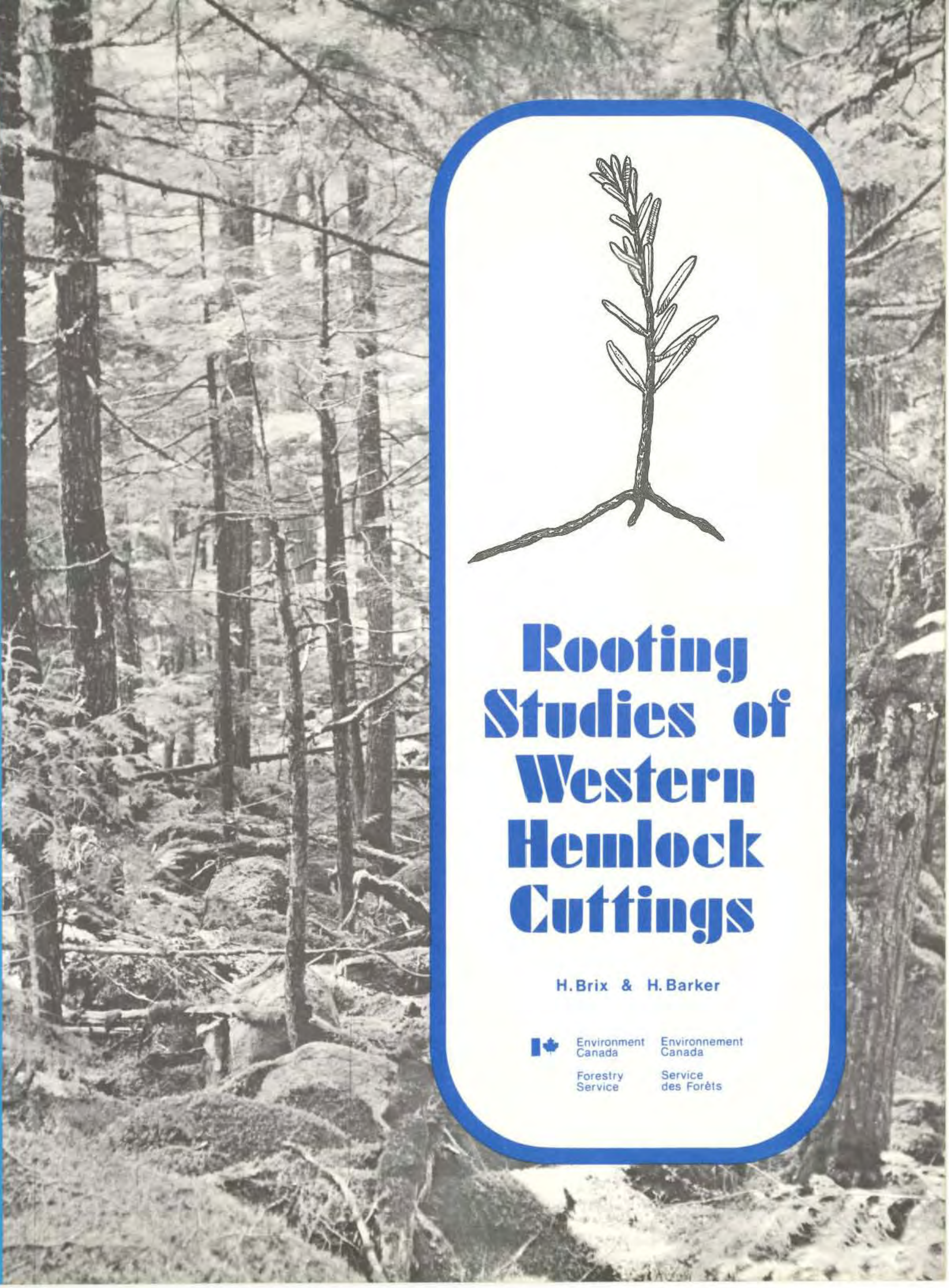

Rooting Studies of Western Hemlock Cuttings

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ROOTING STUDIES OF WESTERN HEMLOCK CUTTINGS

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CONTENTS

ABSTRACT

Rooting studies of western hemlock cuttings are described and recommendations are made in regard to selection of cutting material, time of collection, storage, preparation of cuttings, auxin treatment, fungicides, rooting medium, humidity control and temperature regime. The seasonal pattern of rooting, variation in rootability, and treatment, growth and flowering of rooted cuttings are discussed.

