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BRANCHING CHARACTERISTICS OF RADIATA PINE IN EXPERIMENT RO 905: DATA COLLECTION

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EXECUTIVE SUMMARY

Data on the branching characteristics of 13 radiata pine were collected from seven different thinning treatments within experiment RO 905, using destructive sampling.

The data collected will be used in building a model of branch development.

Branching Characteristics in Radiata Pine in Experiment RO905
Data Collection

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INTRODUCTION

Experiment RO905 in Kaingaroa Forest (Latitude 38.3°, Longitude 176.7°) was planted in 1967, at a spacing of 1.8 x 1.8 m (3086 stems/ha) , using radiata pine from the seedlot R65/760. This seedlot has a GF rating of approximately 3 (G. Vincent pers comm.).

The objectives of experiment RO905 were: " to study the effect of thinning and spacing on increment, yield, stem form and stand quality" (Skinner, 1988). Plots, 20 m * 40 m, were established in 1970 and a variety of thinning treatments were applied (see Table 1 and Fig. 1 for treatments and locations).

Apart from plots 1-8 which were abandoned after wind damage in 1982, the trial has been measured regularly for height and diameter.The experiment is due to be clearfelled sometime after June 1996.

Due to the range of stocking and thinning treatments, we can examine the effect of:

time of thinning
severity of thinning
tree size at time of thinning
branch size and age at time of thinning

on branch diameter growth using destructive sampling techniques.

A method for analysing the data to determine the effect of thinning on branch growth is discussed by Grace (1996a).

Due to time constraints, it was only feasible to select about one dozen trees to be destructively sampled. The methods used to select the sample trees and to collect the branch data are outlined in this report.

Table 1. Thinning treatments in Experiment RO905

Treatment 1 - one thinning in 1979 at a predominant mean height of 20 -22 m.

Plot Numbers	Nominal Stocking after thinning (stems/ha)
1, 5	200
2, 6	300
3, 7	400
4, 8	500

Treatment 2 - one thinning in 1976 at a predominant mean height of 15 - 17 m

Plot Numbers	Nominal Stocking after thinning (stems/ha)
9, 13	200
10, 14	300
11, 15	400
12, 16	500

Treatment 3 - one thinning in 1974 at a predominant mean height of 10 -12 m

Plot Numbers	Nominal Stocking after thinning (stems/ha)
17, 21	200
18, 22	300
19, 23	400
20, 24	500

Treatment 4 - first thinning in 1976 at a predominant mean height of 15-17 m
second thinning in 1980 at a predominant mean height of 20 -22 m

Plot Numbers	Nominal Stocking after 1st thinning (stems/ha)	Nominal Stocking after 2nd thinning (stems/ha)
25, 28	300	200
26, 29	400	200
27, 30	500	200

Treatment 5 - first thinning in 1974 at a predominant mean height of 10 -12 m
second thinning in 1983 at a predominant mean height of 27 m

