KAINGAROA DATA COLLECTION and ANALYSIS: EXPERIMENT RO2098

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Forest Research/INDUSTRY RESARCH COOPERATIVES

EXECUTIVE SUMMARY

Three trees were destructively sampled from Experiment RO2098 (Kaingaroa) to provide data for developing the branch model BLOSSIM. New features included in the data collection procedure are discussed. The data collected were analysed to develop coefficients for some of the model functions.

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INTRODUCTION

The objective of this study was to collect data to:

- determine which branches on which trees will respond to a thinning through increased diameter growth
- determine the morphological pattern of branch development corresponding to increased diameter growth
- validate/ refine current branch diameter growth function

DATA COLLECTION AND OBSERVATIONS

The data collection procedures generally followed those used at other sites (SGMC Report No. 76). The major differences were the inclusion of new procedures: a visual assessment of the tree crowns, and non-destructive ageing of the stem.

Experiment RO2098 was established in 1986 in the "850" polycross trial (planted in 1975 at 625 stems/ha). Six treatments and a control were applied (Table 1).

Table 1. RO2098, treatments and plots examined.

Treatment	Number of plots	Plot examined
Unthinned	6	10/24
Thinned to 100 sph at 12m	3	7/11
Thinned to 200 sph at 12 m	3	5/12
Thinned to 400 sph at 12m	3	6/13
Thinned to 100 sph at 20 m	3	9/25
Thinned to 200 sph at 20m	3	19/36
Thinned to 400 sph at 20 m	3	15/27

The trial was due to be clearfelled in 2000. In order to obtain the maximum information about the response of branches to thinning before the trial was felled, a 3-phase sampling strategy was used.

Phase 1: Visual examination of all trees in 1 plot per treatment

There was some wind damage in the PSP plots in 1988. To minimise any effect of wind damage and subsequent loss of trees after the thinning, one plot from each treatment was selected – the one where the stocking remained closest to the pre- and post-thinning stocking (Table 1).

Each tree in these plots was visually examined to determine whether it appeared that the crown had responded to the thinning (this should be seen as a change in crown width and branch diameter at a given height). This should enable us to determine which trees can respond to the thinning.

Phase 2: PhotoMARVL of selected trees

Four trees in each plot were PhotoMARVLed to provide a permanent record of the trend in branch diameter with tree height and quantify the visual assessment.

The sample trees were selected on the basis of the diameter distribution in the plot at the time of the last measurement (June 1999). Sample trees were selected from the PSP data at the 100, 70. 40 and 10 percentiles of the diameter distribution. For the plots thinned at 20 m and for the plots thinned at 12m, one of the trees was leaning, and another forked. The next closest tree in the diameter distribution was selected. The sample trees selected were:

Trees thinned at 20 m

Plot	Sample Tree	DBH (June 1999)	DBH at time of thinning
9/25	18/2	50.2	37.2
	17/5	56.4	31.8
	16/1	62.3	33.8
	3/3	70.2	35.0
19/36	4/50	36.3	33.0
	4/49	46.5	31.8
	0/29	55.6	38.4
	1 /2	68.4	41.9
15/27	3/17	31.0	unknown – not in list
	2/10	40.1	32.1
	1 /4	49.2	38.2
	0/21	60.0	38.5

Trees thinned at 12 m

Plot	Sample Tree	DBH (June 1999)	DBH at time of thinning
7/11	20/1	52.4	27.1
	10/5	60.4	27.9
	11/3	62.6	30.3
	19/6	71.7	27.4
5/12	0/22	42.2	25.0
	0/53	48.9	27.9
	0/18	55.9	31.3
	0/3	67.7	33.3
6/13	0/5	37.1	24.5
	0/13	43.1	24.4
	4/27	50.5	30.0
	1/7	57.1	28.6

Unthinned control

Plot	Sample Tree	DBH (June 1999)
10/24	3/16	18.4
	4/19	32.8
	3/11	41.5
	3/15	58.3

In selecting these trees, it was noticed that trees were changing position in the diameter distribution with time. This will need to be accounted for in models.

Phase 3 – Sample tree selection and measurement

One objective of the measurements was to determine how branches respond to a thinning in terms of both branch diameter and the morphological patterns along the branch.

Morphological patterns of branch development are not a necessary requirement for the branch model. However knowledge of these patterns link with diameter development may help in designing rules for which branches can respond to thinning.

Some of the questions that this comparison may answer include:

- If a branch only produces one growth unit in a year, what is the diameter increment?
- If a branch produces one growth unit in a year, can the branch respond to the thinning?
- How does a branch respond to a thinning, by increasing the number of growth units formed per year, or by remaining in the current phase for a longer period?

Previous research in Experiment RO905 indicated that it was difficult to measure a response to thinning in trees thinned at 12 m. Branches that might have responded to the thinning had been removed during pruning. It was possible to measure a response on trees thinned later (at 20 m). Hence sample trees were selected from the plots thinned at 20 m. One sample tree was chosen from each thinning treatment (Table 2). The trees were a similar size (DBH) at the time of thinning to allow the influence of stocking on the response to thinning to be examined.

Table 2. Sample trees selected.

Sample Tree Number for analyses	1	2	4
Nominal Stocking after thinning	100 SPH	200 SPH	400 SPH
RO2098 Plot Number	9/25	19/36	15/27
Quadrow/ Tree	3/5	0/34	4/30
DBH (cm) at time of thinning	32.4	32.5	33.5
DBH (cm), June 1999	58.4	50.5	40.1

Sample Tree Assessment.

After felling, all the branches were left attached. The base and top of each branch clusters was marked and the patterns of branching were used to determine the year the cluster had been formed. Determining the age of the clusters from branching patterns was a new feature. Previously only ring counts have been used to age clusters.

Based on the assessed ages, live branches were selected from the zone where branches could have responded to the thinning. These branches were marked adjacent to the stem, removed and put to one side to be aged.

The remaining branches were removed and the height to base and top of each cluster recorded.

Next the trees were cut into clusters. The tops of the clusters were visually examined to see whether any compression wood was present (see Appendix 1). Rings were counted, azimuth angle of branches and cones were recorded together with branch diameter.

The largest complete branch in each cluster (or a previously marked branch) formed prior to thinning was selected as a sample branch and planed. Planed sample branches were examined, and interesting features noted (Appendix 2).

