ROOTING OF CUTTINGS FROM MATURE DOUGLAS FIR

H. BRIX
Pacific Forest Research Centre,
Canadian Forestry Service, Department of the Environment, Victoria, B.C., Canada

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ABSTRACT

Cuttings from most mature Douglas fir (**Pseudotsuga menziesii** (Mirb.) Franco) can be rooted with fair success (average 15%) if they are collected in the autumn, treated with indole-butyric acid and Benlate fungicide, placed in a heated rooting medium (20°C) with no air heating and kept well watered in a humid atmosphere. Clonal variation in rootability is considerable and year-to-year variation has also been found. Cuttings from trees that will not root under these conditions may be induced to root if grafted to cuttings from seedlings. A simple outdoor propagation structure for rooting of cuttings is described.

INTRODUCTION

Until about a decade ago, grafting appeared to be a satisfactory method for vegetative propagation of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco). It then became apparent that many grafted clones propagated several years previously were in declining health or had died (Duffield and Wheat, 1964). A delayed incompatibility between root stock and scion resulted in losses of about half the grafted trees in seed orchards in Oregon and Washington by 1966 (Copes, 1967). Methods have since been devised for early detection of delayed incompatibility (Copes, 1968), thereby reducing the seriousness of the problem, but no method is available for preventing its occurrence.

Propagation by rooting of cuttings has been successful for young Douglas fir trees (Black, 1973; Blankensop and Callaham, 1960; Bodman *et al.;* Griffith, 1940; Heinrich, 1968; Lanner, 1962). However, rootability decreases drastically with tree age and most trees selected in the past for tree improvement programmes have been mature trees. Bodman *et al.* (1952) found good rooting for trees up to 17 years old, but no rooting for 42-year-old trees. Similarly Black (1973) showed that the rooting potential for trees up to 9 years old was 100%, but only 5% for 24-year-old trees. There were some early reports of success with old trees, based on small-scale tests (Hough, 1953; McCulloch, 1943). Results of most of our studies from 1965 to 1972 on rooting of cuttings from mature Douglas fir trees have been published (Brix, 1967; Brix and Barker, 1969, 1971, 1973) and are summarised here, together with other recent advances.

SELECTION OF CUTTINGS

Type of Cutting

For many forest tree species, cuttings from the lower crown root as well or better than those from the upper portions (Black, 1973; Girouard, 1970; Grace, 1939; Hyun and Hong, 1968; Yim, 1962). For this as well as for practical reasons our cuttings have been collected from the lower quarter of the crown. In an early experiment, cuttings were collected from inner and outer portions of the crown and from shaded and exposed sides, but rooting percentages were low for all collections. In agreement with studies of other forest trees, we found that cuttings need not be very sturdy or long. A stem base down to a 2 mm diameter is acceptable and we cut current shoots to a length of 6 to 12 cm. If the current shoots are shorter than 6 cm, part of the 2- and even 3-year-old shoot should be included.Contrary to other reports (Hough, 1953; McCulloch, 1943), old shoots have rooted as well as current ones.

Rooting success has not been significantly different, in our experience, for lateral shoots of various orders when they are treated with auxin, but Roberts (1969) indicated that first-order shoots from young trees rooted better than those of second-order when no auxin was applied. Nearly all our cuttings have been second- and third-order lateral shoots.

The question is often raised whether cuttings from vegetatively propagated stock root better than cuttings from the ortet. This was not so for grafted ramets in our study (Brix and Barker, 1973), although Black (1973) reported rooting percentages of 6 from grafted ramets and 40 from cutting ramets established from old clones compared to 3 for cuttings from Douglas fir ortets.

Time of Collection

Our studies have included collections at different stages of shoot development throughout the year. Rooting has not been obtained for cuttings taken during the periods of shoot elongation and early maturation, but only from mid-September until bud-break the following spring. As found by other workers (Griffith, 1940; Roberts, 1969; Black, 1973), in the northern hemisphere December to March is the best time when using a heated greenhouse. However, the best collection time depends on the subsequent treatment of the cuttings. The overall best results have been obtained with cuttings collected in late autumn (November) and subsequently placed in a warm (20°C) rooting medium, with no air heating. Indeed, cuttings from some trees have rooted only under these conditions, as shown later (Table 1). Under these temperature conditions, cuttings from selected "plus" trees rooted well for the collection period from 19 September to mid-November.

TREATMENT OF CUTTINGS

Storage

Storage may be needed to facilitate a convenient work schedule and it has also been reported to increase rooting (Libby and Conkle, 1966; Roberts, 1969). In one study, cuttings were collected from mature trees on three dates (19 September, 21 October and 5 November) and stored in plastic bags with wet paper towels for 6, 8, 12 or 16 weeks at 0°C or 4.4°C (Brix and Barker, 1973). Rooting of the October cuttings was increased from 9 to 20% by storage for 6 weeks at 4.4°C. Otherwise, rooting was not affected by storage up to 12 weeks at 0°C and up to 8 weeks at 4.4°C for any of the collections, but longer storage at these temperatures was harmful. The beneficial effect of cold air during rooting, as discussed later, is not lessened by a prior cold storage of the cuttings.

