THE INFLUENCE OF SHOOT ORIGIN ON THE ROOTING OF DOUGLAS-FIR STEM CUTTINGS

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Abstract. The influence of collection date on the rooting of Douglas-fir was reported by Roberts (14) at an earlier meeting of this group.

Results reported here show the importance of additional factors in the selection of cutting material. Depending on genotype, cuttings of juvenile trees under nine years of age had the potential for rooting 100%, declining rapidly after this age to less than 5% between ages 14 and 24 years. Genotypic differences in cutting rootability were greatest among the physiologically older trees. Rejuvenation of rooting in old trees and clones was achieved by shearing and successive propagations. Comparisons of sheared and non-sheared portions of old trees showed the rejuvenation effect to be localized in the sheared portion. Cutting ramets established from old clones produced cuttings which rooted 40% compared to 6% from grafted ramets and 3% from the ortet Crown position (cyclophysis) had little influence on the rootability of shoots from trees under 24 years of age. Branch order positions (topophysis), however, were important in cutting selection, with first order lateral (large), and second order terminal positions rooting better than first order terminal, first order lateral (small), or second order lateral cuttings.

Douglas-fir, (*Pseudotsuga menziesii* [Mirb.] Franco), is the most important timber species in North America. It is also one of the best soft woods of the world. Nearly 30% of the commercial forest land in the West carries stands in which Douglas-fir predominates. Most of this timber area is on the Pacific Coast, mainly in the very productive area west of the Cascades, but Douglas-fir stands are also widespread in the Rocky Mountain states. This represents approximately 37,352,000 acres or 7.3% of the total forest crop in the U. S., and almost 25% of the saw timber produced, by far the most important species (6). It is also considered a leading timber species in Canada, where it is a native, and in other countries, where it has been introduced.

It is one of the most important Christmas tree species in those regions where it is adapted. Large Christmas tree plantations are common in the Pacific Northwest. These facts show the importance of this species in meeting the soaring demands for wood products by a growing population and expanding economy.

In maintaining a supply equal to the demands for this species, there is a need in forest genetics, forest management, including

Christmas tree management, for methods of propagating clonal lines of superior phenotypes and genotypes of Douglas-fir on their own roots. This would avoid problems of rootstock-scion incompatibility and rootstock influences common to grafted materials presently used in forest tree improvement. These trees would be useful in site performance evaluation, the establishment of seed orchards, and conceivably in the future for forest and Christmas tree plantations. One need only look at the advancements made with horticultural plants by asexual propagation to see the potential with such an important timber, ornamental, and Christmas tree species.

Large scale propagation of many woody plants from cuttings is a relatively recent development. Prior to 1930, only the "easy-to-root" species and cultivars were so propagated. The discovery by Thimann and Went (18) that naturally occurring auxins contribute to root initiation led to the use of synthetic auxins in rooting many "difficult-to-root" species.

The conifers have been considered by some to be among the most difficult species to root (17). However, some conifers, largely ornamental forms used in landscaping, have been considered by others to be more or less easy-to-root (8).

The forest conifers which have been most widely studied and propagated from cuttings include *Pinus radiata* (2, 5, 9, 19), *Picea abies* (3, 4, 7), *Pinus densiflora* (10, 11), and other species in the genus *Pinus* (12).

There has been a growing interest by foresters throughout the world in tree improvement through various means of vegetative propagation. Grafting scions from select trees onto chance seedlings has been the most common procedure for seed orchard establishment with difficult to root species. An obstacle to the wider use of rooted cuttings has been the inconsistent results obtained and lack of knowledge concerning the many factors which interact and contribute to the rooting potential of these species. Progress in forest tree improvement must rely heavily on the identification and understanding of factors which contribute to the rooting of cuttings, because grafting and budding techniques have been plagued with poor graft unions, incompatibility and rootstock influences. Grafting is not generally suited to the economic mass production of forest planting stock. The current interest in propagating forest species from cuttings has provided the research incentive to clarify the principles involved in rooting specific species.

Success in rooting Douglas-fir has been inconsistent and progress slow. Research has not been sufficiently detailed to obtain basic answers. However, research has shown the feasibility of rooting this leading timber species (1, 14, 15).

These studies were conducted to determine quantitatively how rooting potential of Douglas-fir is influenced by genotype, tree age, shearing, successive propagation, crown level (cyclophysis) and branch order position (topophysis). These variables have been shown to be important in the rooting of other conifers (5, 3, 4, 7).

MATERIALS AND METHODS

Age. Age effects were studied using a factorial experiment with five seedling trees in each of the four age classes (5, 9, 15, 26 years), and six sampling dates over a two-year period. A minimum of twenty cuttings per tree was sampled on each date.