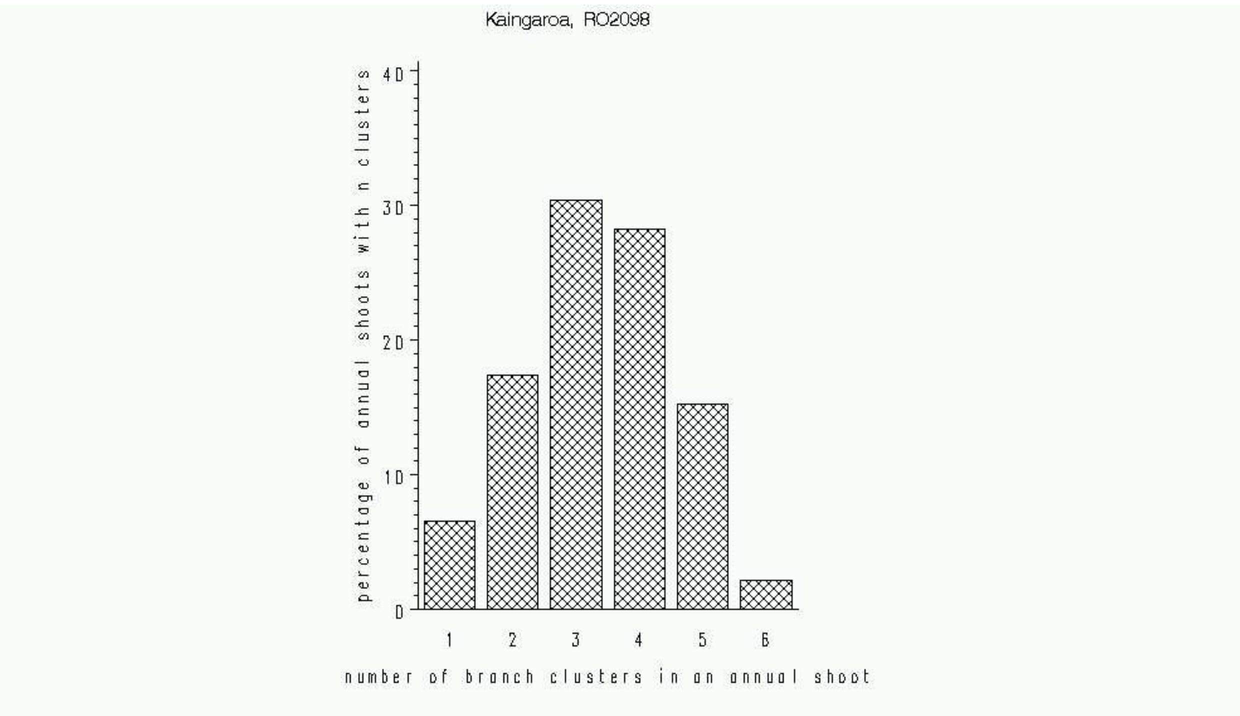
The branches put to one side were aged using architectural features and the number of growth units formed per year were recorded. The initial diameter, length and branchiness of each growth unit were recorded. These measurements were a new feature. The objective was to compare these measurements with diameter increment of the sample branches to better understand how branches respond to a thinning (see Appendix 3).

DATA ANALYSIS

Number of branch clusters in an annual shoot using rings counts

The number of branch clusters in an annual shoot varied between 1 and 6 with a mean of 3.3 (Fig. 1). The observed frequency distribution suggests that these three trees are slightly less multinodal than the eight "850" trees measured in compartment 905, and slightly more multinodal than the eight uninodal trees measured in Compartment 905 (SGMC Report No. 66).

Figure 1. Observed frequency distribution for number of clusters in an annual shoot.



The number of branch clusters formed per year was positively but not significantly correlated with tree age (Table 3 and Fig. 2). The number of branch clusters formed per year was positively and significantly correlated with annual shoot length (Table 3 and Fig. 3). This agrees with the results from other sites (SGMC Report No. 66).

Table 3. Correlation between number of branch clusters in an annual shoot and both annual shoot length and tree age when the cluster was formed

Tree	Number of annual shoots	Correlation with shoot length	Correlation with tree age
1	16	0.73 (p=0.001)	0.15 (ns)
2	15	0.62 (p=0.01)	0.24 (ns)
4	15	0.50 (p=0.06)	0.20 (ns)
All trees	46	0.62 (p=0.0001)	0.18 (ns)

Figure 2. Relationship between number of clusters in an annual shoot and tree age when the cluster was formed

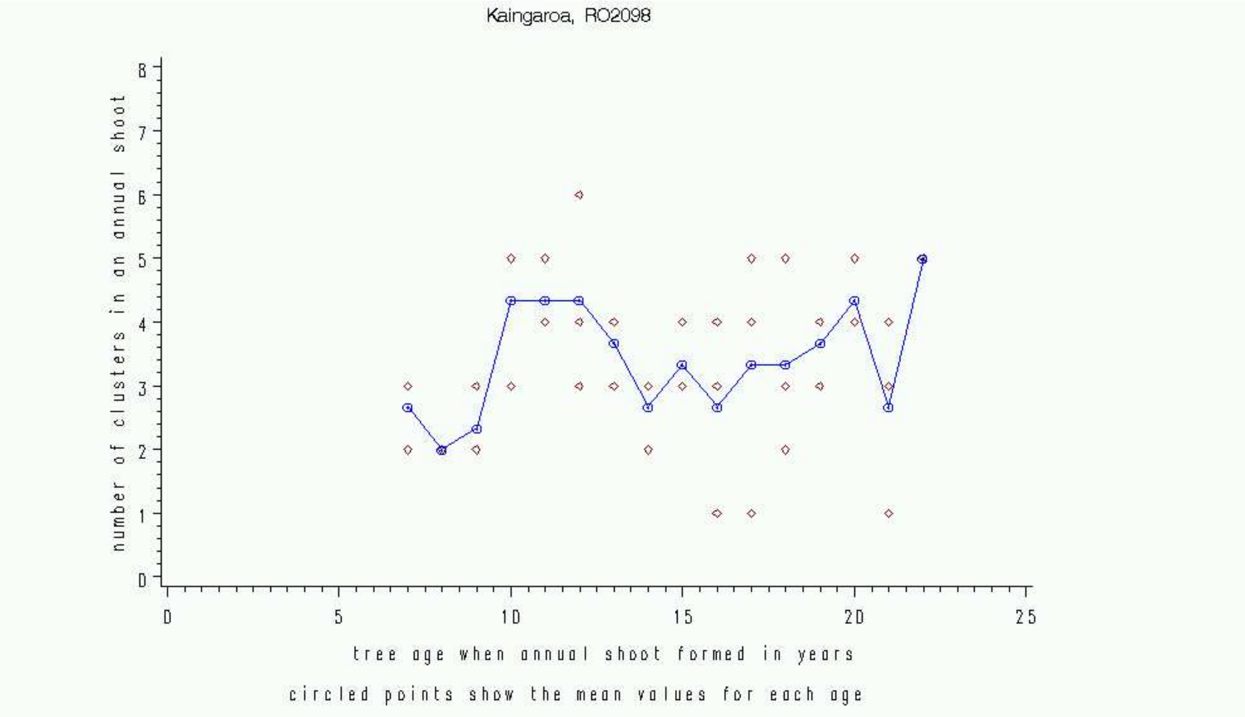
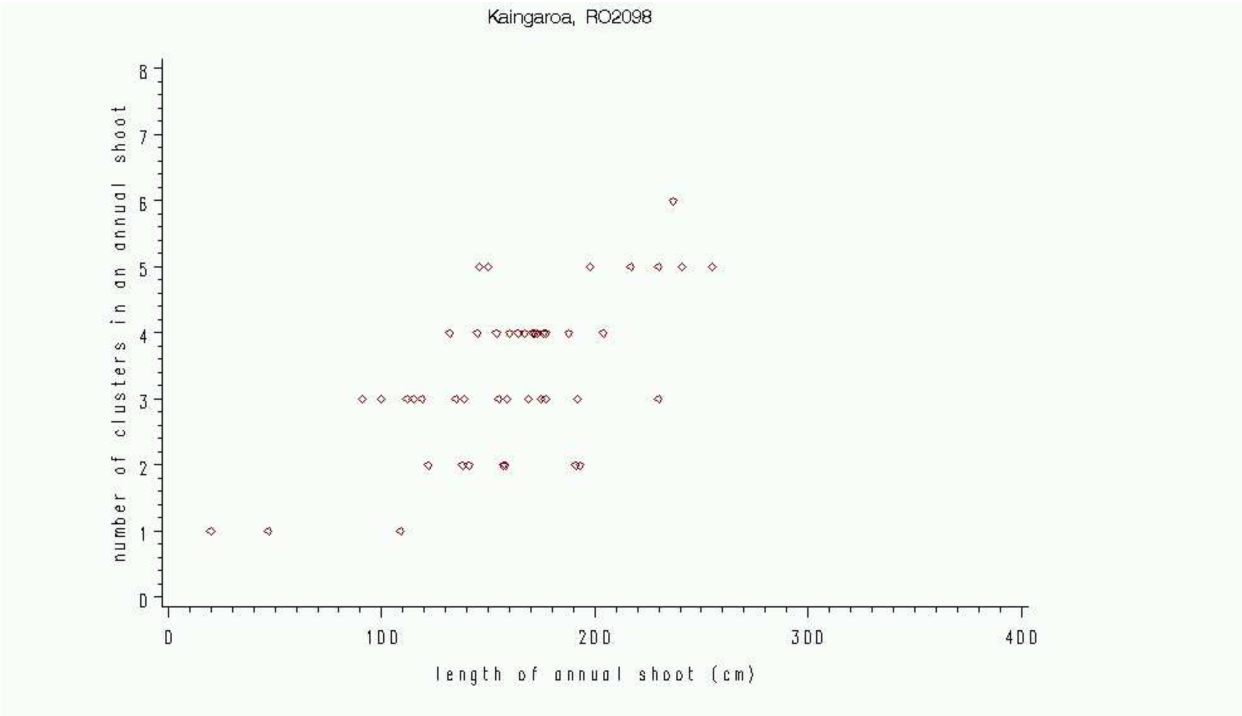