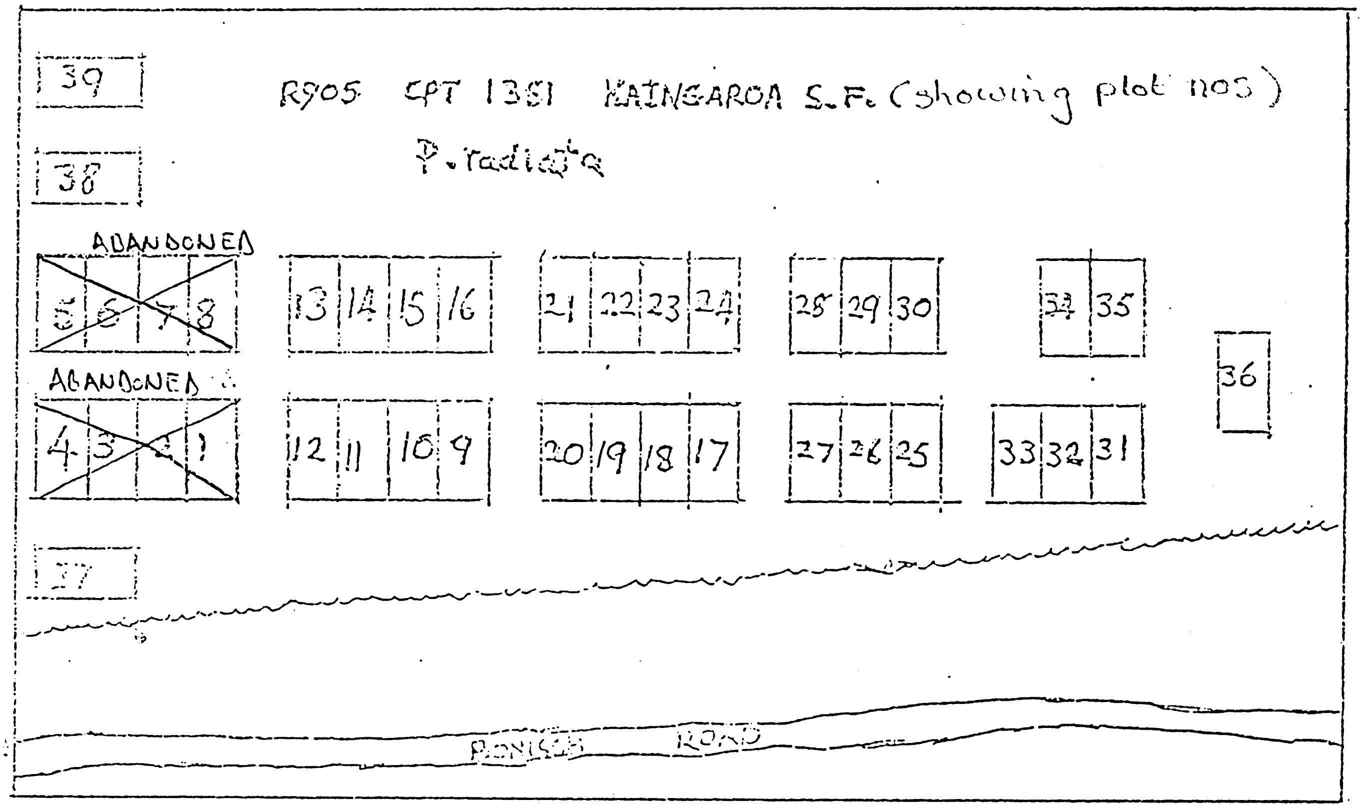
Plot Numbers	Nominal Stocking after 1st thinning (stems/ha)	Nominal Stocking after 2nd thinning (stems/ha)
31, 34	300	200
32, 35	400	200
33, 36	500	200

Treatment 6 - first thinning in 1972 at a PMH of 6.1 m to 1483 stems/ha
second thinning in 1976 at a PMH of 14.7 m to 487 stems/ha
third thinning in 1982 at a PMH of 25.6 m to 203 stems/ha
Plot Number - 37

Treatment 7 - first thinning in 1975 at a PMH of 12.6 m to 603 stems/ha
second thinning in 1982 at a PMH of 25.8 m to 257 stems/ha
Plot Number -38

Treatment 8 - first thinning in 1972 at a PMH of 6.1 m to 603 stems/ha
second thinning in 1982 at a PMH of 25.8 m to 257 stems/ha
Plot Number - 39

Figure 1. Map of Experiment RO905



SELECTION OF SAMPLE TREES

Sample trees were selected from the treatments with a range of stockings and where there was at least 6 years between multiple thinnings (so that the effect of each thinning could be distinguished). A preliminary analysis (Grace, 1996a) indicates that branches older than 6 years at the time of thinning are unlikely to respond to the thinning.

Within each treatment, the sample trees were selected to cover the variation in:

$$(10\ 000\ /SPH) * (DBH^3\ /\ \text{plot mean}\ DBH^3)$$

as this "growing space index" was found to be correlated with the average (over all clusters which had stopped growing) maximum branch diameter per cluster (Grace, 1996b). The DBH of the smaller trees was kept above 30 cm DBH as it was difficult to accurately count the stem growth rings on trees with a DBH of approximately 30 cm in Experiment RO696.

