A STOOL PLANT MANAGEMENT SYSTEM FOR THE PRODUCTION OF NON-PLAGIOTROPIC CUTTINGS OF DOUGLAS-FIR

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DOUGLAS-FIR COOPERATIVE

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Although this report does confirm that the stool-plant treatment will produce apparently orthotropic shoots, the results are based on only a preliminary pilot study. Nurseries are encouraged to start trialing this technique and requesting further advice from Forest Research but until further results from current trials become available we can not guarantee the success of the technique nor the financial viability of the method. This report is confidential to members of the Douglas Fir Cooperative.

Abstract

Clonal propagation of Douglas-fir (*Pseudotsuga menziesii*) is more difficult than for many other forest tree species. Large-scale propagation has been tried in North America, notably by the timber company, Weyerhaeuser, to multiply scarce and valuable controlled-pollinated seed. Up to one million cuttings have been produced per year, but the cost per plant has been unacceptably high. The major reason for the high cost is the intensive system with a controlled climate required for stock plants. Also, there are losses due to plagiotropic (branch-like) growth in rooted cuttings.

The stool-bed management system detailed in this report differs from previous systems in that stool plants are topped to one-third height, branches are cut back and buds are removed in early spring. This forces the production of orthotropic (stem-like) shoots, of which 70-80% will root; however, field-testing is required to confirm that there is continued apical dominance. Stool-plant size appears to be critical, with 18-month-old stool-plants producing around 15 shoots as against more than 30 shoots from 27-month-old stool plants.

The pronounced dormancy period of Douglas-fir is evidently a factor in achieving plant size as there will always be a shut-down of growth, unless intensive climate control is utilised. This study has produced a good guide as to when shoots may be taken and set as cuttings, but the best time of year to ensure reliable top growth has not been established.

The study does confirm that the stool-plant treatment will produce apparently orthotropic shoots three months after treatment, any time from December to August. We were constrained by lack of climate-controlled facilities to set cuttings from March to July, but it appears that the optimum time for setting would be earlier in the summer, so that the cuttings can set roots before winter and are ready to flush in spring. This requires a facility where chilled water can be circulated to reduce the temperature to 20° Celsius. Further research is required to evaluate the performance of cuttings set at different times of the year.

Keywords: *Pseudotsuga menziesii*, stool beds, plagiotropic, orthotropic, rooted cuttings

Introduction and Background

Clonal propagation of Douglas-fir (*Pseudotsuga menziesii*) is more difficult than for many other forest tree species. Large-scale propagation has been tried in North America, notably by the timber company Weyerhaeuser, to multiply scarce and valuable controlled-pollinated seed (Ritchie 1990, 1991, 1992, 1993, 1994). Up to one million cuttings are produced per year, but the cost per plant has been unacceptably high.

A major reason for the high cost is that many rooted cuttings develop plagiotropic growth, where the cutting grows horizontally like a branch, rather than vertically like a tree stem. Such cuttings are discarded, which represents a waste of the time and materials required to set cuttings as well as a reduction in the plants obtained from each stool-plant (mother plant). Another reason is the very definite dormancy period of Douglas-fir, which means that cuttings may not be able to put on top growth for long periods, depending on the setting time. A further reason for the high cost is the intensive system, starting with stool-plants raised in a controlled climate.

Some work was done on propagating Douglas-fir (from 7- to 60-year-old trees) in New Zealand in the 1960s and 1970s. However, the arrival of *Phaeocryptopus guaemannii* and the subsequent reduction of growth in Douglas-fir stands led to a lack of interest in Douglas-fir research. The early work did establish that Douglas-fir cuttings taken from trees less than 10-years-old, could be persuaded to grow roots reasonably easily.