Figure 3. Relationship between number of clusters in an annual shoot and annual shoot length.



A possible equation for predicting the number of clusters in an annual shoot (SGMC Report No. 66) is:

$$NC = a \times A^b \times L^c \quad (1)$$

where:

NC is the number of clusters in an annual shoot
A is the tree age (years) when the cluster was formed
L is the annual shoot length (m)
a, b, c, are model coefficients

The predicted coefficients using these data are shown in Table 4.

Table 4. Predicted coefficients from fitting Eqn. 1 to data from RO2098.

Coefficient	Predicted value	asymptotic standard error
a	0.539	0.169
b	0.525	0.104
c	0.984	0.145

There were no obvious patterns when the residuals were plotted against predicted values, tree age or annual shoot length.

The number of branch clusters in the annual shoot was predicted to 1 or better 96% of the time and 2 or better 100% of the time.

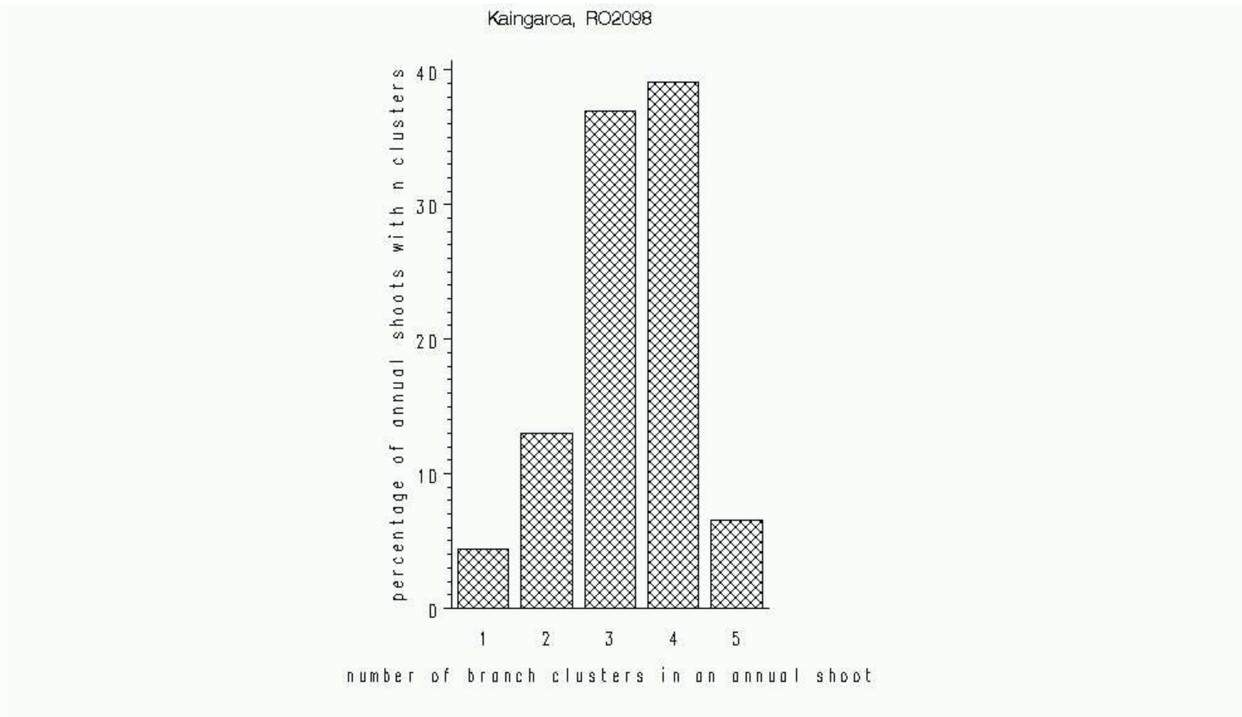
Number of branch clusters in an annual shoot using architecture

Two extra clusters were found after the tree had been cut into discs. These are included in the previous analyses; but have not been included in this analysis as the architectural features used to age the stem are lost once it has been cut into discs.

Apart from these two clusters; the stem age from architecture and from ring counts were generally in agreement.

The mean number of clusters in an annual shoot was 3.3, however the observed frequency distribution is tighter using architectural features compared to ring counts (compare Fig. 4 with Fig. 1).

Figure 4. Observed frequency distribution for number of clusters in an annual shoot using architectural features.



Using architectural features, the number of clusters in an annual shoot was not significantly correlated with either tree age or shoot length (compare Table 5 with Table 3).

Table 5. Correlation between number of branch clusters in an annual shoot and both annual shoot length and tree age when the cluster was formed

Tree	Number of annual shoots	Correlation with shoot length	Correlation with tree age
1	16	0.34 (ns)	- 0.02 (ns)
2	15	0.24 (ns)	0.60 (p=0.02)
4	15	0.18 (ns)	0.15 (ns)
All trees	46	0.29 (p=0.05)	0.20 (ns)

Relative position of clusters within an annual shoot using ring counts

All annual shoots with a given number of branch clusters were combined to determine the relative position of each cluster within an annual shoot (Table 6). These mean values are similar to those observed at other sites (SGMC Report No.66).