This index (see Appendix 1) was calculated for the smallest, mean, and largest DBH trees in one replication of treatments 2 and 3 in Experiment RO905.

The calculated values of the "growing space index" indicated that the range of branch diameter should be covered by the following sampling strategy.

Treatment 1:

- large tree at 200 stems/ha (tree with DBH at 90 or 95 percentile of DBH distribution)
- medium tree at 200 stems/ha (tree with DBH close to mean DBH)

(Most of the plots in Treatment 1 were below their nominal stocking due to severe windthrow in 1982).

Treatment 2 and 3:

- large tree at 200 stems/ha (tree with DBH at 90 or 95 percentile of DBH distribution)
- medium tree at 200 stems/ha (tree with DBH close to mean DBH)
- medium tree at 400 stems/ha (tree with DBH close to mean DBH)
- small tree at 400 stems/ha (tree with DBH at 15 or 20 percentile of distribution)

Treatment 5:

- large tree initially thinned to 300 stems/ha
  - (tree with DBH at 90 or 95 percentile of DBH distribution)
- medium tree initially thinned to 400 stems/ha
  - (tree with DBH close to mean DBH)
- small tree initially thinned to 400 stems/ha
  - (tree with DBH at 15 or 20 percentile of distribution)

In the office, possible sample trees for treatments 2, 3 and 5 were selected from the plot closest to the nominal stocking using the last field measurement of DBH. These trees were then examined in the field to see if they were suitable (e.g. no forks and ability to fell). If not the next closest tree in terms of DBH was selected. For treatment 1, all the trees in the plot were measured for DBH prior to the sample trees being selected.

A North line was approximately 1 m long spray-painted onto the stem of the selected sample trees which are shown in Table 2.

Table 2. Location and DBH of sample trees

Treatment Number	Plot No.	Quad No. (PSP)	Tree No. (PSP)	DBH	Nominal Stocking
1	5	6	2	66.4	200
1	5	5	2	53.5	200
2	13	1	1	63.8	200
2	13	2	1	54.8	200
2	15	8	2	46.6	400
2	15	6	2	33.8	400
3	17	3	2	61.1	200
3	17	8	2	54.4	200
3	19	4	5	43.3	400
3	19	1	3	33.8	400
5	34	1	3	65.8	300 /200
5	35	4	2	51.0	400/200
5	35	6	3	42.5	400/200

DATA COLLECTION

Nominal Stocking and location of neighbours.

In order to provide a more precise estimate of stocking and to investigate whether the position of neighbouring trees influenced branch size, the bearing to and diameter of all trees within a plot centred on the sample tree was measured.
The plot radius was 12.62 m for trees at a nominal stocking of 200 SPH and 8.92 m for trees at a nominal stocking of 400 SPH.
These plot radii were chosen to give 10 trees within the plot at the nominal stocking.

Felling

The felling direction, identified previously, was chosen to minimise beakage and ensure that the heads of the trees did not overlap.
The major vegetation along the felling path was cleared to ensure that as much of the underside of the tree, when it is on the ground, was visible for identifying branches and clusters.
The 13 sample trees were directionally felled. As most of the measuremnts were made when the tree was on the ground, any hazards, particularly suspended broken branches etc, created by the felling were pulled down or made safe. Two extra trees were felled for safety reasons.

When the trees were felled it was discovered that three of the trees were forked.

The entire length of tree was reassembled on the ground from the broken pieces. They were reassembled in such a way that the orientation with respect to North could be identified.
The trees were roughly trimmed so that all branches had clearly identified stubs of 10-20 cm. Ideally these should be pependicular to the branch direction rather than parallel to the stem so that branch diameter perpendicular to the branch direction can be measured.

The vegetation on both sides of the tree stem were also cleared to provide visibility of the stem and easy access for collecting the branch data.

