BARE-ROOT

Scale

0 10 20 feet

- Randomized complete block with split plot.
- Each line consists of two rows of 25 trees each.

SAMPLE OF PLOT LAYOUT, SERIES III (1969-71)



TREATMENT CODE

SEASONS

A - FALL
B - EARLY SPRING
C - LATE SPRING

CONTAINERS

2 - 4 1/2" BULLET
4 - 4 1/2" PLUG
7 - 2 t 0 BARE-ROOT

Scale

0 10 20 *feet*

- Randomized complete block with split plot.
- Each sub plot contains two rows of 25 **stakes** each.
- Cluster of three trees around each stake constitute three "lines".

APPENDIX D

Per cent survival and average heights of Douglas-fir and western hemlock seedlings planted over a three-year period at Franklin River, Copper Canyon, Meade Creek and Robertson River, Vancouver Island.

<u>tow-Medium Elevation (500-1500 ft)</u>

1. Franklin River - West Coast
2. Copper Canyon - East Coast

<u>High Elevation (2500-3500 ft)</u>

3. Meade Creek - Central
4. Robertson River -Central

1-67 *etc.*, refers *to* Replication and year of establishment, respectively.

Franklin River: Douglas-fir and western hemlock, 1-67

Container type	Fall - 1967			Early Spring-1968			Late Spring-1968		
	Douglas-fir								
	PLANTING SEASON								
	PER CENT SURVIVAL1/								
	1968	1969	1970	1968	1969	1970	1968	1969	1970
4½" Bullet	80.5	70.0	67.5	89.0	77.0	71.3	80.3	64.5	58.3
4½" Plug	--	--	--	94.0	88.0	86.0	95.5	82.0	76.5
2+0 Bare-root	83.0	80.0	79.0	94.3	92.0	92.0	97.5	93.3	93.0
	AVERAGE HEIGHT (cm)								
4½" Bullet	13.4	23.1	46.1	12.8	21.0	37.7	13.3	17.1	27.8
4½" Plug	--	--	--	14.2	24.3	46.1	13.2	18.8	30.2
2+0 Bare-Root	31.3	50.2	89.1	33.6	48.2	82.4	33.5	47.1	81.1
	Western hemlock								
	PER CENT SURVIVAL1/								
4½" Bullet	64.5	55.3	47.8	75.8	60.3	56.3	16.5	7.8	6.6
4½" Plug	--	--	--	76.0	64.5	60.4	23.0	14.5	8.3
2+0 Bare-Root	43.8	38.8	35.3	18.5	14.8	14.5	--	--	--
4½" Bullet	12.7	28.7	49.2	11.1	25.4	45.9	10.4	16.9	32.1
4½" Plug	--	--	--	13.7	29.6	55.9	10.4	18.5	29.9
2+0 Bare-Root	32.0	44.5	79.3	32.7	50.8	72.1	--	--	--

-- Not planted.

1/ Based on 8 plots with 350 trees per plot.

Franklin River: Douglas-fir and western hemlock, 11-68

Container type	Fall - 1968		Early Spring-1969		Late Spring-1969	
	Douglas-fir					
	PLANTING SEASON					
	PER CENT SURVIVAL 1/					
	1969	1970	1960	1970	1969	1970
4½" Bullet	69.0	58.5	9.0	5.5	79.0	70.5
4½" Plug	73.5	63.5	19.0	14.5	85.0	59.0
2+0 Bare-Root	74.5	72.5	96.0	95.0	91.5	90.5
	AVERAGE HEIGHT (cm)					
4½" Bullet	9.5	18.6	6.9	12.8	9.1	14.2
4½" Plug	9.3	17.6	6.5	11.4	8.4	18.5
2+0 Bare-Root	27.0	46.6	30.5	55.8	25.7	39.5
	Western hemlock					
	PER CENT SURVIVAL 2/					
4½" Bullet	--	--	57.0	50.5	65.5	47.5
4½" Plug	--	--	62.0	56.5	73.5	60.5
2+0 Bare-Root	--	--	70.5	57.5	59.0	41.5
	AVERAGE HEIGHT (cm)					
4½" Bullet	--	--	10.7	24.6	9.5	20.3
4½" Plug	--	--	10.0	26.5	10.8	22.0
2+0 Bare-Root	--	--	28.5	53.4	21.5	35.0

-- Not planted

1/ Based on 4 plots with 450 trees per plot.