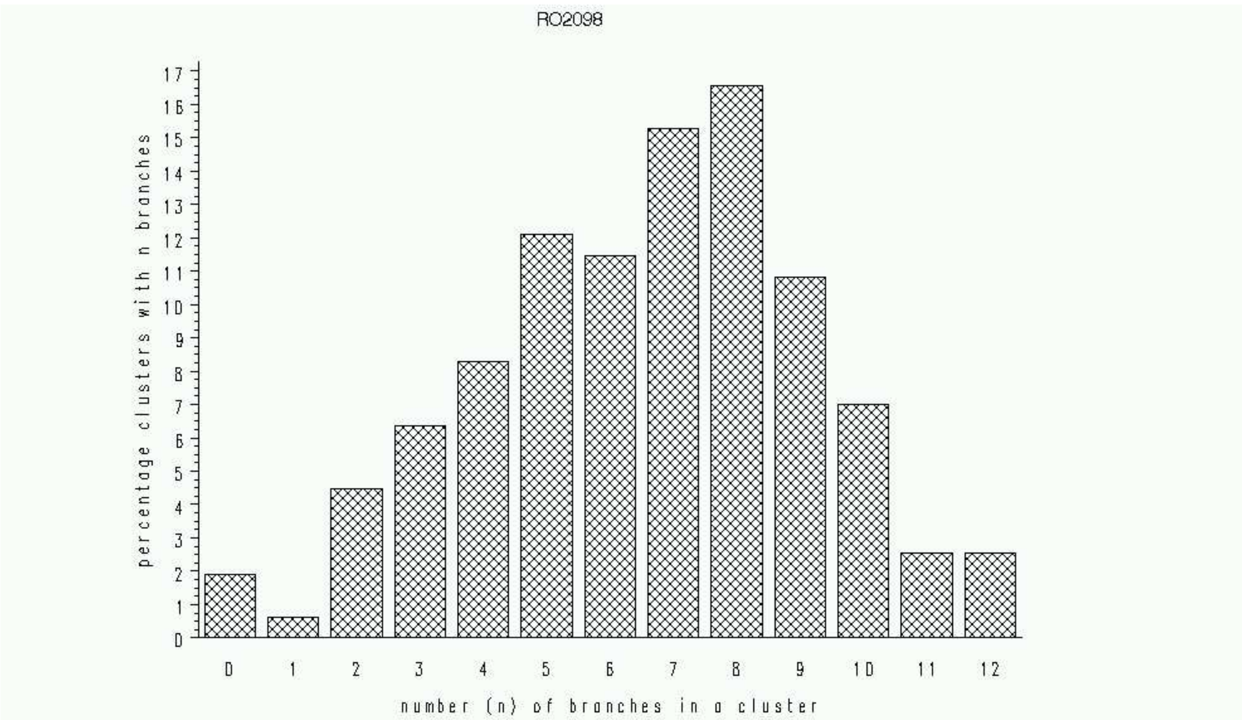
Table 6. Relative position of branch clusters within an annual shoot.

Number of clusters in annual shoot	1	2	3	4	5	6
Number of annual shoots observed	3	8	14	13	7	1
Position of cluster in annual shoot						
1	1.0	0.44	0.35	0.25	0.20	0.11
2		1.00	0.68	0.51	0.40	0.22
3			1.00	0.80	0.64	0.42
4				1.00	0.81	0.69
5					1.00	0.81
6						1.00

Number of branches in a cluster

The number of branches in a cluster varied between 0 and 12 (Fig. 5).

Figure 5. Observed distribution of number of branches in a cluster



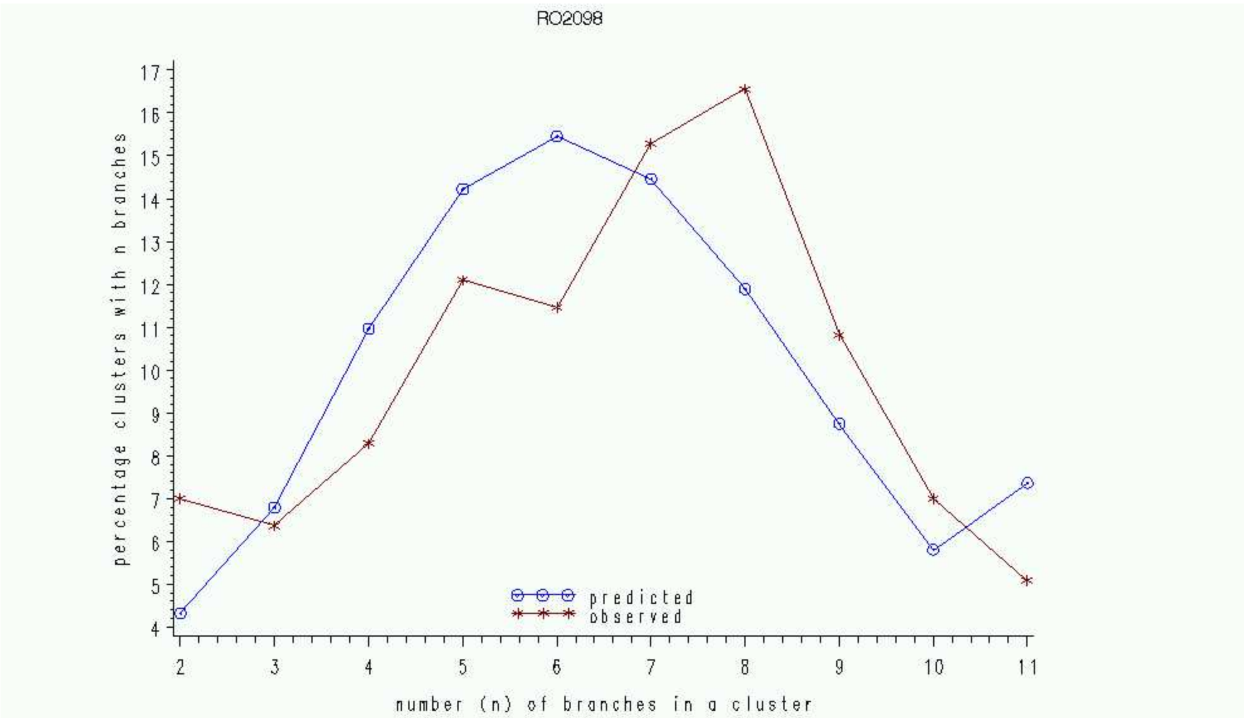
It is interesting to note the high percentage of clusters with 7 or 8 branches. At other sites the mode has been 5 or 6 (SGMC Report No. 68). A Polya-Aeppli distribution was fitted to the data. The predicted coefficients are shown in Table 7. Observed and predicted distributions (Fig. 6) were compared using a χ^2 goodness of fit test (Bailey, 1958).

Clusters with 2 or less branches were combined and clusters with 11 or more branches were combined to avoid small number of observations in any class. It was concluded that the Polya-Aeppli distribution realistically described the distribution for number of branches in a cluster.