Position of branch clusters

Once the trees had been felled, a reference line was continued all the way up the stem. Where possible this was a north line. If the reference line was not the north line, the bearing of the reference line with respect to north was measured. This reference line is used in collecting data on the angular distribution of the branches.
(Note: due to time constraints the angular distribution of branches was only collected for 9 of the 13 trees.)

The base and top of each cluster was then marked by a line drawn across the top surface of the stem and the cluster numbered.
The top of the cluster is above where the highest branch emerges from the stem.
The base of the cluster is where the branches join the pith. It was estimated by tracing the angle of the branches back to the centre of the stem.
Care was taken to distinguish every cluster that had been formed.

On dry bark, STEPHENS VIVID markers with permanent waterproof ink were used. Purple or blue seemed to be the best colours. These numbers stayed on after rain but were difficult to see on wet bark. However these markers would not work on wet bark.
On wet bark, white correction fluid (e.g. Twink) worked well and stayed on, although previously, in Experiment RO696, we had problems with it washing off in the rain.
Currently a "SOLID MARKER" (manufactured by Sakura Color Products Corp.) containing solidified white paint is being tested on some of the samples. It appears promising and is easier to use than a correction fluid.

Once all the clusters on a tree had been marked, the height to base and top of each branch cluster was measured.

The trees were then cut into discs using the markings for the top and base of the clusters as a guide. The discs were wide enough to include base of branches within the disc. In some cases it was not possible to separate two clusters due to them overlapping.

Measurement of clusters and selection of sample branches

Initially it had been planned to measure:

- the number of stem growth rings above and below each cluster (R)
- the azimuth angle of every branch and cone within a cluster (A)
- the horizontal diameter of every branch within a cluster (D)
- select a sample branch from each cluster for growth measurements (S)

However as the cluster positions were being marked and numbered it was observed that the trees in Experiment RO905 had considerably more clusters than the trees previously measured in Experiment RO696. There are two obvious reasons for this which will account for much of the difference. Firstly the trees in RO905 are 29 years old as opposed to 26 years for the trees felled in RO696. Secondly the trees in RO696 had been pruned to approximately 6 m whereas the trees in RO905 had only been pruned to approximately 2.4 m.
During the analysis phase the data will be examined to determine whether there are any significant differences in the number of clusters formed per year.

The measurement strategy was therefore revised to meet the time constraints. Various combinations of steps R, A, D, S (see above) were carried out on each cluster according to the age of the cluster and the treatment the tree had received. Stem growth rings were counted on every disc in order to determine the number of clusters with annual shoots. Sample branches were collected in a zone 2 - 6 years prior to thinning as this was where a response to thinning was anticipated to occur (see Appendix 1). Sample branches were also collected for clusters with 10 - 12 stem growth rings to investigate whether there was any difference in branch growth once silviculture had been completed. Branch diameters and azimuth were only measured on some annual shoots once the thinning had been completed. It was decided to measure alternate annual shoots, rather than alternate clusters so that the pattern of branch diameters within annual shoots could still be investigated. This strategy is outlined more fully in Table 3.

Table 3 Sampling strategy for measurements on branch clusters

Year	Rings in Stem	Treatment 5 Thinned in 1974 and 1983	Treatment 3 Thinned in 1974	Treatment 2 Thinned in 1976	Teatment 1 Thinned in 1979
67	30				
68	29				
69	28	RAD S	RAD S		
70	27	RAD S	RAD S		
71	26	RAD S	RAD S	RAD S	RD
72	25	RAD S	RAD S	RAD S	RD
73	24	RAD	RAD	RAD S	RD
74	23	RAD(thin)	RAD (thin)	RAD S	RD S
75	22	RAD	RAD	RAD	RD S
76	21	RAD	RAD	RAD (thin)	RD S
77	20	RAD	RAD	RAD	RD S
78	19	RAD S	R	RAD	RD
79	18	RAD S	RAD	RAD	RD (thin)
80	17	RAD S	R	R	RD
81	16	RAD S	RAD	RAD	RD
82	15	RAD	R	R	RD
83	14	RAD (thin)	RAD	RAD	RD
84	13	RAD	R	R	RD
85	12	RAD S	RAD S	RAD S	RD S
86	11	RAD S	RAD S	RAD S	RD S
87	10	RAD S	RAD S	RAD S	RD S
88	9	R	R	R	R
89	8	RD	RD	RD	RD
90	7	R	R	R	R
91	6	RD	RD	RD	RD
92	5	R	R	R	R
93	4	RD	RD	RD	RD
94	3	R	R	R	R
95	2	RD	RD	RD	RD
96	1	R	R	R	R