2/ " " " " " 300 " " "

Franklin River: Douglas-fir and western hemlock, I11-69

	Douglas-fir		
	PLANTING SEASON		
	fall - 1969	Early Spring-1970	Late Spring4970
Container type	1970	1970	1970
4½" Bullet	82.5	68.5	73.0
4½" Plug	93.5	80.0	82.0
2+0 Bare-Root	83.0	52.5	90.5
4½" Bullet	18.1	14.6	17.3
4½" Plug	17.4	15.0	19.0
2+0 Bare-Root	23.3	'17.6	27.1
	Western hemlock		
	PER CENT SURVIVAL[1/]		
4½" Bullet	83.0	85.5	65.5
4½" Plug	84.0	86.5	85.0
2+0 Bare-Root	60.5	59.5	55.3
	AVERAGE HEIGHT (cm)		
4½" Bullet	22.1	12.1	10.8
4½" Plug	18.6	12.1	12.6
2+0 Bare-Root	22.7	15.5	18.0

1/ Based on 4 plots with 450 trees per plot.

Copper Canyon: Douglas-fir and western hemlock, 1-67

	Douglas-fir								
	PLANTING SEASON								
	Fall - 1967			Early Spring-1968			Late Spring-1968		
Container type	1968	1969	1970	1968	1969	1970	1968	1969	1970
4½" Bullet	86.0	79.4	74.0	89.4	77.4	71.1	82.9	72.9	65.9
4½" Plug	--	--	--	94.9	91.4	86.9	96.6	90.9	86.1
2+0 Bare-Root	64.9	60.0	59.1	78.9	76.3	71.4	86.0	83.7	83.1
4½" Bullet	10.8	14.2	20.0	10.5	13.2	18.0	13.0	15.7	20.8
4½" Plug	--	--	--	10.5	13.9	20.3	12.2	16.0	24.7
2+0 Bare-Root	25.8	29.8	36.7	28.9	32.8	41.1	29.1	32.2	41.1
	Western hemlock								
4½" Bullet	79.1	68.9	59.4	78.3	65.4	59.1	23.4	18.3	16.9
4½" Plug	--	--	--	86.3	75.4	70.9	41.7	29.1	23.4
2+0 Bare-Root	38.9	36.8	35.7	34.0	32.6	30.0	22.6	20.0	18.3
4½" Bullet	10.1	15.5	23.3	8.7	15.0	24.0	7.3	14.2	21.0
4½" Plug	--	--	--	9.9	17.1	25.5	8.8	14.5	22.8
2+0 Bare-Root	19.7	36.9	31.8	24.8	28.3	32.6	24.6	28.6	32.8

-- Not planted.

1/ Based on 7 plots with 350 trees per plot.

Copper Canyon: Douglas-fir and western hemlock, 11-68

Container type	Fall - 1968		Early Spring-1969		Late Spring-1969	
	Douglas-fir					
	PLANTING SEASON					
	PER CENT SURVIVAL 1/					
	1969	1970	1969	1970	1969	1970
4½" Bullet	68.0	56.0	16.0	13.5	69.0	56.5
4½" Plug	77.0	69.0	28.0	22.5	87.5	75.5
2+0 Bare-Root	88.0	76.0	77.5	70.0	81.5	77.5
	AVERAGE HEIGHT (cm)					
4½" Bullet	10.0	20.0	8.2	15.2	9.6	16.3
4½" Plug	13.3	25.5	8.6	16.4	9.7	17.2
2+0 Bare-Root	25.4	36.6	25.8	37.3	25.0	31.5
	Western hemlock					
4½" Bullet	--	--	45.0	30.0	67.0	40.0
4½" Plug	--	--	47.0	30.0	69.5	44.0
2+0 Bare-Root	--	--	34.5	19.0	69.5	37.0
	AVERAGE HEIGHT (cm)					
4½" Bullet			11.4	22.3	11.2	18.8
4½" Plug			12.9	24.6	11.5	21.7
2+0 Bare-Root	--	--	25.3	33.3	26.4	35.6

-- Not planted.
1/ Based on 4 plots with 450 trees per plot.
2/ " " " " " 300 "

Copper Canyon: Douglas-fir and western hemlock, III-69

	Douglas-fir		
	Fall - 1969	Early Spring-1970	Late Spring-1970
Container type	1970	1970	1970
4½" Bullet	85.0	40.5	39.0
4½" Plug	87.5	72.5	61.0
2+0 Bare-Root	87.0	29.0	56.5
4½" Bullet	23.8	17.1	15.8
4½" Plug	25.8	16.9	17.4
2+0 Bare-Root	26.6	24.9	23.5
	PER CENT SURVIVAL[1/]		
4½" Bullet	63.5	54.5	41.0
4½" Plug	76.0	66.6	61.5
2+0 Bare-Root	44.5	41.0	30.0
	AVERAGE HEIGHT (cm)		
4½" Bullet	23.7	21.7	17.8
4½" Plug	28.1	17.1	20.0
2+0 Bare-Root	27.2	24.1	20.9