TABLE 1—Effect of time of collection and temperature regime of air and rooting medium on rooting of cuttings from five mature Douglas fir trees. Results are expressed as percent of cuttings rooted out of 50. From Brix and Barker (1973).

Collection time	Temperature regime CA/CS*						CA/WS*						WA/WS*					
	Tree no.						Tree no.						Tree no.					
	1	2	3	4	5	avg.	1	2	3	4	5	avg.	1	2	3	4	5	avg.
Sept.	0	0	—	—	—	0	0	0	—	—	—	0	0	0	—	—	—	0
Oct.	0	8	—	—	24	11	4	0	—	24	—	9	0	0	—	10	—	3
Nov.	—	—	0	0	—	0	14	0	50	52	14	26	0	2	2	14	6	5
Dec.	0	—	18	4	—	7	10	0	18	10	12	10	2	0	26	8	0	7
Jan.	0	—	0	0	—	0	0	0	10	16	24	10	0	0	14	4	0	4
Feb.	0	—	2	0	—	1	0	0	0	18	12	6	0	2	26	20	6	11
March	0	—	0	2	—	1	0	0	0	4	2	1	0	0	4	2	10	3
Average	0	4	4	1	24	3	4	0	16	21	13	9	0	1	14	10	4	6

* CA/CS: cold air/cold soil; CA/WS: cold air/20°C soil; WA/WS: 20°C air/20°C soil.
A dash (—) means that this treatment was not studied.

Root Promoting Substances

Prior to chemical treatment, our cuttings are cut to a length of 6 to 12 cm and leaves are stripped from the basal 2.5 cm to facilitate chemical treatment and provide a uniform environment in the rooting bed. To do well, cuttings should have at least a 3.5-cm top with leaves; if all leaves are removed, the cutting will rapidly deteriorate and die. A 1.5-cm longitudinal slit through the bark is made on two sides of the stem base, although the value of this has not been established conclusively.

A great many chemicals reported to have increased rooting of other plants have been tested at different rates and in different combinations. These include various auxins, vitamins, nitrogenous and phenolic compounds, ethylene, sucrose and boron (Brix and Barker, 1973). The only ones promoting rooting were the auxins with indole-butyric acid (IBA) giving best results, either with a basal 24-hour soak in 100 ppm IBA or with a basal application of 0.8% IBA in talc-powder. Griffith (1940) also showed IBA to be superior to indole-acetic and naphthalene-acetic acid. He recommended a 24-hour soak in 50 ppm IBA for young Douglas fir; we also use this prescription for cuttings from seedlings.

Re-treatment with IBA, tested on a limited scale, was found beneficial to rooting Cuttings were collected and treated (24-hour soak in 100 ppm IBA) in November; half of those not rooted in May were re-treated with a 1% IBA powder dip. Of the re-treated cuttings, 54 rooted compared to 32 for the control group.

Fungicides

Mould rarely develops on cuttings during storage, but if it does, it can be eliminated by a 2-minute dip in a 5% solution of commercial bleach (containing 5.25% available chlorine), followed by a rinse in water.

Mortality in the rooting bed has been a serious problem. It appears that the problem is caused in part by physiological conditions of the cuttings which make the stem base intolerant of the chemical treatments and the environment which otherwise is required for good rooting. The result is rotting of the basal stem part embedded in the rooting medium and eventual death of the cutting. This type of damage has been more serious in some years than in others and some clones have been affected very little, whereas most of the cuttings from other clones have died. Pathogens may also cause mortality, but a good general treatment is the systemic fungicide Benlate (Dupont, 50% active benomyl) applied to the stem base either as a 10% Benlate talc-powder dip or as a 24-hour soak in 150 ppm Benlate. *Botrytis* can be especially destructive when new shoots flush out, but Captan (1 tablespoon of 50 W Captan per 7.5 l of water) has provided good control when sprinkled periodically on the cutting top.

Paired Cuttings

Cuttings from seedlings root readily and have been shown to stimulate rooting of cuttings from mature trees when grafted together in pairs at the stem base (Brix, 1967; Brix and Barker, 1971, 1973). This stimulation appears to originate from roots of seedling cuttings. When the "old" cutting has rooted, the "young" one can be removed. Cuttings from some mature trees have rooted only with this technique which should therefore be especially useful for such trees.

ENVIRONMENT DURING ROOTING

Propagation Structure

Our early experiments were done in a heated greenhouse, but later studies showed that cold air combined with a warm rooting medium is beneficial to rooting for cuttings collected in the autumn. These conditions are easily obtained in a simple outdoor frame in which a heating cable is placed beneath the rooting medium. High air humidity is maintained by covering the top of the frame with a tight-fitting, clear, plastic sheet. To avoid overheating direct sunlight should not fall on this cover. This is ensured by orientating the frame east-west, and fitting a shade (white painted plywood) on the sunny side. A second, clear plastic sheet is attached to the top of the shade and covers the open front to prevent precipitation from falling on the inside plastic cover. The frame measures 70 × 244 cm (inside) and has 25-cm-high sides. A 18.3 m (400 W) heating cable is embedded in a layer of sand in the bottom and 8 rooting flats (33 × 61 × 10 cm) are fitted tightly on top. Rooting in this structure has been at least as good as that obtained in the greenhouse.