Cuttings generally rooted well when collected in the period from mid-October to mid-February, treated with a 24 hr basal soak in a solution of 100 ppm IBA and 150 ppm Benlate, placed in a rooting medium consisting of equal volumes of fine peat moss, coarse sand and coarse perlite, kept at high humidity in an enclosure of clear plastic shaded from direct sunlight, and given no heating of air or soil.

In one program, cuttings are collected from 128 trees in 13 plus stands, 42 years of age or older. By using an average of 35 cuttings per tree, rooted cuttings were produced from 117 of the 128 trees, with an average rooting per cent of 43.

Growth performance following rooting has been satisfactory, although plagiotropic growth form is still retained for about a third of the ramets 6 years after rooting. Seed cones were produced 1 year after rooting on many clones, and pollen cones in the fourth year on some clones.

RÉSUMÉ

Les auteurs décrivent les études qu'ils ont faites sur l'enracinement de boutures de Pruche occidentale (Tsuga heterophylla) et ils formulent des recommendations sur le choix des boutures, le temps de les récolter, l'emmagasinement, leur préparation, le traitement à l'auxine, les fongicides, le sol, l'humidité et les températures, Ils discutent le mode saisonnier d'enracinement, la variation de capacité d'enracinement, et le traitement, la croissance et la floraison des boutures qui ont pris racine.

En général, les boutures ont bien pris racine lorsque récoltées de la mi-octobre à la mi-février, traitées en plongeant leur base durant 24 h dans une solution de 100 ppm d'IBA et de 150 ppm de Benlate, placées dans un sol consistant de volumes égaux de fine tourbe, de sable grossier et de perlite grossière, tenues à forte humidité dans une enveloppe de matière plastique transparente et protégées des rayons du soleil, et sans que l'air et le sol fussent chauffés.

Un programme d'études comportait la récolte de boutures sur 128 arbres dans 13 peuplements d'élite âgés d'au moins 42 ans. En utilisant en moyenne 35 boutures par arbre, les auteurs obtinrent des boutures qui s'enracinèrent provenant de 117 des 128 arbres, avec un pourcentage d'enracinement de 43 pour cent.

Après l'enracinement, la croissance s'avéra satisfaisante, bien que la forme plagiotropique de croissance se prolongeât chez environ un tiers des plantes issues de boutures 6 ans après l'enracinement. Dans plusiers "clones", des cônes femelles apparurent un an après l'enracinement, et chez certains autres "clones", des cônes mâles apparurent durant la quatrième année.

INTRODUCTION

In 1968, the Canadian Forestry Service initiated a tree improvement program for western hemlock (Tsuga heterophylla (Raf.) Sarg.) in British Columbia (Piesch 1974). An integral part of such a program is vegetative propagation of selected trees, but little information was available on techniques and success for this species. Indications were that grafting was a difficult and unreliable technique, while attempts to root cuttings were generally unsuccessful. However, the latter method is more attractive in not requiring a specially prepared root-stock, and in avoiding a possible graft union incompatibility that may occur several years after an apparently successful graft has been established (Brix and Barker 1973). In anticipation of future needs, studies in rooting of western hemlock cuttings were initiated in 1966.

Initially all trees for the improvement program were to be selected from stands having reached a size at which a superior growth performance could be recognized (plus stands), so the problem was to propagate mature rather than juvenile trees. In studies reported here, the cuttings were taken from a total of 137 trees, over 40 years of age, growing in widely scattered areas of coastal B.C. Studies were made during the years 1966 to 1974, using a total of 9800 cuttings. The cuttings were placed for rooting in a greenhouse or in other propagation facilities at the Pacific Forest Research Centre in Victoria. The major part of the studies was performed in 1968-69 with cuttings collected from plus stands (Piesch 1974).

This report deals with studies of the broad range of problems that the user is faced with in rooting of cuttings, from selection of cutting material in the field to their preparation and treatment before they are set for rooting and to their treatment in the rooting bed. Also, observations are made on growth and flowering during the first 6 years after rooting. No extensive literature review or general discussion of rooting problems is intended, since this was done in another report (Brix and Barker 1973).

SELECTION OF CUTTING MATERIAL

Cuttings from plus stands were collected from felled trees in the outer section of main branches where the most vigorous shoots are produced, and primarily from the middle one-third of the crown length. As shown later, these cuttings rooted well. Cuttings in other studies were from standing trees and were collected mainly from the lower one-quarter of the crown.