Table 7. Fit of Polya-Aeppli distribution to number of branches in a cluster

Model coefficient, μ	6.46554
Model coefficient, ρ	0.98457
Number of groups	10
χ^2	7.0
Number of degrees of freedom	7
Predicted distribution acceptable at 5%	yes

Figure 6. Observed and predicted distribution for number of branches in a cluster



Probability tree has reached reproductive maturity (forming stem cones)

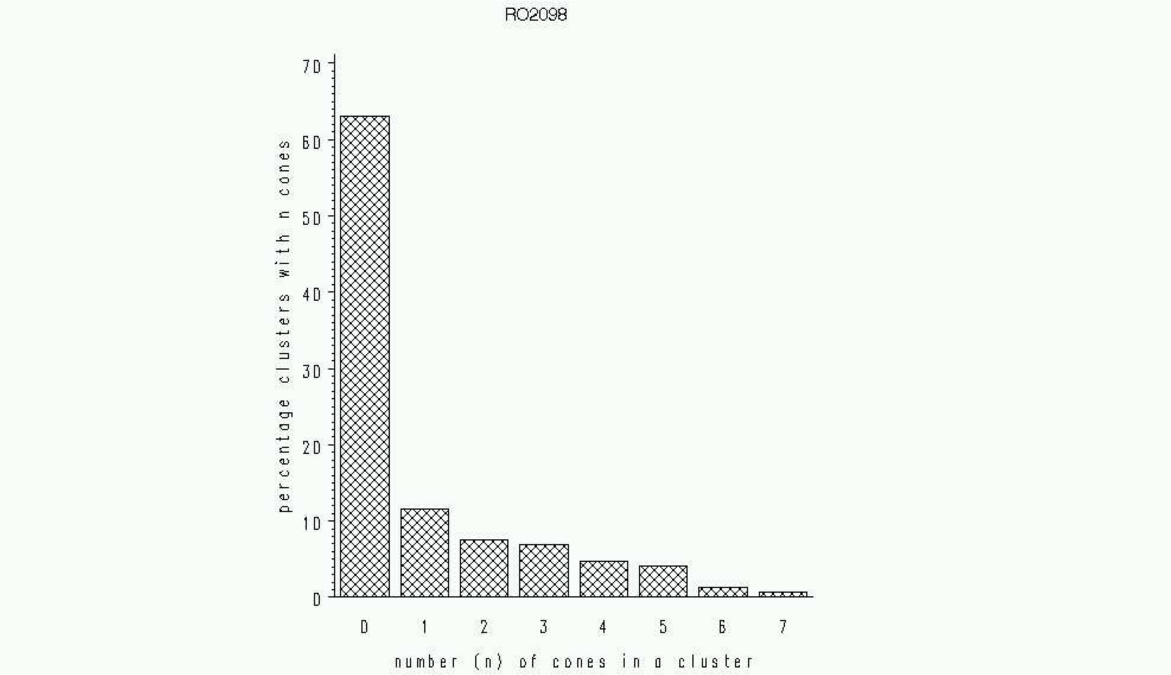
The sample size of 3 trees is too small to develop a model for percentage mature trees at a given age. The tree age when cones were 1st formed were 7 years (Trees 1 and 2) and 10 years (Tree4).

Number of cones in a cluster

Clusters formed in years prior to the tree reaching reproductive maturity (forming stem cones) have been excluded from the data set when developing a probability distribution for number of cones in a "mature" cluster.

The number of cones in a cluster, once the tree had reached reproductive maturity, varied between 0 and 7 (Fig. 7).

Figure 7. Observed distribution for number of cones in a cluster.

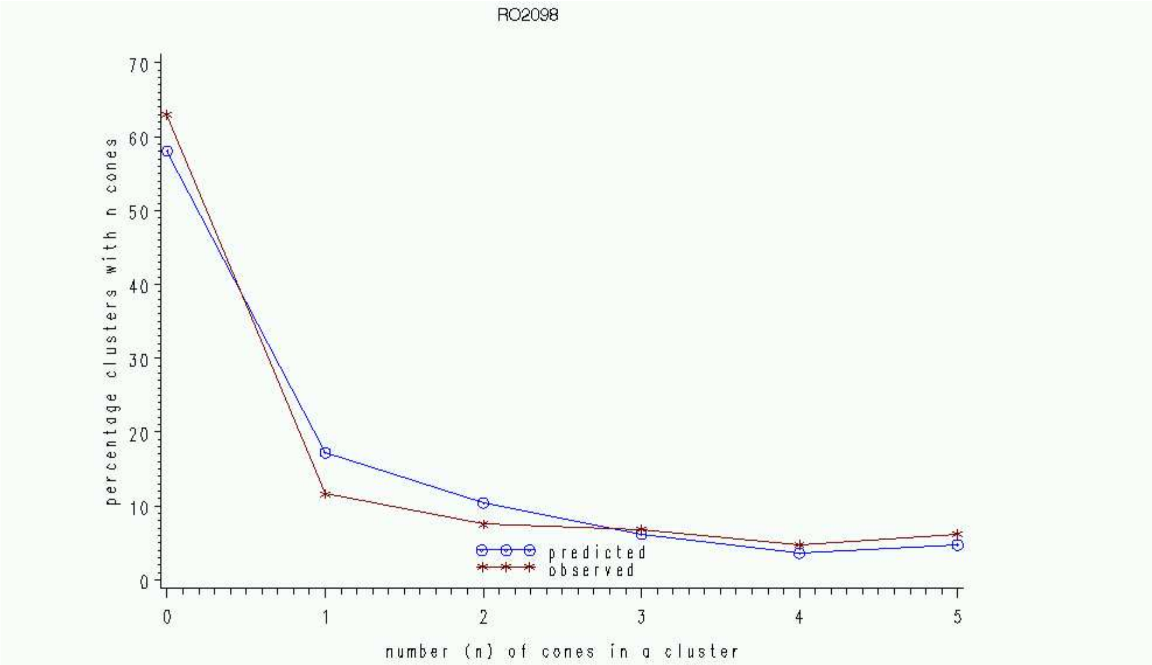


A Polya-Aeppli distribution was fitted to the data. The predicted coefficients are shown in Table 8. Observed and predicted distributions (Fig. 8) were compared using a χ^2 goodness of fit test (Bailey, 1958). Clusters with 2 or less branches were combined and clusters with 11 or more branches were combined to avoid small number of observations in any class. It was concluded that the Polya-Aeppli distribution realistically described the distribution for number of cones in a cluster.

Table 8. Fit of Polya-Aeppli distribution to number of cones in a cluster

Model coefficient, μ	0.54409
Model coefficient, ρ	0.54409
Number of groups	6
χ^2	3.95
Number of degrees of freedom	3
Predicted distribution acceptable at 5%	yes

Figure 8. Actual and predicted probability distributions for number of cones in a cluster



Azimuth angle of largest branch in a cluster

The Rayleigh test of uniformity was used to determine whether the azimuth angle of the largest branch in a cluster was uniformly distributed round the circumference of the stem, or whether there was a preferred direction (see SGMC Report No. 74 for methods used).