Rejuvenation. Rejuvenation in rooting potential of old trees was studied using the following approaches:

a) Old sheared trees in two age classes, 25-28 and 35-42 were compared with the non-sheared trees used in the age study. Again five trees in each class were sampled with the number of cuttings per tree, collection dates, and treatment of cuttings the same for both studies. The trees used in these two experiments were growing in the Willamette Valley, Oregon, but were not necessarily of the same seed source or growing at the same site.

b) The effects of shearing on rejuvenation were studied further by comparing sheared and non-sheared portions of the same old trees ranging in age from 25 to 56 years. Three samples of 20 cuttings each from sheared and non-sheared portions of eight different trees were taken on two dates during 1971-1972.

c) The effects of successive propagations on rejuvenation of rooting potential was studied by comparing cuttings from clonal material representing: (a) the parent ortet, (b) grafted ramets of the ortet, and (c) rooted ramet cuttings. These plants were all growing in the same area, (b) and (c) in the David T. Mason seed orchard near Sweet Home, Oregon, and (a) in the forests near Sweet Home. Twenty cuttings were sampled from each source on two dates during 1971-1972. Five clones ranging in age from 25-84 years were included in this study. Rejuvenation resulting from successive propagations was further evaluated by comparing cuttings from 15- to 25-year-old seed orchard understock plants with three-year-old rooted cuttings of these same clones. Eleven clones with samples of 20 cuttings from each source, placed in the rooting bench on two dates, were included in the study.