While establishing the Gwavas *Pinus radiata* seed orchard in the early 1960s, it was observed that a large population of rabbits had browsed a neighbouring planting of Douglas-fir so heavily that all trees were completely de-budded. These de-budded seedlings produced many shoots from the axils where needles joined the bark. The shoots had strong apical dominance and had foliage distributed evenly around their stems, like seedlings, as opposed to normal Douglas-fir branches, where the foliage is more parallel to the ground, presumably to capture the maximum amount of light. Out of this came the idea of the "rabbit method" and the potential for stool-plant management and production of orthotropic cuttings (i.e. apically dominant or upright in form).

New Zealand interest in Douglas-fir did pick up in the late 1980s and early 1990s, especially as good prices were paid for New Zealand grown Douglas-fir logs and timber. In 1992, the New Zealand Douglas-fir Research Co-operative was formed and substantial research was promoted in mensuration, tree breeding and wood property studies.

PROSEED, the New Zealand seed company, had the foresight to establish an orchard of selected parents from best available provenances of Douglas-fir in 1988. By 1992, this orchard was starting to produce cones and the production of good controlled-pollinated seed became a reality.

A project to propagate Douglas-fir by cuttings was put to the research co-operative, but some of its members felt that tissue culture would provide a better option. ***Forest Research*** decided to proceed with the project, regardless, as it appeared that no-one else had tried an approach of debudding stool plants to induce formation of orthotropic cuttings. The research described in this project record was carried out by Trevor Faulds in the ***Forest Research*** nursery under the direction of Mike Menzies.

It later transpired that tissue culture of Douglas-fir is fraught with problems, including plagiotropism, so it is evident that finite solutions have not yet been found. Application of the "rabbit method" has great potential for the multiplication of superior Douglas-fir stock, via a simple and cost-effective system. However, we need to do further research to determine if the orthotropic shoots produced result in rooted cuttings that remain orthotropic and perform at least as well as comparable seedling stock.

Objectives

The overall objective was to develop a nursery-based stool-bed system for cost-efficient multiplication of superior Douglas-fir. More specifically this included:

1. Determine the effect of topping height and debudding of stool-plants on production of orthotropic cuttings.
2. Evaluate cuttings production from stool plants of various ages topped at various times.
3. Evaluation of rooting and subsequent flushing.

Materials and Methods

In July 1994, 1-year-old Douglas-fir seedlings of Fort Bragg origin were lined out in a nursery bed at a spacing of 60 cm by 60 cm. The seedlings received normal nursery care with the exception of root pruning, for one year, then a number of different experiments were initiated.

Experiment A1, October 1995, 6 of the seedlings described above, aged 27 months, were selected for each of the following treatments:

1. Stool-plants topped to one-half original height.
2. Stool-plants topped to one-third original height.
3. Stool-plants topped to one-half height and all branches cut back to non-budded stumps.
4. Stool-plants topped to one-third height and all branches cut back to non-budded stumps.

Figure 1 shows a typical stool plant from treatment 4, three months after treatment, after axillary shoots had sprouted. Figure 2 shows a stool –plant from the same treatment three months further on and Figure 3 shows a stool-plant from treatment 2 at the same stage of growth. Note the mixture of plagiotropic and orthotropic shoots in Figure 3 and the even arrangement of needles around the stem on the orthotropic shoots in Figures1 and 2. The number of potential cuttings were counted in December 1995.

Experiment A2: In December 1995, six seedlings now aged 29 months, were topped to one-third height and debudded. Cuttings produced were counted in March and 15 cuttings per stool plant were set in March 1996. Root formation was assessed in August 1996.

Experiment A3: In September 1996, eight seedlings now aged 38 months were topped to one-third height and debudded. Cuttings were counted in January 1997.

Experiment A4: In September 1997, eight seedlings now aged 41 months were topped to one-third height and debudded. Cuttings were counted in March 1998.

Meanwhile, further seed was sown in planter boxes in March 1996, then seedlings were pricked out into nursery beds at 60 cm by 60 cm spacing in April 1996. These seedlings were used for the following experiments:

Experiment B1: In October 1997, 30 seedlings now 18-months-old were cut back to one-third height and debudded. Cuttings were counted in January 1998.