Although vigorous shoots were selected in the plus stands, the basal cutting diameter was usually less than 2 mm and not more than 3 mm. Diameter of cuttings does not appear to be critical, since those less than 1 mm rooted equally well. Cuttings should be of sufficient length to permit insertion in the rooting medium to a depth of at least 2 cm for uniform and adequate support and, ideally, should have a top of 4 cm or more. Current shoots are preferred but, in case of older trees, 2- and even 3-year-old shoots may have to be included to obtain cuttings of sufficient length.

TIME OF COLLECTION

Effects of treatments such as temperature of rooting medium and of air, hormones and storage were studied for cuttings collected in different months from October to April (Tables 1-3).

Table 1. Rooting percentage for 3 collection dates in the 1967-68 season, using 3 temperature regimes and 3 trees*

Collected and set		4 Dec.			4 Jan.			22 April
Temp regime no.		3	4	5	3	4	5	4
Tree no.	2	94	32	40	-	-	-	-
	3	32	0	2	0+	5	30	0
	4	-	-	-	0+	35	60	0

* All cuttings treated with 100 ppm IBA (see later) and 4% Arasan prior to setting for rooting. Tree no. 2 was felled following the first collection, preventing further use. Data marked + are unreliable due to accidental soil drying and were not considered in the analysis. For temperature regimes, see Table 9 (page 8). Cuttings collected 22 April were close to bud flushing.

Table 2. Rooting percentage for 3 collection dates in the 1968-69 season compared for different temperature regimes and humidity controls. *

Collected and set		19 Dec.		12 Feb.				27 March		
Regime no.		1	6	1	4	5	6	1	4	6
Tree no.	3	26	64	12	38	48	14	0	0	0
	4	8	0	36	38	28	2	14	20	0

* Cuttings treated with 100 ppm IBA and 4% Arasan. Data based on 40-50 cuttings per treatment. For temperature regimes, see Table 9 (page 8).

Table 3. Rooting percentage for cuttings from plus stands collected in October and November 1968. *

Collected	15-23 Oct.	19-25 Nov.
Per cent rooted	40	41

* Data averaged for trees from 8 stands and a total of 2340 cuttings. Cuttings treated with 100 ppm IBA and 4% Arasan and placed in unheated greenhouse (Regime 1) with intermittent misting.

Conclusion: Different trees may react somewhat differently to time of collection of the cuttings and to rooting treatments; but, generally, collections can be made from mid-October to mid-February with equally good results. Rooting was significantly lower ($P<0.05$) and unsatisfactory for collections in late March and April until the time of bud flushing. No test was made with newly flushed or with elongating shoots.

STORAGE

For convenience of work schedule, it often becomes desirable to store cuttings, and rooting of some conifers may benefit from storage (Brix and Barker 1973). Effects of storage in plastic bags, with wet paper towels to maintain high humidity, were tested for storage periods up to 12 weeks at a temperature of 4 C. Cuttings were from the plus stand collections and included 2340 cuttings from 78 trees in 8 stands. Current shoots were used and they were treated with 100 ppm IBA for 24 hr before being placed in an unheated greenhouse under intermittent mist.

Table 4. Rooting percentage for cuttings stored for different periods at 4 C

Stand	Collection	Storage, weeks				
no.	date	0	8	9	11	12
4	22 Oct.	41				58
8	23 Oct.	38			19	
9	19 Nov.	23	37			
10	19 Nov.	50	53			
11	15 Nov.	36		48		
12	25 Nov.	40	45			

Conclusion: Rooting averaged 38% for unstored and 43% for stored cuttings and storage up to 12 weeks at 4 C had no adverse or beneficial effect on rooting for cuttings collected in October and November ($P>0.05$).

PREPARATION AND TREATMENT OF CUTTINGS

Preparation, size and shoot age

Cuttings should preferably be cut to a length of 6-10 cm with a clean right-angle basal cut. The standard procedure has been to remove the leaves from the basal 2.5-3.5 cm length of the cutting to be inserted in the rooting medium. Because of the small size, no additional wounding, such as the longitudinal slit used for Douglas-fir cuttings, is done. Since shoots from old trees are often short, it may be necessary to include 2- and sometimes 3-year-old growth on the cutting. Rooting of cuttings with the current shoot only was, therefore, compared with rooting of those that included older shoots.

Three cutting types were tested in 1972-73: (1) the top of, or the entire current shoot, (2) the basal portion of the current shoot which was cut to leave a bud near the apex, and (3) the current plus the 2- and 3-year-old shoots. Data include results with cuttings from 2 trees, about 50 years old, prepared with or without various IBA treatments subsequent to 3 weeks of storage.