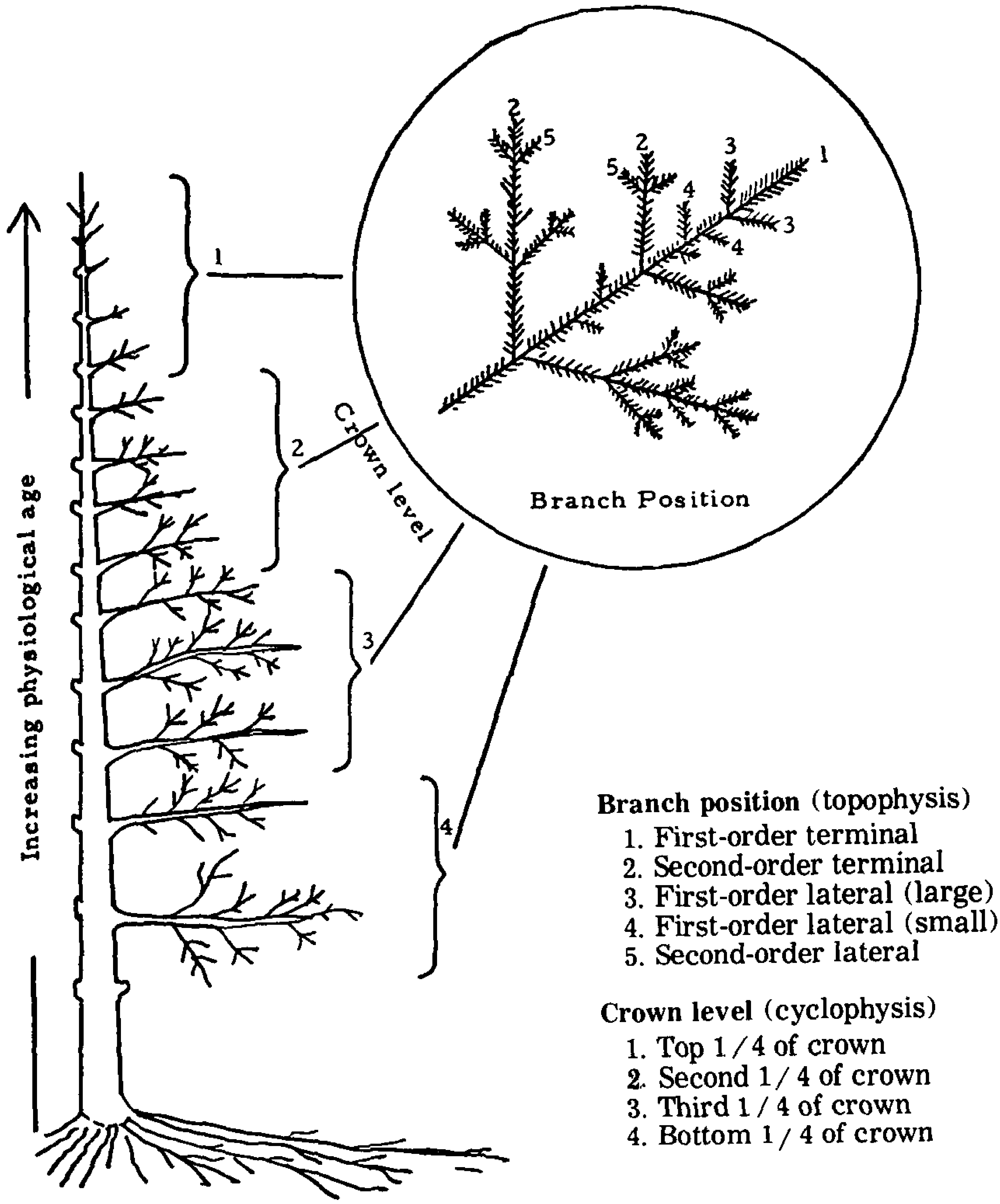

Fig. 1. Topophysis and cyclophysis. Diagram showing the physiological age levels and branch order positions used in this study.

Genotype and Position. Genotypic and positional effects were studied using a factorial experiment with cuttings selected from at least five trees in each of four age classes (4, 8, 14, and 24 years), two branch order positions (terminal and lateral), and four crown levels (Fig. 1). Five samples of ten cuttings from each position of each tree were included in this study during 1970-1972. Each sample was analyzed separately.

Branch order effects were studied in more detail by comparing shoot rootability within five branch orders of three 9-year-old, field-grown trees. Branch order positions compared were (1) first order terminal, (2) second order terminal, (3) first order lateral (large), (4) first order lateral (small), and (5) second order lateral. Three samples of ten cuttings from each position of each tree were analyzed in this experiment.

RESULTS AND DISCUSSION

Aging. Rooting potential decreased with increasing age of the seedling trees at all dates sampled. However, the results indicate that the decline in rootability of Douglas-fir may not be as rapid as in some other conifers.

Up to 100% rooting was common in the cuttings from trees up to 9 years of age. Rooting declined rapidly at tree ages beyond 9 years, and reached a very low level (less than 5% at all sampling dates), at 24 years. This decline in rooting does not appear to be due to the onset of flowering, since no evidence of strobili could be observed in the 15 year old trees or any of the younger trees used in this study. Only the 24-25 year age class showed any evidence of cones or cone development.

Root quality was better and the rate of root development was faster in younger trees. Cutting mortality before and after rooting was less and the amount of extension growth was greater in cuttings from younger trees. (Table 1).

Rejuvenation. Various criteria have been used to distinguish between the juvenile and adult stages. "Most authorities consider that the greater ability of cuttings to root is most closely associated with juvenility" (13). Significant rejuvenation in rooting and growth potential occurred as a result of shearing.

a) *The Rejuvenation of Rooting by Shearing.* At all sampling dates the 24-28 and 35-42 year old sheared trees, some of which had numerous strobili in the crown, rooted better than the 24-year-old, non-sheared trees. Cuttings from the 24-28 year old sheared trees generally rooted better than those from the 14 year old non-sheared trees, but not as good as those from the 8 year old class (Table 1). Shearing also improved root quality. The rate of root development was significantly faster in cuttings from sheared trees, being comparable to the much younger, non-sheared trees. Bud break occurred sooner and cutting mortality was lower in cuttings from sheared trees, again reflecting the rejuvenating effect of shearing. (Table 1).

Table 1. The effects of age on the response of cuttings from different age classes of non-sheared and sheared trees.

Tree age (yrs)	Dec. 1, 1970 C.S.[a]	Aug. 1, 1971 N.S.[a]	Dec. 1, 1971 N.S.	Dec. 1, 1971 C.S.
	Percent rooting			
Non-sheared				
4	55.2	6.3	57.0	67.5
8-9	62.7	23.0	35.3	45.5
14-15	21.5	2.5	9.5	19.8
24-25	4.7	1.9	0.8	0.8
Sheared				
24-28	45.2	2.0	11.2	26.0
35-42	15.3	1.0	14.0	6.0
LSD .05	5.8	4.3	3.4	3.15
	Percent of rooted cuttings of good quality			
Non-sheared				
4	12.0	14.0	49.0	61.0
8-9	57.0	24.0	42.0	27.1
14-15	15.0	0.0	16.0	11.4
24-25	0.0	0.0	0.0	0.0
Sheared				
24-28	18.0	25.0	15.0	6.1
35-42	18.0	0.0	11.0	6.7
	Percent bud break in bench			
Non-sheared				
4	61.5	0.0	55.0	98.9
8-9	59.4	0.0	5.8	49.0
14-15	43.0	0.0	13.3	99.0
24-25	8.0	0.0	0.0	38.8
Sheared				
24-28	67.0	0.0	8.0	70.4
35-42	45.0	0.0	26.0	84.8
LSD .05	6.4	0.0	11.0	1.97