Experiment B2: In November 1997, 29 seedlings now 19-months-old were topped to one-third height and debudded. Cuttings were counted in January 1998.

Experiment B3: In November 1998, 20 seedlings now 29-months-old were topped to one-third height and debudded. Cuttings were counted in January 1999.

Experiment B4: In January 1999, 20 seedlings now 33-months-old were topped to one-third height and debudded. Cuttings were counted in March 1999, then 9 cuttings from each of 10 stool plants were set in March 1999. Root formation was assessed in August 1999.

Experiment B5: In March 1999, 20 seedlings now 35-months-old were topped to one-third height and debudded. Cuttings from 10 stool plants were counted in June 1999 then 9 cuttings from each of the 10 stool plants were set in June 1999. Root formation was assessed in December 1999.

Experiment B6: 9 cuttings from each of the other 10 stool plants from Experiment B5 were counted in July 1999, then 9 cuttings per stool-plant were set in July 1999 and root formation assessed in December 1999.

Experiments A1, A2, A3 and A4 all used the stool plants that were transplanted as 1-year-old-stock in July 1994. Experiments B1, B2, B3, B4, B5 and B6 all used stool plants that were pricked out in the nursery bed shortly after germinating in winter 1996.

Results and Discussion

In January 1996, 3 months after treating the stool plants, potential cuttings were counted on all treatments on all stool plants in Experiment 1A. These were also graded as being plagiotropic or orthotropic. These counts are shown in Appendix 1. Analysis of variance was performed using PROC GLM of the SAS® software package (SAS INSTITUTE 1989). Treatment means are shown in Table 1, with letters beside each mean from the Tukey's multiple range test.

Table 1. Treatment means, Experiment A1 (2-year-old stool plants, 3 months after treatment)

Treatment	Treatment description	plagiotropic	orthotropic	total shoots*
1	topped to one-half height	15 b	5 c	20 b
2	topped to one-third height	14 b	4 c	18 b
3	topped to one-half height, debudded	11 b	29 b	40 a
4	topped to one-third height, debudded	3 a	37 a	40 a

* any means not sharing the same letter are considered to be significantly different with a probability of $P \leq 0.05$

The results shown by Experiment A1 showed very clearly that treatment 4 was the preferred option, so subsequent experiments used this treatment only. The number of plagiotropic shoots produced was also considered irrelevant as only orthotropic shoots would be set as cuttings; consequently, these are the only cuttings shown for other experiments. Analysis of variance was performed on these counts and the mean counts of orthotropic shoots per experiment are shown in Table 2.

Table 2. Mean numbers of cuttings per experiment

Experiment number and description	No. stools	cuttings*
A1 27-month-old plants topped October, counted January	6	37.30 ab
A2 29-month-old plants topped December, counted March	6	31.33 bc
A3 38-month-old plants topped September, counted January	8	40.25 a
A4 41-month-old plants topped December, counted March	20	33.30 abc
B1 18-month-old plants topped October, counted January	30	16.10 d
B2 19-month-old plants topped November, counted January	28	13.89 d
B3 29-month-old plants topped September, counted January	19	31.37 bc
B4 33-month-old plants topped January, counted March	10	37.30 abc
B5 35-month-old plants topped March, counted June	10	28.50 c
B6 35-month-old plants topped March, counted July	10	30.40 bc

* any means not sharing the same letter are considered to be significantly different with a probability of $P \leq 0.05$

Experiments A2, B4, B5 and B6 had cuttings set and root formation was assessed. Cuttings were set in containers in a glasshouse using bottom heat and misting. The counts of rooted cuttings were converted to the percentage of cuttings that rooted per stool-plant and these percentages were then analysed. Percentage rooting is shown in Table 3, the differences between experiments were not considered to be significant at the $P \leq 0.05$ level. A sample of cuttings from experiment A4 is shown in Figure 4.