Table 5. Rooting percentage of cuttings of different types with and without IBA treatment.

Cutting type	No. IBA	IBA
1	34	32
2	-	7
3	6	13

Conclusion: The intact current shoot rooted best ($P<0.05$) and IBA had no effect on rooting.

The experiment in 1968-69, with cuttings from plus stands, tested also for rootability in relation to shoots of different ages included on the cuttings (Table 6). Each treatment had 15 cuttings, treated with 100 ppm IBA, and were placed in an unheated greenhouse under intermittent mist. Each tree could provide only 2 of the 3 cutting types because of insufficient cutting material.

Table 6. Rooting percentage in relation to shoots of different ages included on the cuttings. Age 1 is the current shoot.

Shoot ages	Tree no.									Avg
years	1	2	3	4	5	6	7	8	9	
1	73	-	46	13	66	0	-	-	100	50
1 + 2	-	40	-	-	-	-	13	46	-	33
1+2+3	26	26	13	0	33	13	0	13	13	15

Conclusion: Cuttings of current shoots rooted significantly better ($P < 0.05$) than those with 1+2+3-year-old shoots, and cuttings with 1+2-year-old shoots did not root better ($P > 0.05$) than those with 1+2+3-year-old shoots. This experiment does not show whether rooting is affected by shoot age per se or by shoot vigor, since 2- and 3-year-old shoots were included because the current shoots were not long enough to produce acceptable size cuttings and may have been less vigorous.

Auxin treatment

In our studies with Douglas-fir cuttings, the best chemical treatment was an application of 3-indolebutyric acid (IBA), using a 24-hr basal soak in a 100 ppm concentration (Brix and Barker 1973). This was adopted as a standard treatment for hemlock cuttings. Initially, there were indications that the ethyl alcohol (ETOH) used to dissolve the IBA might be harmful to the cuttings. This was confirmed in tests using ETOH concentrations of 1, 2.5 and 5% in the 100 ppm IBA solutions applied to the cuttings. We now dissolve 1 g IBA in 110 ml of 95% ETOH and then dilute to give 100 ppm IBA; the final solution will contain approximately 1% ETOH, which is satisfactory. The potassium salt of IBA (KIBA) is water soluble, but it was not as effective in a test with cuttings from 2 trees. A commercial rooting product, Jiffy Grow no. 2 (C&R Products, Portland, Oregon), applied as a quick dip, was tested in concentrations of 100, 50 and 10% with cuttings from 2 trees. Its active ingredients are: 0.5% IBA, 0.5% NAA, and 0.0175% B. The 100% Jiffy Grow was superior to both 50 and 100 ppm IBA for a collection made on October 3, but was inferior in all concentrations to IBA at 100 ppm for a February 12 collection. No general conclusion of the value of this product can be made without further tests.

The method of IBA application was tested using a 24-hr basal dip in IBA solution and a basal dip in an IBA mixture in powder (talc). These treatments were combined with a fungicide treatment consisting of Benlate (50% a.i. benomyl, Dupont), also applied either in solution or as a talc powder mixture. Cuttings, 35 per treatment, were collected from 2 trees on November 28, 1972, and were placed in a plastic covered frame with no heating (Regime 3, Table 9).

Table 7. Rooting percentage in relation to auxin and fungicide treatments applied in the form of solution or in a powder mixture.

Tree No.	Control (no IBA, no Benlate)	Solutions Benlate, 150 ppm			Powder mixture Benlate, 10%		
		IBA-ppm		KIBA-ppm	IBA-%		KIBA-%
		0	100	100	0	0.8	0.8
3	0	0	54	21	36	39	42
4	12	16	12	0	48	36	24

Conclusion: IBA in solution and, to a lesser degree, KIBA had a beneficial effect on rooting of cuttings from one tree (No. 3) but not on the other. Benlate in solution had no effect but Benlate in a powder mixture (or talc) increased rooting. IBA in powder mixture had no additional effect to that of Benlate, but its effect alone was not tested.

Usually IBA is applied before cuttings are placed in the rooting bed; but, in one experiment, cuttings were not treated until 9 weeks thereafter. This was ineffective, giving a rooting percentage of only 3 compared to 38 for those treated before placement.

Although IBA increased rooting percentage in some tests, the effect was not universal, as illustrated by Table 5. More studies on IBA effect are needed in relation to collection time for different trees and for different forms of application. Effects on speed of rooting and on root quality should also be evaluated. At present, our standard procedure is a 24-hr basal dip in 100 ppm IBA solution.