Continued

Table 1. (Continued)

Tree age (yrs)	Dec. 1, 1970 C.S.[a]	Aug. 1, 1971 N.S.[a]	Dec. 1, 1971 N.S.	Dec. 1, 1971 C.S.
	Dead cuttings in the rooting bench			
Non-sheared				
4	0.0	24.3	3.8	0.0
8-9	7.5	12.0	11.8	5.5
14-15	16.8	12.0	21.8	1.0
24-25	27.0	17.8	1.8	0.5
Sheared				
24-28	19.3	48.5	11.6	2.8
35-42	30.7	33.5	1.2	13.2
LSD .05	7.5	8.1	9.3	2.0
	Alive callused unrooted cuttings			
Non-sheared				
4	21.5	16.8	34.3	6.3
8-9	15.7	40.0	46.5	46.5
14-15	39.9	59.0	66.3	75.0
24-25	50.1	54.5	96.0	98.5
Sheared				
24-28	33.0	26.0	67.2	71.0
35-42	53.0	57.5	74.4	78.0
LSD .05	10.8	11.9	15.1	6.0
	Percent mortality of rooted cuttings			
Non-sheared				
4	7.0			
8-9	11.6			
14-15	16.8			
24-25	44.0			
Sheared				
24-28	14.0			
35-42	31.7			
LSD .05	17.3			

[a]N.S. — non-stored cuttings
[a]C.S. — cold-stored cuttings

A comparison of the rooting potential of cuttings from sheared and non-sheared portions of the same tree confirmed the possibility of rejuvenating old clones by shearing, and revealed the localized nature of the response (Table 2). In each of the eight trees, there was significantly better rooting in cuttings from the sheared portions of the tree. Even more significant perhaps was the greater number of trees that proved rootable when cuttings were taken from the sheared portions of the tree.

Table 2. Percent rooting of cuttings from the sheared and non-sheared portions of the same old trees. Values are the average percentage rooting of 20 cuttings from each portion of eight trees (320 cuttings).

Sample (Date and cold) storage	Sheared portion	Non-sheared portion	LSD .05
	(%)	(%)	
Aug. 1, 1971	9.3	1.2	7.0
Dec. 1, 1971	10.0	3.8	6.1
Dec. 1, 1971 [a](C.S.)	20.0	9.4	11.2

[a]C.S. — Cuttings stored for 60 days at 0 ±1° C.

b) *Rejuvenation Effects of Successive Propagation.*— Cuttings from cutting ramets rooted significantly better than cuttings from grafts or cuttings from the parent ortet of the same clone (Table 3). With the five clones included in this study and sampled December 1, 1 percent of the cuttings from the parent, 9 percent from the grafted ramet, and 45 percent from the cutting ramet rooted. Cuttings from only one of the parent trees rooted, while those from three of the grafted trees and those from all five of the cutting trees rooted. Since these trees were all growing in the same area under similar environmental conditions and represent comparisons within clones, it was evident that the cutting ramets were rejuvenated.

While it can be concluded that rooting and root quality decreased with age of the ortet, there is considerable evidence that old clones can be rejuvenated by heavy shearing, and successive propagation. Cuttings from established cutting ramets show the greatest potential for rejuvenation, even for clones up to 84 years from seed. Genetically identical trees (clone) with identical chronological age appear to be quite different physiologically, as evidenced by the increased rooting potential of cuttings from grafted and most particularly of cutting ramets. Cutting ramet plants show more juvenile morphological characteristics, such as differences in needle and bud form and lack of lower production, than the ortet or grafted ramet trees.

Table 3. A comparison of the rooting potential of cuttings of the same clone but from different sources. Values are percentage rooting.

Harvest date	Ortet	Source of cuttings: Grafted ramet	Source of cuttings: Cutting ramet	LSD .05
	(%)	(%)	(%)	
A. Ortet versus grafted ramet versus cutting ramet (average of five clones).				
Dec. 1 Non-stored	1.0	9.0	45.0	10.3
Dec. 1 Cold-stored	7.0	6.0	48.0	12.0
Feb. 1 Non-stored	0.0	2.0	26.0	4.1
B. Ortet versus cutting ramet (average of 11 clones).				
Dec. 1 Non-stored	12.7		39.5	8.3
Dec. 1 Cold-stored	9.0		36.0	17.7

Genotype. Throughout these studies, genotype was observed to be a most important factor affecting cutting rootability. Trees growing side-by-side under apparently identical environmental conditions, and of the same chronological age, showed extreme variability in rooting potential (Table 4). These differences were not as great in younger trees as older ones. This confirms the findings reported earlier (16) that seedling differences in rooting potential become more exaggerated with age, and suggests that the aging process proceeds more rapidly in some genotypes.