Table 3. Mean percentage of cuttings with successful root formation per experiment

Experiment number and description	No. stools	cuttings set/stool	roots
A2 29-month-old plants topped December, counted March	6	15	83%
A4 41-month-old plants topped December, counted March	20	9	77%
B4 33-month-old plants topped January, counted March	10	9	80%
B5 35-month-old plants topped March, counted June	7	9	71%
B6 35-month-old plants topped March, counted July	7	9	73%

The rooted cuttings from experiments A2, B4, B5 and B6 were assessed for flushing in late December. These percentages are shown in Table 4. The results are somewhat mystifying (for those of us who work with radiata pine), as it appears that Douglas-fir cuttings will form roots readily, but do not necessarily flush in the spring. If they do not flush, then only root growth is taking place, so such cuttings will require a further year in the nursery to reach a plantable size, which is not a good outcome.

Previous research showed that Douglas-fir cuttings require the full period of winter chilling to ensure flushing in spring. These results indicate that this is still a sensitive area, which requires further research.

Table 4. Mean percentage of cuttings that flushed per experiment

Exp	No. stools	Experiment description	flushing
A2	5	29-month-old plants topped December, cuttings set in March, flushing assessed December	48%
B4	10	33-month-old plants topped January, cuttings set in March, flushing assessed December	0%
B5	7	35-month-old plants topped March, cuttings set in June, flushing assessed in December	0%
B6	7	35-month-old plants topped March, cuttings set in July, flushing assessed in December	61%

Conclusions

The stool-bed management system gives good numbers of (orthotropic) shoots, of which 70-80% will grow roots. Stool-plant size appears to be critical, with 18-month-old stool-plants producing approximately 15 shoots as against more than 30 shoots for 27-month-old stool-plants.

The pronounced dormancy period of Douglas-fir is evidently a factor in achieving plant size as there will always be a shut-down, unless intensive (and expensive) environmental control is utilised. We have a good guide as to when cuttings may be produced and set (the optimum appears to be in January), but information on the best time of year to ensure reliable top growth is inconclusive.

It has been established that the stool-plant treatment will produce what appears to be orthotropic shoots three months after treatment, any time from December to August. This study was constrained (by lack of climate-controlled facilities) to setting cuttings from March to July, but it appears that the optimum time would be earlier in the summer, so that the cuttings are ready to flush in spring. This requires a facility where chilled water can be circulated to reduce the temperature to 20° Celsius. Further research is required to evaluate the performance of cuttings set at different times of the year.

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Appendix 1. Counts from all treatments in experiment A1

Treatment	Stool plant	plagiotropic	orthotropic	total
1	1	15	7	22
	2	15	3	18
	3	17	4	21
	4	10	4	14
	5	14	5	19
	6	17	4	21
	total	88	27	115
2	1	18	2	20
	2	11	6	17
	3	12	5	17
	4	14	5	19
	5	11	4	15
	6	15	4	19
	total	81	26	107
3	1	16	28	44
	2	14	19	33
	3	9	31	40
	4	12	36	48
	5	7	26	33
	6	10	31	41
	total	68	171	239
4	1	2	38	40
	2	2	35	37
	3	3	42	45
	4	4	31	35
	5	0	36	36
	6	4	42	46
	total	15	224	239

Figure 1. Stool-plant from treatment 4, shown three months after topping to one-third height and de-budding

Figure 2. A stool plant from the same treatment as the stool plant shown in figure 1, with a full season's re-growth after topping and de-budding. Note the strong apical dominance of the orthotropic shoots.

Figure 3. Two-year-old stool plant from treatment 2, showing one season's re-growth after topping, note mixture of plagiotropic and orthotropic shoots

Figure 4. Rooted cuttings set from Experiment A4 (stool plant topped to one third height, de-budded in December, cuttings set in March)