Fungicides

Following collection, the cutting material may have to be stored for long periods during which deterioration may occur through growth of moulds and other harmful fungi. The effectiveness of commercial bleaches (with 5.25% available chlorine) in preventing this was studied. Before cuttings were made, branches were dipped in 2.5 or 5% solutions of bleach for 2 minutes and then rinsed thoroughly under running water. No mould developed on control cuttings, so beneficial effects of the treatment could not be evaluated. However, no harmful effect of bleach was noted, so the treatment could be potentially useful, as shown for Douglas-fir (Brix and Barker 1973), if the problem of moulding during storage does develop.

For protection of cuttings in the rooting bed, several fungicides were tested, i.e., Arasan (42% thiram), Benlate (50% a.i. benomyl) and Captan.

Benlate was tested (a) as a basal powder dip mixed with talc, (b) as a 24-hr basal soak in a 150 ppm solution made up with the ETOH dissolved IBA (Benlate is not water soluble), and (c) as a 300 ppm soil drench using 5 litres of solution per 1 m^2 of rooting bed. A 4% Arasan powder mix, applied as a basal dip, was used for comparison. A total of 460 cuttings from 3 trees were collected and set on December 15, 1970. All were treated with 100 ppm IBA in a 24-hr basal soak.

Table 8. Rooting percentage in relation to Benlate and Arasan treatments.

Cutting treatment	Benlate soil drench, ppm	
	0	300
Benlate powder dip, 0	16	24
Benlate powder dip, 2.5%	28	16
Benlate powder dip, 5%	36	36
Benlate powder dip, 10%	66	24
Arasan powder dip, 4%	26	12
Benlate solution, 150 ppm	66	73

Conclusion: Soil drench had no significant effect on rooting, but Benlate, applied either as a basal powder dip or as a 24-hr soak, increased rooting, the best result coming from the highest concentration (10% and 150 ppm). Arasan had no significant effect in this experiment, but has been used extensively in other tests where good rooting was obtained. For instance, all cuttings from plus stands were treated with 4% Arasan and rooted an average of 43%. A 10% Benlate powder dip was also shown to increase rooting in a previous experiment (Table 7). We recommend this application, or the 150 ppm Benlate solution prepared with the ETOH dissolved IBA.

Botrytis has been less of a problem for hemlock than for Douglas-fir cuttings. Captan will provide protection if an attack is detected in an early stage of development. The cutting tops should be wetted periodically, using 1 tablespoon of 50% W Captan per 2 gal water.

ROOTING MEDIUM

For Douglas-fir cuttings, we determined that a mixture of equal volumes of fine peat moss, washed coarse sand and coarse grade perlite provided favorable aeration, drainage and moisture retention for rooting with the water regime used (Brix and Barker 1973). No special study was made for hemlock cuttings, but the same medium was adopted with apparently favorable results. As a precaution against introduction of pathogens, the medium is heat sterilized before use.

ENVIRONMENT DURING ROOTING

Humidity Control

Studies in 1966-69, for the most part, used an intermittent misting system with a Geiger Mist-A-Matic control (Brix and Barker 1973). In 1968-69, a comparison of rooting was made using this misting system (1) (Fig. 1), flats with cuttings enclosed in a clear plastic sheeting (4 mil) and placed under the intermittent mist (2) (Fig. 1), and a plastic enclosed box with no mist and shaded from direct sunlight (3) (Fig. 2). The latter was watered once or twice a week. No heat was provided to air or soil (rooting medium) except to keep the greenhouse, in which all cuttings were placed, frost free. The regimes are listed in Table 9. Cuttings were from the plus stand collections and, because of limited material, it was not possible to cover all 3 regimes with cuttings from the same trees. For the comparison between (1) and (2), 405 cuttings from 27 trees were used, and between (1) and (3), 225 cuttings from 15 trees were used. Rooting percentage averaged 33, 42 and 45 for regimes 1, 2 and 3, respectively, and although the trend was for 1 to be the poorest, no statistically significant differences were found ($P > 0.05$). Following the 1968-69 season, regime 3 with plastic covered boxes was used as the standard system.

Temperature

The temperature regimes and methods of humidity control are listed in Table 9. The outside propagation box is described by Brix and Barker (1973). Soil heating was provided by General Electric leaded soil heating cables (115 V, 3.5 amp) with a thermostat.

Table 9. Temperature conditions and humidity controls.