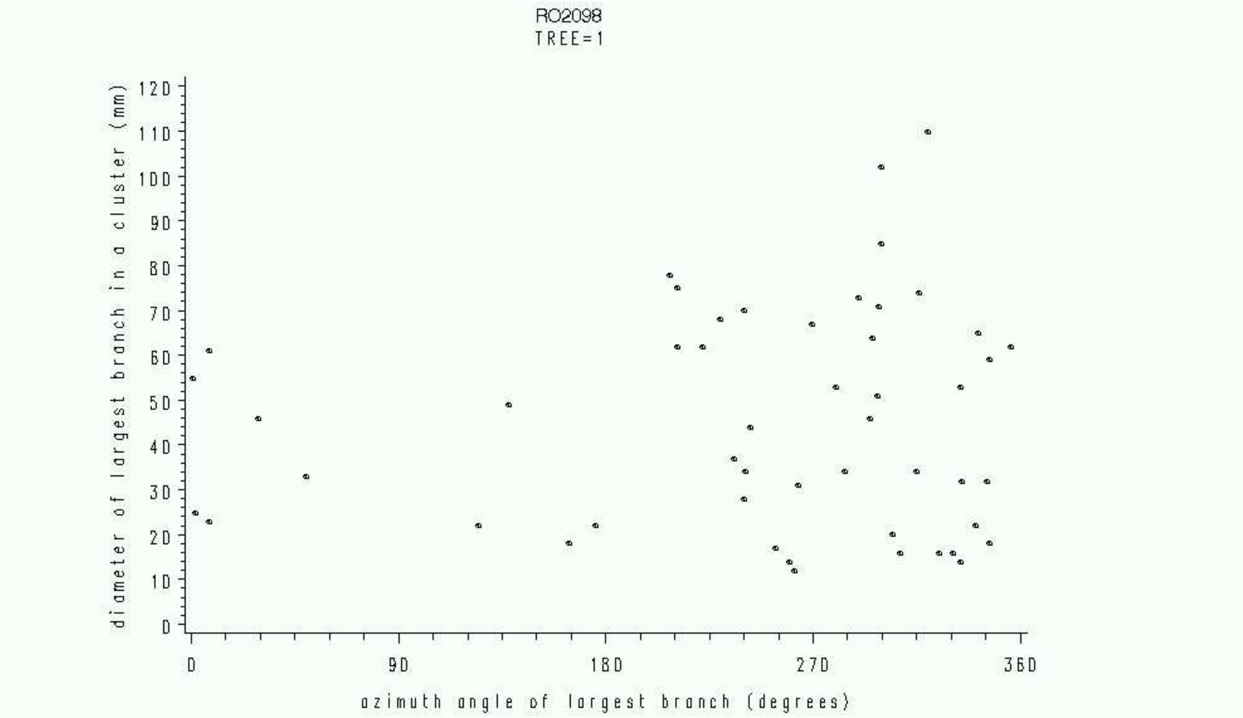
For all trees the azimuth angle of the largest branch was highly variable. For trees 1 and 4, southerly aspects were avoided (Fig. 9) which resulted in the mean azimuth angle being on the northern side of the tree (Table 9). For tree 2, northerly aspects were avoided (Fig. 9) which resulted in the mean azimuth angle being on the southern side of the tree (Table 9). The influence of the neighbouring trees on the mean angle is unknown as the position of all neighbouring trees was not mapped. The position of trees in the PSPs (mapped previously) did not provide sufficient information.

The correlation between branch diameter and azimuth angle, calculated using the method described in SGMC Report No. 74, was not significant for any of these trees.

Table 9. Circular statistics for sample trees.

Tree	Number of clusters	Mean vector length	Mean azimuth angle (degrees)	Significant ($p \leq 0.05$)
1	50	0.55	297	Yes
2	55	0.52	156	Yes
4	40	0.30	354	Yes

Figure 9. Relationship between diameter of largest branch in a cluster and its azimuth angle.



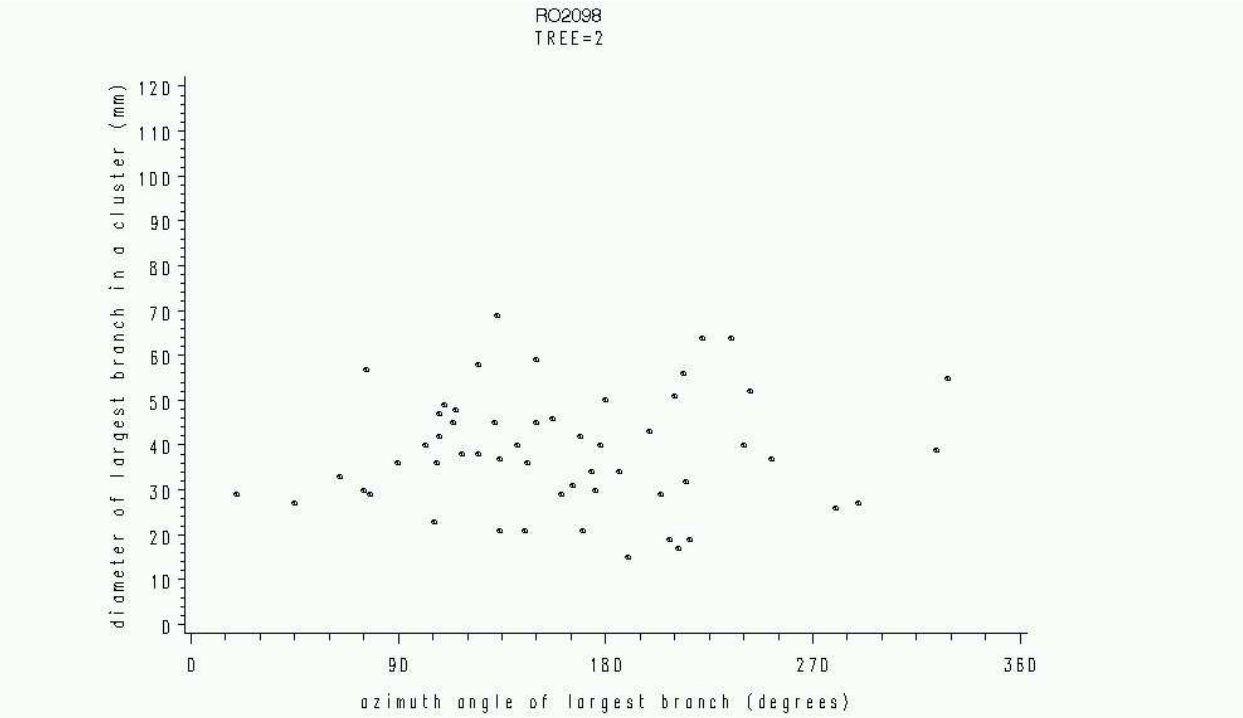
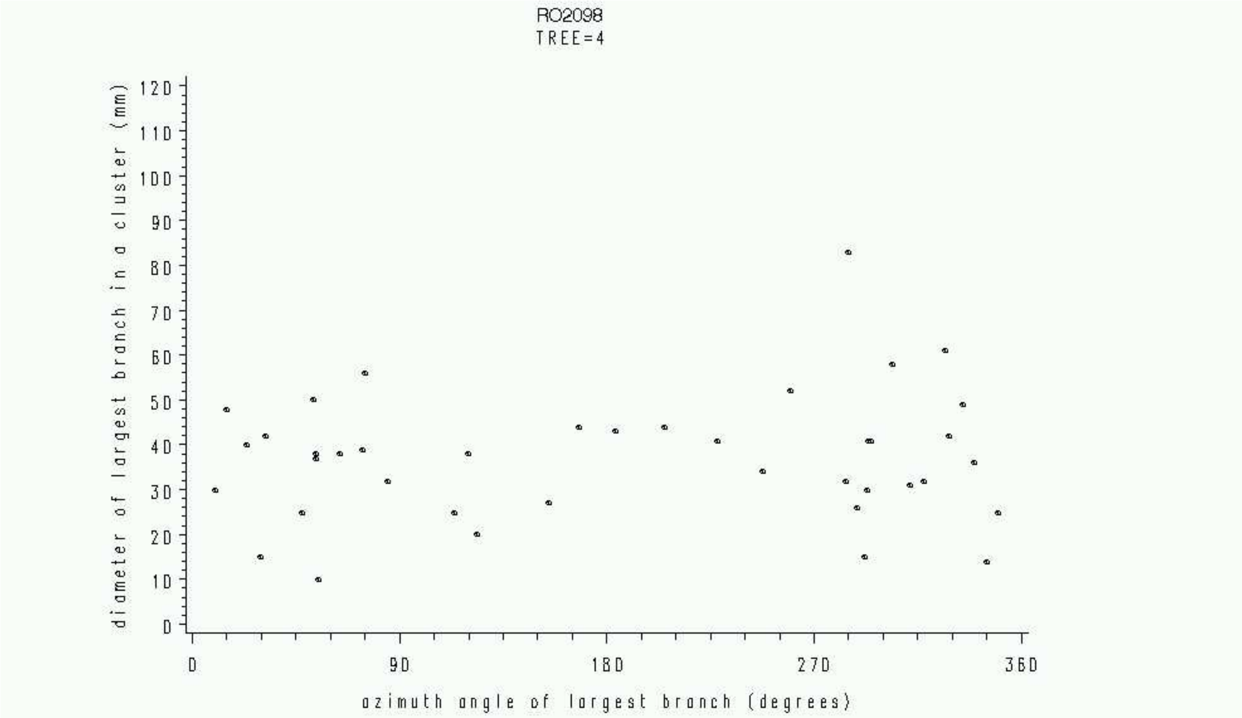