Note: only one of the three trees in treatment 5 had azimuths measured.

Stem Growth Rings

The number of stem growth rings were counted on both the top and bottom surface of the discs. They were also recorded on a separate sheet so we could observe the trends while measuring. This strategy was used in order to clearly identify where annual shoots end. (In the previous study the stem growth rings were only counted on the base of the cluster and recorded with the branch diameter data. When it came to analyse the data discrepancies were found between the number of rings counted in the field and the number of rings counted on sample branches.)

In many instances there often appeared to be a fine line, similar to but not as obvious as the other stem growth rings close to the pith. It was difficult to decide if this was a growth ring or not and comments were recorded if this was the case.

It was also more difficult to count the number of stem growth rings on the older discs and on the smaller trees as, in both cases some the rings were very narrow.

Azimuth angle of branches and cones

For each disc, a circular protractor was placed on the top surface of the disc with the centre of the protractor on top of the pith and 0° on the marked reference line. The azimuth angle of each branch and cone was then recorded.

Branch Diameter

Horizontal branch diameters, overbark, were measured for each branch using calipers.

Selection of sample branches

The selection strategy for choosing sample branches was to choose the largest diameter branch from one cluster and then the branch of mean diameter from the next cluster. There were instances where this could not be applied strictly, eg. branch broken or branch very likely to be curved within the stem. This strategy was chosen to avoid collecting too many branches with small diameters. Small branches will be selected as some cluster contain only small branches. The largest branch was not chosen in every instance as the largest branches can be the steep angled branches which are not necessarily representative of the tree.

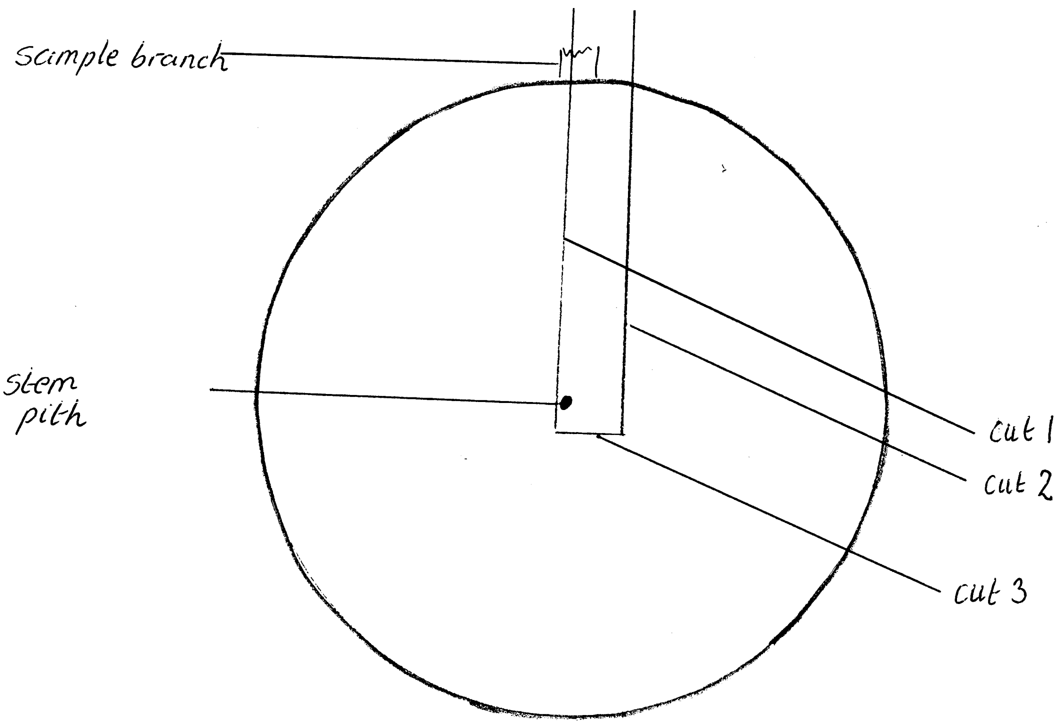
The diameter distribution of the sample branches will be analysed and compared with the diameter distribution within the trees.