Rooting Medium

The best rooting medium is likely to vary with the watering system used. If an abundance of water is supplied, the rooting medium must be well drained and have a low water-holding capacity, e.g., perlite or coarse sand. With less water supplied, some peat moss may be desirable. A mixture of equal volume of fine peat moss, washed coarse sand and coarse-grade perlite is a good rooting medium, and has provided sufficient water in the frame covered with a plastic sheet, with watering twice a week. This medium was also favourable with the intermittent misting system used in our early experiments.

Watering

Initially, watering and air humidity were controlled by intermittent misting. The weight of mist falling on a balanced screen, and evaporation of mist therefrom, tripped a mercury switch which controlled the on-off operation of a solenoid valve in the water line; various misting nozzles were used from time to time. Although this system usually worked well, occasional power and mechanical failures did interrupt its function. The system adopted later, using a plastic cover to maintain high humidity and watering twice a week, has worked well as long as the plastic covering was kept completely tight.

Temperature

Various rooting promoters are produced in the top of the cuttings and translocated to the base of the stem where they are used in root initiation and development. The processes involved in these two parts of the cutting are, therefore, quite different and may have different optimal temperatures which, in turn, may depend on the physiological condition of the cutting at the time of collection.

Three temperature regimes were tested for cuttings from five mature trees (70- to 100-years-old) collected at different times from September to March (Table 1). The regimes were: (1) air and rooting medium were not heated except to keep cuttings frost-free; (2) air was not heated but rooting medium was kept at 20°C; (3) air and rooting medium were kept at 20°C. The best rooting was obtained with the November collection which was given the cold air combined with warm rooting medium (Treatment 2). Cuttings from one tree (No. 1) rooted in significant numbers only under these conditions. Later collections did not do as well and the best regime for the February-March collections was the warm air and warm rooting medium. Rooting of Douglas fir was poor with no heating, although this treatment has been the best for autumn-collected western hemlock cuttings (Brix and Barker, 1969). A notable feature is the great variation in rooting among trees, although they were growing in the same general area and were of the same age class. In addition to its beneficial effect on rooting for autumn-collected cuttings, cold air is also needed for normal bud flushing in the spring.

Light

An early study of rooting, using different intensities of shading, was not conclusive because of heavy mortality, but indications are that heavy shading is detrimental to rooting (Brix and Barker, 1973). Some shading of the outdoor frames is needed to avoid overheating from direct sunlight, but shading is kept to a minimum by using white-painted, narrow boxes. The effect of photoperiod on rooting has not been tested.

ANATOMICAL AND SEASONAL PATTERN OF ROOTING

Roots develop only from the basal stem cut and not up the stem, even when it is wounded longitudinally. Heaman and Owens (1972) showed that root primordia arise in the basal callus, proliferated from the lowest cells of the vascular cambium, in association with the differentiating phloem and wound cambium.

Cuttings are slow to root, usually requiring from 2 to 6 months or more (Griffith, 1940; Blankensop and Callaham, 1960; Brix and Barker, 1973). In a study where cuttings were collected in November-December and set in cold air and warm rooting medium, a few rooted as early as January and a significant number in February. Half the cuttings that eventually rooted had done so by the end of April. For the February-March collection, the 50% rooting level was reached at the end of June. Only a few cuttings rooted after the end of July for either of these collections. Although bud flushing is accompanied by a period of good rooting, most rooting is not associated with time of flushing and, indeed, cuttings may flush without producing roots.

ROOTING SUCCESS

Rootability and mortality of cuttings from different trees have varied greatly. In a study with cuttings from 32 "plus" trees, all over 80 years old, rooting percentages ranged from 0 to 80 and averaged 15. The cold air and warm rooting medium regime was used for the autumn-collected cuttings. Although only 25 cuttings were used per tree, some cuttings rooted from 25 of the 32 trees.

A strong genotypic variation in rootability is suggested from results in Table 1 and from other studies (Black, 1973; Brix and Barker, 1973), but environmental factors also appear to be important, since some trees have rooted well in one year but poorly in another (Brix and Barker, 1973). These variations in rooting have complicated our studies considerably and made it difficult to prescribe a technique that will work well for all trees in every year.

GROWTH AND FLOWERING OF ROOTED CUTTINGS

In the year of rooting, the new shoot is very short (1-7 cm) and is often produced before roots have developed. A good root system is usually developed later in that year. Shoot growth the following year or two is normally also short (10 cm) but plants are thereafter sturdy, have a well-developed root system and are ready for outplanting in the field. A height growth of 30 cm or more the first year in the field has been common. Plants retain a plagiotropic growth for several years and should be staked. Although staking does produce an upright tree, it does not hasten the natural transition from plagiotropic to orthotropic growth (Black, 1973).

Both male and female flowers have developed on several clones a few years after rooting, but no long-term prediction of flowering behaviour can be given at this time.

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