Regime no.	Temperature condition	Humidity control
1	unheated greenhouse, unheated soil $^+$	intermittent mist
2	unheated greenhouse, unheated soil $^+$	flats plastic covered under mist
3	unheated greenhouse or outside box, unheated soil $^+$	box plastic covered
4	warm greenhouse (20 C), warm soil (20 C)	intermittent mist
5	unheated greenhouse or outside box, warm soil (20 C)	box plastic covered
6	unheated greenhouse, warm soil (20 C)	intermittent mist

$^+$thermostat set at 2 C to keep soil frost free

The mean weekly air temperature in the unheated greenhouse ranged from 6 to 15 C during the months November-April; the weekly minimum ranged from 2 to 5 C and the maximum from 7 to 18 C.

Preliminary results with cuttings collected December 4, 1967, from 2 trees, showed that best rooting was obtained when neither the soil nor the air was heated (Brix and Barker 1969).

Fig. 1. Flats with western hemlock cuttings in the greenhouse under intermittent misting system. Cuttings in some flats are exposed to misting; in others, they are enclosed in clear plastic sheeting.

Fig. 2. Box in greenhouse with cuttings enclosed in clear plastic sheeting. Cuttings are shaded from direct sunlight and no mist is applied.

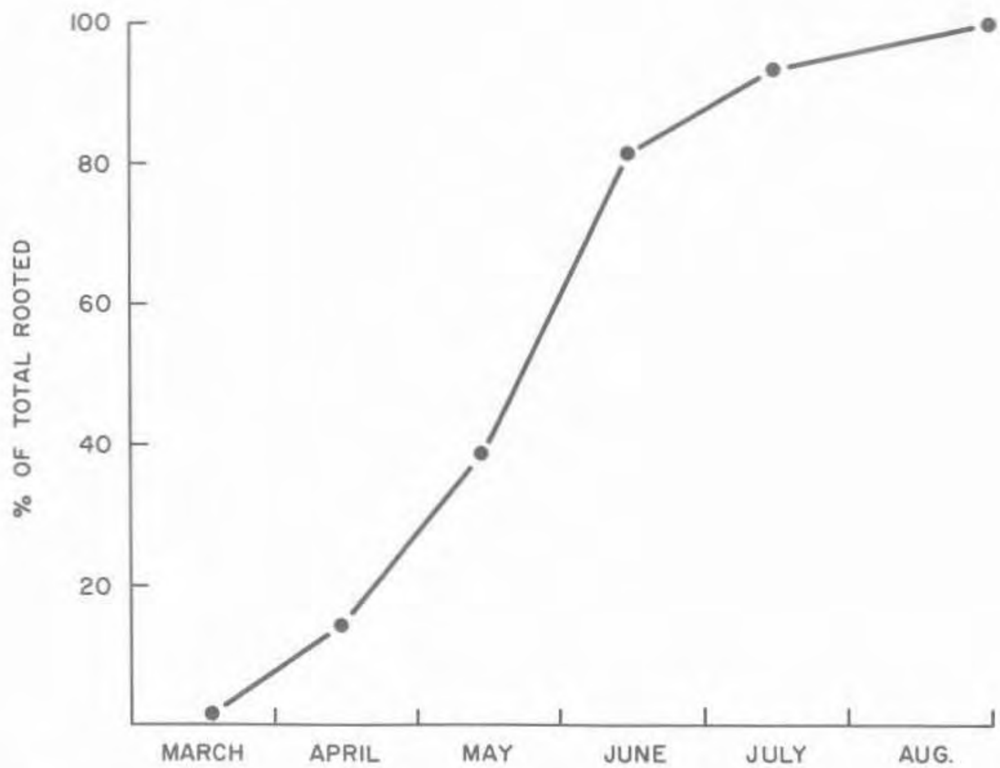

Fig. 3. Seasonal pattern of rooting of western hemlock cuttings collected and set in early December.

Rooting percentages averaged 62, 16 and 34 for regimes 1, 4 and 6, respectively. This led to further studies on temperature effects.

Cuttings from 2 trees were collected February 12, 1969, treated with 100 ppm IBA and 4% Arasan, and placed under regimes 3, 4 and 5 in a greenhouse (Table 10). Each treatment contained 50 cuttings.

Table 10. Rooting percentage in relation to temperature and humidity control. Cuttings collected February, 1969.

Tree	Regime no.		
no.	3	4	5
3	92	38	48
4	90	38	28

Exceptionally good rooting was obtained in this trial for cuttings in the unheated greenhouse with a plastic covered box and no soil heating.

A similar experiment was performed with cuttings collected February 5, 1970, except that regime 2 was tested instead of regime 3 (Table 11).