Preparation of sample branches

The sample branches were cut from the disc, using a chain saw, as follows:

first cut close to middle of sample branch
second cut parrallel to the first cut, but approx 100 mm away
a third cut at right angles to the first two, that includes pith in wedge (see Fig. 2)

Figure 2. Diagram showing how sample branch was cut from the disc



The sample branches were taken to the location of a portable generator (at the edge of the experiment) where they were planed, using an electric planer, to expose the pith of the branch and stem.
It was easy to plane right through the pith of the branch particularly if the branch was curved within the stem.

In this experiment 270 branches were cut from the discs. Less than 5 samples were obviously useless after they had been cut from the disc. However once planing had been completed only 185 samples were suitable for providing data on branch growth, (i.e. 31% of samples were not suitable).

In comparison in RO696, only approximately 20% of the samples were not suitable for measurement. In this case the branch was encased within a block brought back from the forest. The block was cut to approximately the middle of the branch using a band saw and then planed to expose the pith.

There are several possible reasons for these differences. The chainsaw cut was further from the branch pith than the bandsaw cut. More planing was therefore required before pith was reached. This tended to be done quickly. However as the branch pith is thin and one pass of the planer could remove the pith. Also the curvature of the branch between the pith and the bark contributed to some of the losses.

From a practical viewpoint, planing the sample branches within the forest was superior to using the band saw at NZFRI. Planing the branches also took much less time than the field measurements.
It is suggested that for future studies we plane the samples in the forest but that the people planing have several dummy runs before working on the trial samples. Also, the planing should be done more slowly to see if this improves the acceptance rate.

Measurement of sample branches

Once the sample branches had been planed, they were brought back to NZFRI and stored for a week while the fieldwork was completed. The surface of the samples had dried slightly during this time which made it a little more difficult to see the growth rings.

The sample branches were marked and measured as follows:

A line was drawn parallel to the stem pith through the centre of the pith. The point where the branch pith joined the stem pith was marked and a line drawn perpendicular to the first line. The radius of the stem at the end of each growth ring was measured along this line. These radii were collected in order to see if branch diameter growth was related to stem diameter growth.

The vertical distance from the end of a stem growth ring to the branch pith was measured for each year that the stem was growing rapidly in diameter and then every two to three years. These data were collected to determine the angle of the branch within the stem.

The stem growth rings were followed through to the branch and the diameter of the branch was measured at right angles to the branch pith for each year that the branch was growing .

These are underbark diameters. The underbark diameter for the final stem growth ring was also measured. The difference between the last two diameters is usually less than 5 mm. It is planned to estimate the branch diameter for the other years by allocating the difference between the last two diameters to the other years either linearly or based on ring width.

For the branch that were still growing, the radius of the stem immediately above the branch was measured as the stem was wider here than where the stem diameters were measured. These measurements will help in generating a graphical model of crown development. When bark encasement occurred, the stem wood curved inwards and it was difficult to decide where to measure the maximum radius.

The ring number at which bark encasement occurs was recorded for both the top and bottom side of the branch. These were similar but not always the same.

The total length of the section containing the sample branch was measured as were the length to the base and the top of the branch.
It is planned to use these measurements to investigate how well we were estimating the base of the clusters.