Meade Creek: Douglas-fir and western hemlock, 1-68

Container type	Fall - 1968 1969	Fall - 1968 1970	Early Spring-1969 1969	Early Spring-1969 1970	Late Spring-1969 1969	Late Spring-1969 1970
Douglas-fir						
PLANTING SEASON						
4½" Bullet	77.0	68.0	97.0	89.0	95.0	85.0
4½" Plug	90.8	81.8	99.0	84.0	98.0	71.8
2+0 Bare-Root	59.0	57.0	97.5	93.5	100.0	96.0
AVERAGE HEIGHT (cm)						
4½" Bullet	8.5	11.3	8.8	9.9	9.5	11.1
4½" Plug	8.9	10.4	9.2	11.1	9.1	12.1
2+0 Bare-Root	26.4	28.0	31.7	33.8	29.6	30.8
Western hemlock						
PER CENT SURVIVAL 1/						
4½" Bullet	--	--	81.0	60.0	53.0	39.0
4½" Plug	--	--	94.0	81.0	79.0	62.0
2+0 Bare-Root	--	--	65.0	58.0	55.0	44.0
AVERAGE HEIGHT (cm)						
4½" Bullet	--	--	8.8	10.4	11.2	12.7
4½" Plug	--	--	9.0	11.7	11.2	13.0
2+0 Bare-Root	--	--	25.4	26.4	18.4	20.6

-- Not planted.

1/ Based on 2 plots with 450 trees per plot.
" " " " 300 " " "

Meade Creek: Douglas-fir and western hemlock, 11-69

Container type	'Fall - 1969	Early Spring-1970	Late Spring-1970
	1970	1970	1970
4½" Bullet	73.0	50.0	13.0
4½" Plug	92.0	83.0	70.0
2+0 Bare-Root	86.0	45.0	38.0
	[illegible]		
4½" Bullet			
4½" Plug			
2+0 Bare-Root			
4½" Bullet	72.0	14.0	3.0
4½" Plug	93.0	61.0	30.0
2+0 Bare-Root	51.0	41.0	28.0
4½" Bullet	18.6	14.4	7.2
4½" Plug	21.2	14.7	19.1
2+0 Bare-Root	15.9	14.4	13.2

1/ Based on 2 plots with 450 trees per plot.

Robertson River: Douglas-fir and western hemlock, 1-68

Container type	Douglas-fir					
	Fall - 1968		Early Spring-1969		Late Spring-1969	
Container type	1969	1970	1969	1970	1969	1970
4½" Bullet	68.0	63.0	72.0	67.0	58.0	50.0
4½" Plug	90.0	88.0	53.0	46.0	82.7	73.0
2+0 Bare-Root	89.0	87.0	95.0	95.0	99.0	98.0
4½" Bullet	8.1	12.2	10.5	12.6	9.4	10.8
4½" Plug	7.5	13.2	10.0	15.2	9.0	12.5
2+0 Bare-Root	26.2	30.0	28.1	34.4	28.2	33.7
	Western hemlock					
4½" Bullet	--	--	29.0	16.0	43.0	35.0
4½" Plug	--	--	49.0	37.0	79.0	62.0
2+0 Bare-Root	--	--	84.0	82.0	67.0	56.0
4½" Bullet	--	--	6.4	11.2	10.7	12.6
4½" Plug	--	--	5.9	10.2	11.5	14.8
2+0 Bare-Root	--	--	27.4	34.3	19.7	22.2

-- Not planted.

1/ Based on 2 plots with 450 trees per plot.

2/ " " " " " 300 " " "

Robertson River: Douglas-fir and western hemlock, 11-69

Container type	Fall - 1969	Early Spring-1970	Late Spring-1970
	Qouglas-fir		
	PLANTING SEASON.		
	PER CENT SURVIVAL 1/		
	1970	1970	1970
4½" Bullet	49.0	14.0	0.0
4½" Plug	79.0	61.0	22.0
2+0 Bare-Root	94.0	78.0	33.0
4½" Bullet	14.2	14.4	0.0
4½" Plug	13.2	15.8	20.3
2+0 Bare-Root	17.9	19.9	16.6
	Western hemlock		
	PER CENT SURVIVAL 1/		
1½" Bullet	64.0	37.0	0.0
1½" Plug	73.0	62.0	3.0
2+0 Bare-Root	65.0	49.0	6.0
1½" Bullet	12.5	10.0	0.0
1½" Plug	13.9	12.5	13.3
2+0 Bare-Root	12.2	19.3	15.5

1/ Based on 2 plots with 450 trees per plot.