Table 11. Rooting percentage in relation to temperature and humidity control. Cuttings collected February, 1970.

Tree	Regime no.		
no.	2	4	5
2	20	5	40
3	25	0	28

Regime 4, with warm air and soil, gave poor rooting, although results with this condition were fair in 1969.

In the 1972-73 program, all cuttings (1440) were in the outside box under regime 3. Rooting was good when other treatments tested were favorable.

Although soil freezing was generally avoided, the soil did freeze solidly for 1 week in January, 1971, in the outdoor box, but with no apparent effect.

Conclusion: The most consistently good results were obtained when neither the air nor the soil was heated. The warm air and warm soil combination (Regime 4) was generally the worst, being poor for trials in 1967 (16%) and 1970 (3%), but fair in 1969 (38%). The unheated air and warm soil condition (Regimes 5 and 6) was consistently good, but was inferior to unheated air and soil in 2 of the 3 trials and was not tested for fall collections.

Considering the favorable rooting under the plastic cover, where the possibility of failure in a misting system is also avoided, our standard procedure now is this humidity control combined with no heating of air or soil in an outside propagation box (Regime 3).

SEASONAL PATTERN OF ROOTING

The seasonal pattern of rooting was followed for cuttings collected and set for rooting December 4, 1967, using unheated air and 20 C soil. The final rooting percentage when the experiment was terminated at the end of August was 40. In other studies, some rooting has been observed after the end of August and even in the following year. Rooting began in mid-March and half of the total rooted cuttings were produced by the third week of May (Fig. 3). The period of most rapid rooting was from mid-April to mid-June. Most of the hemlock cuttings rooted after bud flushing, which occurred at the end of April. Douglas-fir cuttings rooted somewhat faster under similar rooting conditions in the same year. Some had rooted by mid-February and half of the rooted cuttings were produced by the end of April (Brix and Barker 1973).

VARIATION IN ROOTABILITY

As mentioned, the main experiment was done with cuttings collected in the fall of 1968, in 13 plus stands selected in widespread locations on Vancouver Island and adjacent islands. Cuttings were taken from 10 trees in each stand, with the exception of one in which only 8 trees were sampled. Each of the 128 trees was represented by 15 cuttings in a standard treatment (100 ppm IBA, 4% Arasan, Regime 1), and additional cuttings were used to study effects of shoot age, storage, auxin treatment, humidity control and temperature regime. An analysis of variance for cuttings under the standard treatment did not show a significant stand effect on rootability and there was, therefore, no effect associated with stand age. The age varied from 42 to 67 years for 8 stands and was about 150 years for the remaining 2 stands. Tree-to-tree variation in rooting percentage within stands was considerable, and in one stand ranged from 0 to 100. However, cuttings from most trees that rooted poorly under the standard treatment rooted well in one of the subsidiary tests. Out of 128 trees, only 11 failed to produce any rooted cuttings, although the average number of cuttings used per tree was low (35). Some of the failures were likely caused by suboptimal handling of cuttings during transportation to Victoria, which took from 2 to 5 days. The average rooting percentage for all cuttings from plus stands was 43. This indicated that hemlock cuttings, given appropriate treatment, generally root well and that there is not likely to be a serious problem with difficult-to-root trees, as is the case for Douglas-fir (Brix and Barker 1973).

TREATMENT, GROWTH AND FLOWERING OF ROOTED CUTTINGS

Following rooting, the same cultural procedure for growth was followed as that outlined for Douglas-fir (Brix and Barker 1973). Shoot growth in the year of rooting is slow and is often limited to the short shoot produced before rooting. In the second year, a height growth of 5-10 cm is common. Given favorable conditions, height growth will continue to improve to 25 cm or more in the third season.

Growth form was assessed in the fall of 1975 for ramets from the plus-stand collections which were rooted in 1969. A total of 63 clones, each with 1 to 5 ramets, were inspected. An assessment of growth into orthotropic and plagiotropic form cannot be done for the current leader since this is naturally drooping for western hemlock. A further complication for this species is that a bi-lateral shoot symmetry is not a good criterion of plagiotropic growth since stem shoots of seedlings often exhibit this symmetry for 2 or more years. The main feature used, therefore, was the angle of stem growth from the vertical, discounting the current shoot. About one-third of the clones appeared normal 6 years after rooting, one-third had evidence of previous plagiotropic form which had been overcome, and one-third still retained a plagiotropic form. Even for the latter group, the degree of plagiotropism was not severe for most ramets and far less than is common for cuttings from mature Douglas-fir trees.