Crown Level and Branch Order. No significant differences were noted in rooting potential of cuttings from different crown sections (Table 5). These results are different from those generally reported for this and other species (3, 5, 7). Randomly selected cuttings from terminal and lateral positions gave no significant

Table 4. Percent rooting of cuttings at different harvest dates over a two-year period for individual trees of different ages.

Clone	Age (yrs)	Date and treatment: Dec. 1 '70 CS [a]	Feb. 1 '71 NS [b]	Aug. 1 '70 CS	Dec. 1 '71 NS	Dec. 1 '71 CS	Feb. 1 '70 NS	Mean
		Number of cuttings / clone						
		80	20	80	80	80	20	
young	4	55	53	6	57	68	95	55.6
30	8-9	35	87	50	31	68	80	58.4
31		56	40	15	5	44	90	58.4
32		55	73	10	36	36	40	41.6
33		73	60	0	51	14	40	39.6
34		95	67	40	53	74	90	69.7
55	14-15	24	20	0	2	24	20	15.1
56		3	7	0	0	8	10	4.5
57		9	0	0	0	8	50	6.0
58		42	27	0	33	20	30	25.4
59		30	53	12	11	40	50	32.8
61	24-25	3	0	5	1	1	10	3.3
62		0	0	0	0	0	0	0.0
63		16	0	5	1	1	0	3.9
64		0	0	0	0	0	40	6.7
65		6	0	0	1	3	20	1.5

Continued

Table 4. (Continued)

Sheared								
45	24-28	49	23	0	20	18	40	25.0
46		25	3	5	8	22	30	15.5
47		57	43	0	24	58	0	30.3
48		41	43	5	4	30	0	20.5
49		44	20	0	0	2	0	11.0
40	35-42	5	0	1	8	0	0	2.4
41		6	0	0	22	2	0	5.0
42		10	3	0	6	2	0	3.5
43		33	37	3	8	4	0	14.1
44		16	50	1	26	22	30	24.2
Mean		30.2	27.2	6.1	15.8	21.8	29.4	

LSD .05 date and cold storage = 4.44
LSD .05 clone = 7.9

CS = cold storage for 60 days at 0 $\pm$ 1° C.
[b]NS = non-stored

Table 5. Rooting, mortality and growth of Douglas-fir stem cuttings from terminal and lateral branch positions. Four samples of 10 cuttings x 4 levels x 4 age classes x 5 clones per age.

	Dec. 1, 1970 cold-stored		Aug. 1, 1971 non-stored		Dec. 1, 1971 non-stored		Dec. 1, 1971 cold-stored	
	terminal	lateral	terminal	lateral	terminal	lateral	terminal	lateral
Total rooting (%)	30.2	40.6 [a]	8.4	6.6	24.5	26.7	39.9	26.8
Percent of rooted cuttings good quality	29.2	40.6 [a]	23.0	0.0 [a]	37.5	43.0	50.0	29.5
Percent of cuttings callused unrooted	26.0	44.5 [a]	42.7	43.1	55.8	65.6 [a]	55.5	70.1
Percent of cuttings dead in rooting bench	18.2	8.8 [a]	16.4	18.2	19.8	3.7 [a]	3.0	0.5
Percent cutting mortality six months after rooting	30.0	14.0 [a]						
Shoot growth the summer following rooting (cm)	9.3	7.2 [a]						

[a] Differences due to branch order position significant at .05 level.

Table 6. Rooting, mortality and growth of Douglas-fir stem cuttings from different crown positions. Four replications of ten cuttings x 2 branch order positions x 4 age classes x 5 clones per age are included for comparison. Differences due to crown positions are not significant at .05 level. Values are in percent rooting.

	Dec. 1, 1970 cold-stored				Aug. 1, 1971 non-stored				Dec. 1, 1971 non-stored				Dec. 1, 1971 cold-stored			
Crown level[a]	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Total rooting	27	24	30	33	12	10	9	9	21	27	26	29	32	30	31	41
Callused unrooted	26	30	40	32	40	38	32	29	58	58	66	62	57	69	68	57
Dead in bench	21	14	6	10	13	16	14	23	14	10	5	5	5	1	0	1
Bud break	49	41	43	41	0	0	0	0	12	18	26	20	67	75	71	71
Good rooting													47	33	55	40

[a]Level 1 — top ¼ of crown
Level 2 — second ¼ of crown
Level 3 — third ¼ of crown
Level 4 — bottom ¼ of crown

differences in rooting with any of the age classes studied (Table 6).