Figure 9. cont.



Bark inclusion above branches

Using data collected at Compartment 905, Kaingaroa and Taringatura, Southland (both "850" seed lots), a discriminant function was developed for predicting bark inclusion above branches from overbark diameter at the time of felling (SGMC Report No. 67), namely:

If overbark diameter < 41.6 mm, the predicted defect code is 0
If overbark diameter ≥ 41.6 mm and < 58.6, the predicted defect code is 1
If overbark diameter ≥ 58.6 mm then the predicted defect code is 2

This function correctly identified 76% of branches with defect code 0, 31% of branches with defect code 1, and 64% of branches with defect code 2.

This discriminant function was applied to the sample branches measured from the 3 trees from Experiment RO2098 in Compartment 327, Kaingaroa (Table 10).

Table 10. Observed and predicted defect codes using the discriminant function developed in SGMC Report No. 67.

	Defect Code observed =0	Defect Code observed=1	Defect Code observed=2
Overbark diameter < 41. 6 mm	31 **41**	10	0
41.6 mm ≤ Overbark diameter < 58.6 mm	11	9 **24**	4
Overbark diameter ≥ 58.6 mm	2	1	1 **4**

Note: predicted number of branches with each defect code are in bold.

In this case the discriminant function correctly identified:

70% of branches with defect code 0
45% of branches with defect code 1
25% of branches with defect code 2

The sample size is rather small, but the discriminant function (developed using data from Kaingaroa and Taringatura) appears reasonable for this site.

A probability model for predicting the severity of bark inclusion based on the maximum diameter attained by the branch was also developed using the data from Kaingaroa and Taringatura data (SGMC Report No. 67) and was used to predict the severity of defects in RO2098 (Table 11).

Table 11. Observed and predicted defect codes using maximum branch diameter.

Maximum branch diameter (mm)	Number of obs	Actual and predicted number of sample branches with each defect code					
		0 actual	0 pred	1 actual	1 pred	2 actual	2 pred
0-20 mm	10	10	10	0	0	0	0
20-40 mm	34	22	30	12	4	0	0
40-60 mm	22	11	13	7	7	4	2
60-80 mm	1	0	0	0	1	1	0

The results (Table 11) suggest that the probability function based on maximum diameter is reasonable for RO2098.

When the samples were examined it was noted that amount of bark trapped was very small for some branches with code 1. Four of the 5 branches with code 2 were in the last cluster of the annual shoot. The distance between stem and 1st cluster of laterals on the branches in these clusters was large.

In contrast to the Esk (SGMC Report No. 87) and Wairau (SGMC Report No. 88), branch angle was not useful for distinguishing branches with defect code 2 (Fig.10). Branch diameter was better (Fig 11) as was the case for Compartment 905, Kaingaroa and Taringatura (SGMC Report No. 67).

Figure 10. Influence of primary age and branch angle on branch defects.

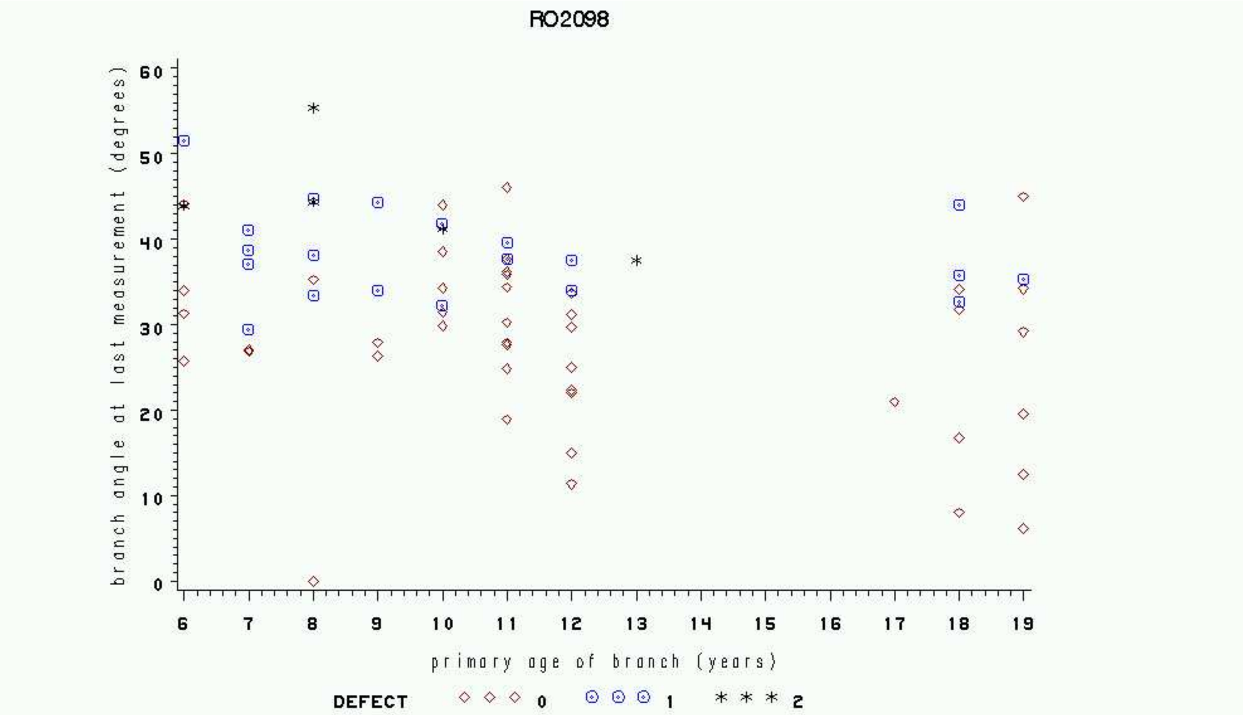
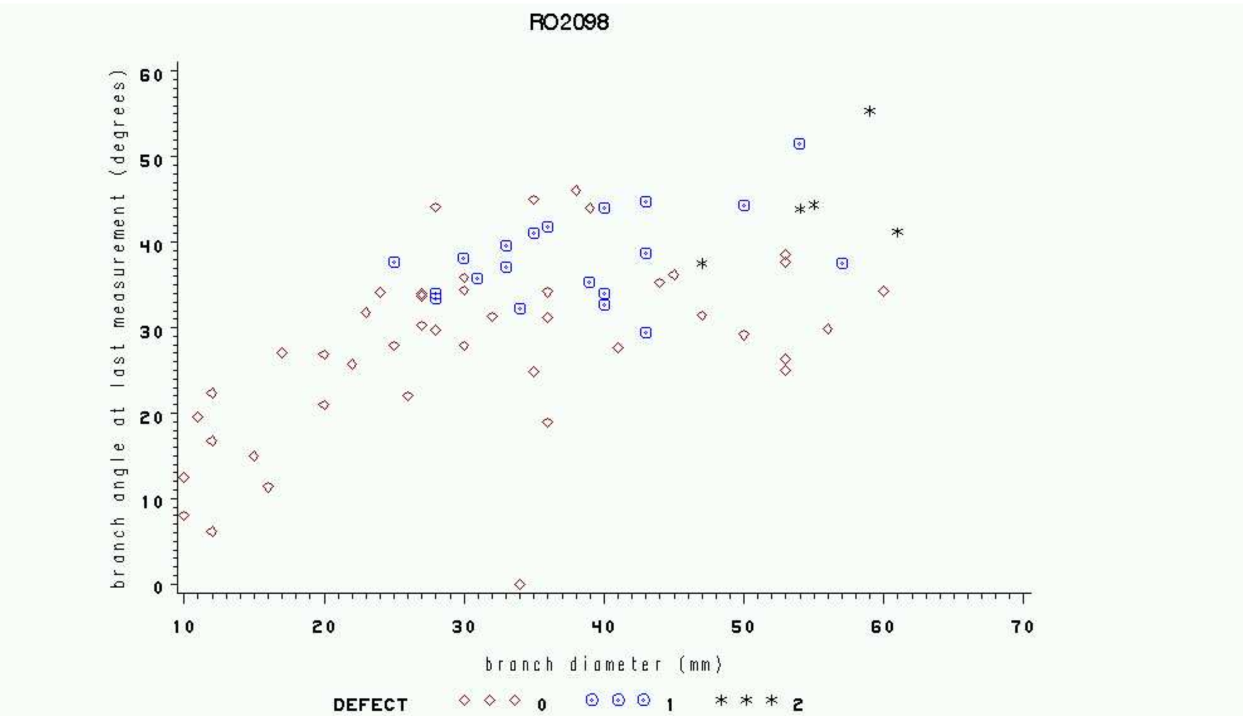