Seed cones were first produced 1 year after rooting on 68 of the rooted cuttings, representing 32 clones, in the plus stand propagation program (Piesch 1972). Cone production has increased, and about 30% of 108 clones produced seed cones in 1975. Pollen cones were not produced until 4 years after rooting and, in 1975, about 15% of all clones produced pollen cones. Controlled breeding has been successfully conducted using these cones (R.F. Piesch, per. commu.).

CONCLUSIONS AND SUMMARY

Studies reported here have dealt with some important aspects of rooting. Treatment effects were found to vary somewhat with different trees and in different years. For instance, cuttings from some trees responded to IBA treatments, whereas others did not, and rooting was better in some years than in others. This probably was caused in part by variation in physiological conditions of the trees, but a variable environment during rooting would be a contributing factor. A fully controlled environment which could be achieved in growth rooms was not sought because such facilities are not available to most users. Considering the number of variables involved in a rooting program and the often important interactions among them, it can be expected that further investigations will improve on present recommendations. Nevertheless, the procedure summarized below gave reasonably good results with most trees in different years.

(1) **Selection of cutting material:** Crown position effect was not studied, but in the major study involving plus stands, cuttings were taken from the outer section of main branches in the middle one-third of the crown. The average rooting for this material was good (43%). Cuttings in other studies which also rooted well, came from the lower one-quarter of the crown. The diameter of the cuttings does not appear to be critical but cuttings should preferably be at least 6 cm long.

(2) **Time of collection:** Generally, rooting was good for cuttings collected from mid-October to mid-February, but unsatisfactory for collections in late March and April.

(3) **Storage:** Cutting material collected in October and November was stored in plastic bags with wet paper towels at 4 C for up to 12 weeks with no adverse effect on rooting.

(4) **Preparation, size and shoot age of cuttings:** Cuttings were cut to a length of 6-10 cm and leaves from the basal 2.5-3.5 cm were removed. Cuttings from current shoots rooted better than those with 1-, 2- and 3-year-old shoots, but use of the latter was often necessary to obtain cuttings of adequate length.

(5) **Auxin treatment:** Although IBA increased rooting in some tests, its beneficial effect was not universal. Conversely, no harmful effects were found, and our standard treatment is a 24-hr basal dip of the cuttings in a 100 ppm IBA solution.

(6) **Fungicides:** A basal dip of cuttings in a 10% Benlate talc powder mixture or a 24-hr basal soak in a 150 ppm Benlate solution increased rooting. Captan provided protection against Botrytis if the attack was detected early.

(7) **Rooting medium:** This aspect was not studied, but a mixture of equal volumes of fine peat moss, washed coarse sand and coarse grade perlite was used with good results.

(8) **Humidity control:** Rooting was studied for cuttings placed under intermittent misting, either directly exposed to the mist or enclosed under a clear plastic sheeting; others were enclosed under plastic sheeting and shaded from direct sunlight, but with no misting. No statistically significant differences in rooting were found, but the latter has been adopted as our standard treatments.

(9) **Temperature:** Different combinations of unheated and heated (to 20 C) air and soil were tested. The most consistently good results were obtained with unheated air and soil. Unheated air, but heated soil was also a good combination, though inferior to the former in most trials. Heated air and soil was generally the poorest combination. Unheated air and soil is now our standard treatment.

(10) **Seasonal pattern of rooting:** Rooting began in mid-March for cuttings collected and set in December in unheated air and 20 C soil. The period of most rapid rooting was from mid-April to mid-June. Half the rooted cuttings were produced by the third week of May.

(11) **Variation in rootability:** One experiment involved cuttings from 128 trees selected in 13 stands from widespread locations on Vancouver Island and adjacent islands. Stand effect on rootability was not significant, but tree-to-tree variation was considerable. However, rooted cuttings were produced from all but 11 of the trees, although the average number of cuttings per tree was only 35 and the handling of cuttings in transportation, which for some lots took up to 5 days, was probably suboptimal. Rooting percent averaged 43 in this experiment.

(12) **Treatment, growth and flowering of rooted cuttings:** These were treated in the same way as outlined for rooted Douglas-fir cuttings (Brix and Barker 1973). Shoot growth was slow in the year of rooting and in the following year, but good growth was obtained thereafter. About one-third of the cuttings still retained a plagiotropic growth form 6 years after rooting. Seed cones were produced on many clones 1 year after rooting and 30% of 108 clones produced seed cones in the sixth year. Pollen cones were not produced until the fourth year.

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