The more refined study of five branch order positions revealed that random selection of terminal and lateral cuttings is inadequate for determining the influence of branch order on rooting. A comparison of five positions (Fig. 1) showed that cuttings from position two and three (first order lateral—large and second order terminal), rooted best on the three winter sampling dates (Fig. 2). Cuttings from positions four (first order lateral—small) and five (second order lateral) were least vigorous and gave the poorest rooting. Root quality was also best in cuttings from positions two and three.

By combining the terminal and lateral cuttings of this study into separate categories, the differences due to position are erased. These results show the necessity for identifying branch order position in comparing terminal and lateral cuttings.

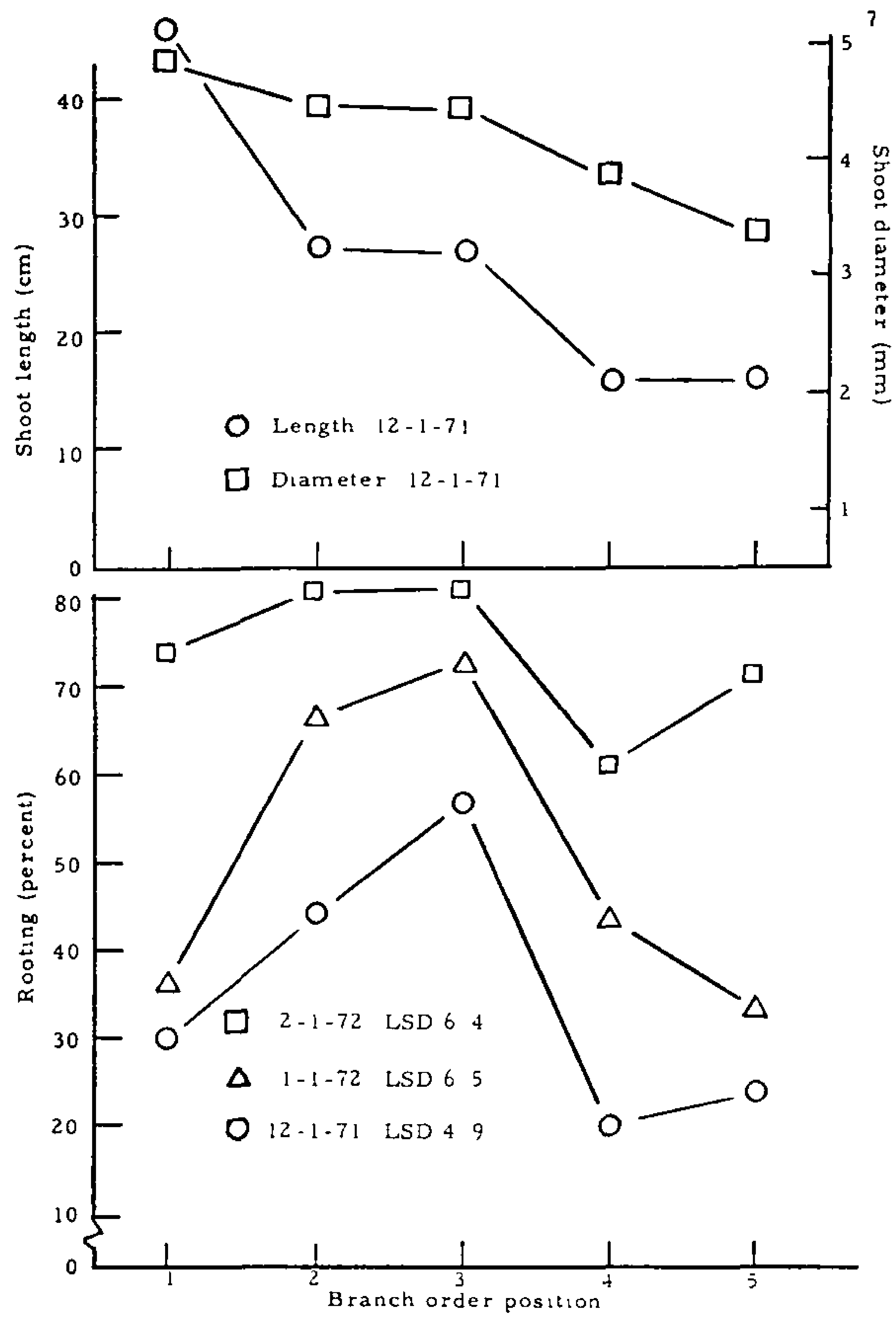

Fig. 2. **Shoot size (above) and percent rooting (below) of cuttings from different branch positions in nine-year-old Douglas-fir trees (Fig. 1). Dates given are harvest dates.**