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REFERENCES

Grace, J.C. 1996a. Branch growth in response to thinning: Test of method. Project Record No. 5177

Grace, J.C. 1996. Diameter of branches within a cluster in Experiment RO696. Stand Growth Modelling Report No. 50

Skinner, J. 1988 Interim assessment of RO905- thinning experiment. Project Record 1834 (unpublished)

Appendix 1. Growing Space Index for largest, mean and smallest trees in terms of DBH in selected plots in Experiment RO905

Treatment 3 - one thinning at predominant mean height of 10 -12 m

Plot No.	Stems/ha	Tree DBH (cm)	Growing Space Index
17	200	68.7	97.48
17	200	54.2	47.84
17	200	37.5	15.85
18	300	60.5	55.67
18	300	49.3	30.12
18	300	21.7	2.57
19	400	60.2	59.36
19	400	43.4	22.20
19	400	20.6	2.37
20	500	64.8	67.19
20	500	40.2	16.08
20	500	17.0	1.21

Treatment 2 - one thinning at predominant mean height of 15-17 m

Plot No.	Stems/ha	Tree DBH	Growing Space Index
9	200	66.1	84.58
9	200	55.0	48.59
9	200	44.5	25.81
10	300	62.5	67.18
10	300	47.7	29.92
10	300	30.0	7.43
11	400	57.9	51.48
11	400	44.0	22.59
11	400	28.6	6.20
12	500	59.4	49.25
12	500	42.2	17.66
12	500	22.1	2.53

APPENDIX 2

Summary of field procedure

1. Select the sample trees, mark a north line on the stem, and identify the felling direction. It is important that the trees are felled in such a manner that breakage is minimised and that the heads of the trees do not cross over.

2. Clear major vegetation along the felling path. A primary function is to have as much of the underside of the tree, when it is on the ground, visible for cluster and branch identification.

3. Directionally fell the trees. As many measurements are made when the trees are on the ground any hazards, particularly suspended broken branches etc, created by the felling, must be pulled down or made safe.

4. Reassemble the broken pieces on the ground on such a way that their orientation with respect to North can be identified. This may include lifting out bits vertically buried up to 1 metre into the ground.

5. Roughly trim the trees so that all branches have clearly identifiable stubs (10-20 cm). This cut should be perpendicular to the direction of the branch rather than parallel to the stem.

6. Continue the North line all the way up the stem. Mark the base and top of each branch cluster (cluster boundaries) and number. The top of the cluster is above where the highest branch in the cluster emerges from the stem. The base of the cluster is the lowest point where branches are estimated to meet the stem pith.

7. Measure the height to the base and top of each branch cluster in relation to the base of the tree.

8. Crosscut the tree at each cluster boundary, provided that the cluster do not overlap. Record the tree number and cluster number on the top surface of each cluster.

9. Record the number of stem growth rings on the base and top of each disc, measure the azimuth for branches and cones, measure branch diameters, and mark a sample branch.

10. Cut a block from the disc containing the sample branch. Record the tree and cluster number on the block.

11. Plane the block to expose the full length of branch pith and stem pith. If necessary, re-identify with the tree and cluster number.

12. Measure branch diameter, perpendicular to the branch pith for each year that the branch is growing; measure final branch diameter, perpendicular to branch pith. Measure stem radius for each year that the tree has grown, measure position of branch within sample.

NOTES.

Items 1-10 are undertaken in the bush. Items 11 and 12 can be done away from the bush. This is an inherently "at risk" operation for all field crew. Chainsaw work was undertaken in accordance with NZ FRI and Forestry Corporation safety rules.

Organisation of the measurements must be done in such a way that the cross-cutting and sample branch cutting (both requiring extensive chainsaw use) is relatively out of earshot of the measuring crew.

Some prior practice on cutting out and planing of the sample branches would minimise the risk of samples being overcut.

In RO905 all 13 sample trees (plus the two felled for safety reasons) were felled prior to step 6 (above). In RO696 (the previous study) the sample trees were felled as required, and the pruned log extracted, by an adjacent logging contractor.