Figure 11. Influence of branch diameter and branch angle on defect code.



REFERENCES

Bailey, N.T.J. 1959: Statistical methods in biology. The English Universities Press Ltd. 198p.

APPENDIX 1. Observations when trees cut into discs.

Tree 1

There appeared to be at least half a ring of compression wood in the 89/90 growth ring for clusters 52-60.

There did not appear to be any obvious compression wood above this point – it was difficult to decide as it would have been on sapwood / transition wood boundary.

It was difficult to decide whether there was any compression wood below cluster 60 due to the amount of sap running.

Tree 2

There was a resin pocket visible on the top of cluster 57 and base of cluster 56. It was not determined whether these were linked. These resin pockets were in the 89/90 growth ring.

There was a resin pocket on the top of cluster 53 in the 89/90 growth ring.

There was compression wood in the 96/97 growth ring for clusters 21-34.

There were possibly two zones of compression wood in clusters 18-20.

Tree 4

There was approximately half a ring of compression wood in 1 ring for clusters 40- 50.

There were two zones of compression wood for clusters 33-38. The 2^{nd} zone of compression wood occurred in the rings formed 89/90 and 90/91.

There was possibly compression wood in clusters 29-32.

There was compression wood on one side of the stem in clusters 24-28, probably due to the leader change at cluster 23.

APPENDIX 2. Observations on planed sample branches.

Tree1

No resin pockets were observed on this tree. From sorting the samples it appeared that there were more dead branches at the base of this tree compared with the other two.

Tree2

A resin pocket was observed below six branches (see Table A2.1)

Table A2.1. List of sample branches with resin pockets

Cluster Number	Branch Number	Branch azimuth (degrees)	Growing season for ring containing resin pocket
65	4	186	93/94
64	3	114	95/96
58		87 *	97/98
581		93 *	93/94
56	3	118	97/98
50	2	217	95/96

* : azimuth estimated from photograph

Tree 4

No resin pockets were observed on this tree.

APPENDIX 3. Morphological features of sample branches

Tree/ Cluster/ Branch	Branch age at time of thinning	Annual number of growth units	Annual length increment	Branch diameter increment	Comments
1/ 45/ 9	3	Jumped to 2 at time of thinning and remained at 2 for 8 years	Still increasing at time of thinning	Increasing before thinning; no increase after thinning but still growing	It is considered that this branch has responded to the thinning (number of years with 2 growth units)
1/ 47/ 3	3	2 growth units in year before and year after thinning	Increasing slightly at time of thinning but generally decreasing after thinning	Decreasing before thinning; still growing after thinning	It is considered that this branch may have responded to the thinning (diameter growth)
1/ 49/ 4	3	2 growth units in year before and year after thinning, otherwise 1	Decreasing at time of thinning, continues to decrease (in general)	Increasing before thinning; no increase after thinning but still growing	It is considered that this branch may have responded to the thinning (diameter growth)
1/ 51/ 3	4	Dropped to 1 in year after thinning, and then increased to 2 for 4 years	Decreasing at time of thinning; continues to decrease (in general)	Decreasing before thinning, but increases after thinning for 4 years.	It is considered that this branch has responded to the thinning (growth units)
1/ 54/ 11	5	Dropped to 1 in year of thinning, and then increased to 2 for 6 years	Decreasing at time of thinning; continues to decrease	Increasing before thinning, no increase after thinning but still growing	It is considered that this branch has responded to the thinning (growth units)
1/ 55/ 7	5	Dropped to 1 year before thinning and remained at 1	Decreasing before thinning and continues to decrease	Increasing before thinning, no increase after thinning, but still growing	It is considered that this branch may have responded to the thinning (diameter growth)
1/ 56 / 1	5	Dropped to 1 after thinning	Decreasing before thinning, continues to decrease after thinning (in general)	Decreasing before thinning, small increase in 2nd year after thinning	It is considered that there has been a slight response to the thinning (diameter growth)

2/ 47/ 1	3	Never more than 1 growth unit	Decreasing before thinning, continues to decrease after thinning (in general)	Possible increase in 2nd year after thinning (only 1 mm)	May have responsed to thinning (diameter growth)
2/ 48/				** need to check whether feasible to measure branch – other data looks interesting	
2/ 49/ 3	3	Dropped to 1 growth unit after thinning	Decreasing before thinning, continues decreasing after thinning	Decreasing before thinning, continues to decrease	Unlikely to have been any response
2/ 51/ 9	4	Dropped to 1 after thinning	Decreasing before thinning, continues decreasing after thinning	Decreasing before thinning, continues decreasing after thinning	Unlikely to have been any response
4/ 40/ 1	4	Stayed at 2 for 1 year after thinning	Decreasing before thinning; continues decreasing	Increase after thinning	Probably a response