LITERATURE CITED

1. Black, D.K. 1972. Influence of shoot origin and certain pre-and post-severence treatments on the rooting and growth characteristics of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stem cuttings. Ph. D. thesis. Corvallis, Oregon State University. 143 pp.
2. Cameron, R.J. 1968. The propagation of *Pinus radiata* by cuttings: influences affecting the rooting of cuttings. *New Zeal. J. Forest.* 13(1):78-89.
3. Deuber, C.C. 1940. Vegetative propagation of conifers. *Trans. Conn. Acad. Arts Sci.* 34:1-83.
4. Farrar, J.L. 1942.Vegetative propagation of conifers. XI. Effects of type of cutting on the rooting. *Can. J. Res. Ser.* C 20:116-121.
5. Fielding, J.M. 1969 Facors affecting the rooting and growth of *Pinus radiata* cuttings in the open nursery. *Forest. Timb. Bur. Bull.* 45. Canberra, Aust. 38 p.
6. Forest Service. 1965. Timber trends in the United States. *U.S. Forest Service Res.* 17 235 p.
7. Grace, N.H. 1939. Vegetative propagation of conifers. I. Rooting of cuttings taken from the upper and lower regions of a Norway spruce tree. *Can. J. Res Ser.* C 17:178-180.
8. Hartmann, H.T. and D.E. Kester. 1968. Plant Propagation: Principles and Practices, 2nd ed., Prentice-Hall, Inc. Englewood Cliffs, New Jersey. 702 p.
9. Libby, W.J. and M.T. Conkle. 1966. Effects of auxin treatment, tree age, tree vigor and cold storage on rooting young Monterey pine. *Forest Sci.* 12(4):484-502.
10. Agasawara, R. 1960. Physiological studies on the formation of the adventitious roots in *Pinus densiflora*. I. Relationship between growth substance and tree age. *J. Jap. Forest Soc.* 42(10):356-358.
11. Ooyama, Namio and A. Toyoshima. 1965. Rooting of pine cuttings and its promotion *Bull. Gov. Forest. Exp. Sta.* Meguro, Tokyo. 179:99-125.
12. Reines, M. and J. H. Bamping. 1960. Seasonal rooting responses of slash and loblolly pine cuttings. *J. Forest.* 58(8):646-647.
13. Robbins, W.J. 1957. Physiological aspects of aging of plants. *Amer. J. Bot.* 44:289-294.
14. Roberts, A.N. 1969. Timing in cutting propagation as related to developmental physiology. *Proc. Int. Plant Prop. Soc.* 19:77-82.
15. Roberts, A. N. and L. H. Fuchigami. 1972. Seasonal changes in auxin effect on rooting Douglas-fir stem cuttings as related to bud activity. (In press).

16. Satoo, T., K. Negis and K. Nakamura. 1953. Relationship between the rooting and age of trees from which cuttings are taken. An experiment using clonal materials. *J. Jap. Forest Soc.* 35:69-70.

17. Thimann, K. V. and A. L. Delisle. 1939. The vegetative propagation of difficult plants. *J. Arnold Arboretum* 20:116-136.

18. Thimann, K. V. and F. W. Went. 1934. On the chemical nature of the root forming hormone. *K. Akad. Wetenschap,* (Amsterdam) *Proc. Ect. Sci.* 37:456-459.

19. Thulin, I. J. and T. Faulds. 1968. The use of cuttings in the breeding and aforestation of *Pinus radiata. New Zeal. J. Forest.* 13(1):66-77.

AL ROBERTS: The utilization of this, as all three of our speakers have brought out—the rooting of cuttings—is centered primarily around assisting the geneticist in establishing seed orchards. The four Douglas fir trees that Kim showed you in the picture looked like four peas out of a pod; this was a photo I took at Johann Kleinschmidt's place at Lower Saxony in Germany where they've got fifty years of work behind them on this. Now I think those trees were 10 or 15 years old. He has Douglas fir there that are 25 years old and they are tooling up to grow spruce in Germany which is a principal European timber source. They're tooling up rapidly; he says within a few years they will have most of the spruce planted, in his area anyway, from cuttings. Of course, the Japanese have done a lot with *Retinospora* and one or two other species. But it does show the trend and the necessity for lots of this kind of work.

KIM BLACK: The foresters are interested mainly for two reasons. (1)Seed orchard establishment with select clones, and (2) forest site performance evaluation using clonal lines.

The Christmas tree growers are interested for another reason. Seedling Douglas fir require considerable shearing. Some self-branching bushy trees could be propagated vegetatively as clonal lines as cuttings, eliminating the need for shearing.

BRUCE BRIGGS: What effect did light have upon the curvature?

KIM BLACK: Thank you. I meant to comment on it. I worked with light, put the cuttings in tubes and produced, by providing an opening on the side, an opening on the top and so on, and it produced no effect. Our work with plants grown in tubes with some open on the top and others on the sides revealed that unidirectional light produced no phototropic response in Douglas fir. Research on this species in France has shown that the phototropic response is lost by seedlings after three or four years. Apparently the cutting ramets I was working with were physiologically older than four years because they didn't respond to light.

BRUCE BRIGGS: Another question, have you obtained small juvenile trees that you also could shear heavily? Did this help to increase their rooting ability?

KIM BLACK: I didn't try that; the only thing I did on shearing was to sample these trees that had been heavily sheared and I can't tell you for sure how long they had been sheared. I wish I could say that you could go into the forest and cut the tree heavily for two or three years and get this rejuvenation effect; I don't know how long it will take to reproduce this juvenility —or rejuvenation in rooting potential.

AL ROBERTS: I would like to clarify Kim's comments about rejuvenation, and we're stretching this term a little bit — calling this rejuvenation. Because usually we think of rejuvenation as going back to the basal portion of the original seedling and picking up some mysterious factor there that you can't get this from adventitious buds but we have yet to find what we could identify as an adventitious bud on a Douglas fir.

KIM BLACK: We've argued about this juvenility term, rejuvenation, for two years and I hold to Robbins' concept in an article in *Plant Physiology*. He makes a statement there and I quote him, "Most authorities," this is the way he puts it, "agree that one of the most identifiable features of juvenile trees is their rootability." Now there's a lot of other things you could look at. You can look at shape of bud and shape of leaf, leaf morphology of all types — lots of other things physiologically. But if they'll root, in my book, they're juvenile. Because that's very characteristic of juvenile trees, so I'm using it that way.

AL ROBERTS: Of course, the other camp traditionally has used the mature form, or the flowering form, as the first indication of maturity.

VOICE: What was your optimal hormone treatment?

KIM BLACK: I used Jiffy-Grow which includes 5% IBA, and 5% NAA, and boron. I wasn't interested in studying the effects of hormone. I used a 10% quick dip of Jiffy-Grow through all my studies.

BILL WEBB: We all noticed, I think, the difference in root development around the axis of the callus ball. What's your assessment in regard to the age of the cutting and also clonal differences?

KIM BLACK: I noticed that on cuttings from old trees there is more of a tendency to form a big callus ball before rooting occurs. Often on young clones, roots will develop on the cutting without much callus evident. On some of these old clones you'll get a very large hard callus ball before the root emerges. So in partial answer to your question, it may be because of this large callus ball that rooting is difficult on these old clones. Why, I don't know.

BILL WEBB: The question really was how do you get the best quality of rooting? You know, in many cases, you get roots out one side the callus ball; this is obviously not desirable from the standpoint of future growth for that tree. It may grow well but, for instance, in an alpine situation it may be susceptible to wind throw and other problems. What do you see is the way of getting around this?

KIM BLACK: I really can't answer that. I wasn't evaluating the location of the root on the cutting as I took the data so I really don't have any information on it that I could back up with data. I do know that wounding did not help. I tried wounding the cutting up and down the sides and compared with controls I got just as good a rooting without wounding. I think with wounding, you have more of a tendency to get roots up along the wound rather than at the base. But I really can't answer your question.

ANDY LEISER: You mentioned the callus on the older cutting. Did you examine the callus; was it real soft callus material or was it an entirely different material under the outer layer of callus?

KIM BLACK: It appeared to be quite consistently callus throughout.

ANDY LEISER: The reason I asked, we were doing some work with pine which also callused. It looked like callus but when we peeled it off, it was a lignified material that actually made the callus ball.

AL ROBERTS: One thing we've observed over the period of years we've been on the Douglas fir is the fact that the callus increases in volume progressively as we go through the season; by midwinter we get tremendous callus development from the same clone.

Very recently, in fact a week ago, our next speaker, Dr. Mel Westwood, participated in a symposium at the University of Minnesota at the national meetings of the American Society of Horticultural Science where they considered various aspects of growth regulator chemistry. His topic there was the influence of these materials on rooting in plants and so today he has agreed to come up here and discuss this matter — the use of growth regulators and the rooting of cuttings of various woody plants. So we should have a very interesting discussion, Mel: