USE of PhotoMARVL to DETERMINE RESPONSE to THINNING: FURTHER RESULTS FROM EXPERIMENT RO2098

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EXECUTIVE SUMMARY

One of the goals for developing the model TreeBLOSSIM was to be able to predict the final diameter for branches from their size at mid-rotation. The response of branches to any thinning needs to be built into the model. Destructive sampling of selected branches provided the necessary data to develop a theory of how branches responded to thinning. However larger sample sizes are needed to determine on which trees a response can occur. Non-destructive techniques are the logical alternative. In this study PhotoMARVL was used to obtain quantitative data from a wider sample of trees. The relationship between diameter of the largest branch visible in each cluster and cluster height was predicted and used to determine tree level response to thinning. The results will be used as validation data for TreeBLOSSIM to check that the model predicts response to thinning correctly across the dbh distribution.

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INTRODUCTION

Experiment RO2098 was established in the "850" polycross trial, planted in 1975 at 625 stems/ha. Six thinning treatments and a control were applied (Table 1). All trees in one sample plot per treatment were visually assessed to determine whether there was any obvious change in branch diameter with height in the crown that could be attributed to the thinning treatment. Due to the underlying phyllotaxy of a cluster, the diameter of the largest branch in a cluster visible in a PhotoMARVL picture is generally significantly correlated with the diameter of the largest branch on the opposite side of a tree (SGMC Report No. 73). Hence PhotoMARVL is applicable for quantifying branch diameters before and after thinning, and the height at which the response to thinning occurred. PhotoMARVL photographs were taken of four trees per plot selected at fixed points from the dbh distribution.

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 visual assessment and PhotoMARVL estimate of response height agreed reasonably for the plots thinned to 100 stems/ha (see SGMC Report No. 93). The results for the other treatments are presented in this report.

METHODS

The visual assessment consisted of examining the tree to see how the branch diameter varied within the crown. Notes were made for each tree: if there appeared to be a change in branch diameter, and at approximately what height it occurred. Branch diameters were not estimated. Based on these notes, a subjective branch response score was assigned to each tree. The scoring system used was:

0: no response
1: possible response
2: obvious response
3: large branches all way up stem, implying response from base of crown

The trees selected for PhotoMARVL were at the 100, 70, 40 and 10 percentiles of the diameter distribution based on the PSP measurements in July 1999. For the plots thinned at 20 m and for the plots thinned at 12m, one of the trees was leaning, and another forked. In these cases, the next closest tree in the diameter distribution was selected.

The photographs were enlarged and measurements of cluster position and branch diameters recorded using PhotoMARVL procedures on the AP190 analytical stereoplotter (Firth *et al.* 2000). Base and top of all clusters were measured prior to branch diameters. The position where branch diameters are measured is generally close to but above the top of the cluster. Hence each branch was assigned to the nearest cluster below its recorded position. For 3 trees in plot 6/13, the last few branch diameters measured were obviously above the highest cluster. These measurements were deleted. The diameter of the largest branch measured in each cluster was plotted against the height to the base of the cluster to assess any trend.

When there was no change in nominal stocking, and for the stem section below the actively growing crown, there was generally no significant correlation between diameter of the largest branch in a cluster and cluster height (SGMC Report No. 50). This is in agreement with results from a much larger sample of trees (Grace, 1989). This study showed that there was little variation in whorl branch index[1] with cluster height.

When a single thinning occurs, it is suggested that the stem below the actively growing crown could be split into three zones. In the lowest zone, branch diameters would be determined by the pre-thinning stocking. In the uppermost zone branch diameters would be determined by the post-thinning stocking. Branches in the middle zone would be those formed prior to thinning and that had grown more in response to the thinning. On this basis it is suggested that a sigmoid curve would be appropriate for describing the relationship between diameter of the largest branch in a cluster and cluster height. The lower and upper asymptotes would give the mean diameter averaged over the largest branch in each cluster before and after thinning respectively; and the sloping part of the curve represents the zone where branches respond to the thinning. If there was no response to the thinning then the asymptotes would be the same. A 4-parameter Gompertz equation, which is asymmetrical about the point of inflection (Eqn. 1), was fitted to each tree individually.

$$D = \alpha + \beta \exp(-\exp(\gamma - \delta \times H)) \qquad (1)$$

D is the branch diameter
H is the height of the cluster above the base of the crown
α, β, γ, δ are model parameters
α gives the mean diameter averaged over the largest branch in each cluster prior to the thinning
β gives the change in the mean diameter as a result of the thinning
$\alpha+\beta$ gives the mean diameter averaged over the largest branch in each cluster after the thinning
the ratio γ/δ gives the point of inflection

When this equation was used previously (SGMC Report No 93), it was necessary to fix one parameter (δ) to obtain realistic estimates and asymptotic standard errors for the other parameters. For the current analyses δ was fixed at 15. With this value, realistic solutions were obtained for all trees where there were obvious changes in branch diameter. Eqn. 1 could not be fitted for trees where there were no major changes in branch diameter. If no solution was found, and there were no obvious changes in branch diameter, the mean branch diameter was calculated.

The decision as to whether Eqn. 1 or a straight line was appropriate for each tree was made prior to the comparison with the visual assessment.

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[1] Whorl branch index was defined as the sum of the diameter of the largest branch in each quadrant of a whorl (cluster) divided by n, where n is the number of quadrants containing branches.

RESULTS

The visual assessments of trees and predicted coefficients from Eqn. 1 are shown in Table 2. Plots of PhotoMARVL measurements of diameter of the largest visible branch in each cluster and predicted curve (Eqn. 1) are shown in Figures 1 –20. The y-axis label "maximum branch diameter" refers to the diameter of the largest visible branch in a cluster. These results are discussed in more detail below.

Plot 10/24 – unthinned

All the small trees in the plot were dead, so only 3 trees were PhotoMARVLed. There was no visible change in branch diameter with height from the ground for these three trees (Table 2, Figures 1-3) nor for any of the other trees in the plot (SGMC Report No. 93). PhotoMARVL confirmed these results for 2 of the 3 trees. For the third tree (3/11), diameter of the largest visible branch on a cluster tended to increase slightly with increasing height from the ground (Figure 2).

This is the only tree where the proposed hypothesis appears not to hold. It is difficult to decide on the importance of this result, is it just chance, or does the hypothesis need modification? One possible explanation for the change in branch diameter is that this tree was competing with a suppressed tree and gradually obtained more space to grow. If this were the case one would expect a suppressed tree to show decrease in branch diameter with height. A PhotoMARVL assessment of all trees in one or more unthinned plots would be a way to resolve the issue.

Plot 5/12 – thinned to 200 stems/ha at 12 m

Of the 4 trees PhotoMARVLed, only 1 tree (0/22) showed a visible change in branch diameter, and this was only slight. PhotoMARVL confirmed the slight change for this tree and no change for the other 3 trees (Table 2 and Figures 4 –8).

The original analysis for tree 0/18, indicated that there was a large branch (over 10 cm) at approximately 18 m (Figure 6). This seemed strange given the visual assessment, so the photograph was re-examined. The large branch measured was almost horizontal, which is clearly atypical behaviour (large branches generally have a steep angle). Also due to foliage it was difficult to see exactly where the branch originated, possibly it was a broken top hung up in the canopy. This measurement was removed from the dataset. The branch measured as 82 mm was also re-checked and found to be only 55 mm. This error appears to have occurred due to material caught between the branch and the stem. When these corrections were made to the dataset, there was no trend in the diameter of the largest visible branch in a cluster with height to the base of the cluster.

Plot 6/13 – thinned to 400 stems/ha at 12 m

Four trees were PhotoMARVLed (Table 2 and Figures 9-12). When these trees were assessed visually, branch diameter did not change on two of the trees while the other 2 trees showed a possible change in branch diameter. The visual assessment and PhotoMARVL results were in agreement for 3 of the 4 trees. The visual assessment for the other tree (0/13) was large branches on the whole stem (i.e. no change in branch diameter), whereas PhotoMARVL predicted a significant change in the diameter of the largest visible branch in a cluster above 13.1m (Figure 10).

Plot 19/36 – thinned to 200 stems/ha at 20 m

Four trees were PhotoMARVLed. The results agreed reasonably with the visual assessment for 3 of the 4 trees. The atypical cluster on tree 4/50 was picked up by PhotoMARVL. Visually there appeared to be a change in branch diameter on tree 0/29, whereas PhotoMARVL indicated a slight but non-significant change in the diameter of the largest visible branch in a cluster (Figure 15).

Plot 15/27 – thinned to 400 stems/ha at 20 m

Four trees were PhotoMARVLed. One of these (2/15) was forked and was assessed to have smaller branches above the fork. This was confirmed by the analysis of the photograph. A fork /spike knot occurred at approximately 7 m (Figure 17).

Visually there was no obvious change in branch diameter with height on the other trees. This was confirmed for two trees. For the third tree (0/21), the PhotoMARVL picked up a slight but non-significant change in the diameter of the largest visible branch in a cluster (Figure 20). This was due more to less small branches being visible higher in the tree than any increase in the diameter of the larger branches.

Comparison

Plot mean values of α and β were calculated (Table 3). These means indicate:

- a mean branch diameter of approx. 4 cm before thinning (all plots had same initial stocking),
- a mean increment of approx. 2 cm in plots thinned to 100 stems/ha,
- a much smaller increment (1cm or less) in the plots thinned to 200 or 400 stems/ha.

The positive value for β for the unthinned plot is the result of one tree showing a significant change in branch diameter. This was discussed earlier.

Another point to note is that the predicted height of inflection was similar regardless of the time of thinning. This may be an artefact of the sampling – the small sample size and the observed response for each tree. The results from repeating this study in the replicate of RO2098 at Eyrewell Forest may help in understanding this result.

Table 2. Visual assessment of response to thinning, and predicted response to thinning from PhotoMARVL measurements.

Tree	Position of tree in dbh distribution	Visual assessment	Predicted mean diameter averaged over the largest branch in each cluster before thinning (α) (cm)	Predicted change in mean diameter averaged over the largest branch in each cluster (β) (cm)	β significant at 5% level	Predicted height of inflection (γ/δ) (m)
Plot 10/24 – unthinned						
4/19	40%	No change in branch diameter	3.1	-	-	-
3/11	70%	No change in branch diameter	3.1	0.7	yes	12.9
3/15	100%	No change in branch diameter	5.3	-	-	-
Plot 5/12 – thinned to 200 stems/ha at 12 m						
0/22	10%	Possibly larger branches above approx. 12 m	3.5	0.7	no	13.7
0/53	40%	No change in branch diameter	4.2	-	-	-
0/18	70%	Large branches on whole stem	4.9		-	-
0/3	100%	Large branches on whole stem	5.2	-	-	-
Plot 6/13 – thinned to 400 stems/ha at 12 m						
0/5	10%	Possibly larger branches above 20 m	3.3	1.3	yes	16.3
0/13	40%	Large branches on whole stem	4.1	1.5	yes	13.1
4/27	70%	No change in branch diameter	4.0	-	-	-
1/7	100%	Possibly larger branches above 12 m	3.8	1.1	yes	13.5

Table 2 cont. Visual assessment of response to thinning, and predicted response to thinning from PhotoMARVL measurements.

Tree	Position of tree in dbh distribution	Visual assessment	Predicted mean diameter averaged over the largest branch in each cluster before thinning (α) (cm)	Predicted change in mean diameter averaged over the largest branch in each cluster (β) (cm)	β significant at 5%	Predicted height of inflection (γ/δ) + base height (m)
Plot 19/36 – thinned to 200 stems/ha at 20 m						
4/50	10%	No change in branch diameter. Basket whorl approx. 15 m.	4.0	-	-	-
4/49	40%	No change in branch diameter	4.6	-	-	-
0/29	70%	Larger branches above approx. 12 m	4.1	0.8	no	17.5
1 /2	100%	Possibly a change in branch diameter	4.0	1.8	yes	14.2
Plot 15/27 – thinned to 400 stem/ha at 20 m						
2/15	10%	Forked, smaller branches above fork	-	-	-	-
4/30	40%	No change in branch diameter	4.4	-	-	-
1 /4	70%	No change in branch diameter	4.6	-	-	-
0/21	100%	No change in branch diameter	4.0	0.8	no	13.0

Table 3. Plot level results from PhotoMARVL measurements.

Treatment	Plot mean values for α (cm)	Plot mean values for β (cm)
thinned to 100 stems/ha at 12 m	4.1	2.3
thinned to 100 stems/ha at 20 m	4.0	1.9
thinned to 200 stems/ha at 12 m	4.4	0.2
thinned to 200 stems/ha at 20 m	4.2	0.6
thinned to 400 stems/ha at 12 m	3.8	1.0
thinned to 400 stems/ha at 20 m	4.3	0.2
unthinned	3.8	0.2

Note:
α is the mean diameter averaged over the largest branch in each cluster prior to the thinning
β is the change in the mean diameter as a result of the thinning
$\alpha+\beta$ is the mean diameter averaged over the largest branch in each cluster after the thinning

DISCUSSION

One of the aims of the branch model, BLOSSIM, is to be able to grow branches forward after a mid-rotation inventory. To be able to do this successfully there is a need to be able to predict whether a particular branch on a particular tree will grow in response to a thinning.

Destructive sampling of individual branches has provided quantitative data for modelling the change in branch diameter as a result of a thinning. The sheer number of measurements required has limited the number of trees that can be sampled. However larger sample sizes are needed to determine on which trees a response can occur. Non-destructive techniques are the logical alternative. In this study both visual assessment and PhotoMARVL were investigated.

Visual assessment seems appropriate for sampling a lot of trees quickly for one particular aspect, in this case to answer "has there been a response to thinning?" As the results, in this report and SGMC Report No. 93, indicate that the visual assessment and the PhotoMARVL estimates agreed for most of the trees, the estimate of the percentage of trees that had responded to thinning (SGMC Report No. 93) are likely to be reliable.

PhotoMARVL is more time-consuming than a simple visual assessment. Consequently less trees can be assessed in the same time period. In this study approximately 5 trees could be assessed visually (for 1 feature) in the time required to PhotoMARVL 1 tree. Four trees per plot is really too small a sample to estimate the percentage of trees that show a response to thinning. However PhotoMARVL has provided more precise information on the mean diameter (averaged over the largest branch in each cluster) before and after thinning, and the height at which any response to the thinning has occurred.

This extra information would have been difficult to obtain with a traditional MARVL inventory as branch diameter is recorded in broad classes of several cm. The change in the mean branch diameter (averaged over the largest branch in each cluster) as a result of the thinning is generally less than 2 cm for these trees but was up to 4 cm for the plots thinned to 100 stems/ha (SGMC Report No. 93).

These results clearly show that the sampling strategy needs to be appropriate for the question to be answered. As the need for more quantitative information increases, PhotoMARVL becomes a more viable option for collecting the required data.

The results from this study will be used in a sensitivity analysis of TreeBLOSSIM. These results will be compared with estimates to see whether response to thinning has been modelled in a realistic manner.

REFERENCES

Stand Growth Modelling Cooperative Reports.

50: Grace, J.C. 1996: Diameter of branches within a cluster in Experiment RO696.

73: Grace, J.C. 1999: Implications of branch arrangement for PhotoMARVL.

93: Grace, J.C. ; Brownlie, R. K. 2000: Suitability of PhotoMARVL for measuring crown structure.

Other reports/ papers.

Firth, J.G.; Brownlie, R.K.; Carson, W.W. 2000: Accurate stem measurements, key to new image-based system. New Zealand Journal of Forestry 45 (2): 25-29.

Grace, J.C. 1989: Branch size prediction for radiata pine. Stand Management Cooperative Report No. 18 (unpublished).

Figure 1. Tree 4/19, Plot 10/24 – unthinned.

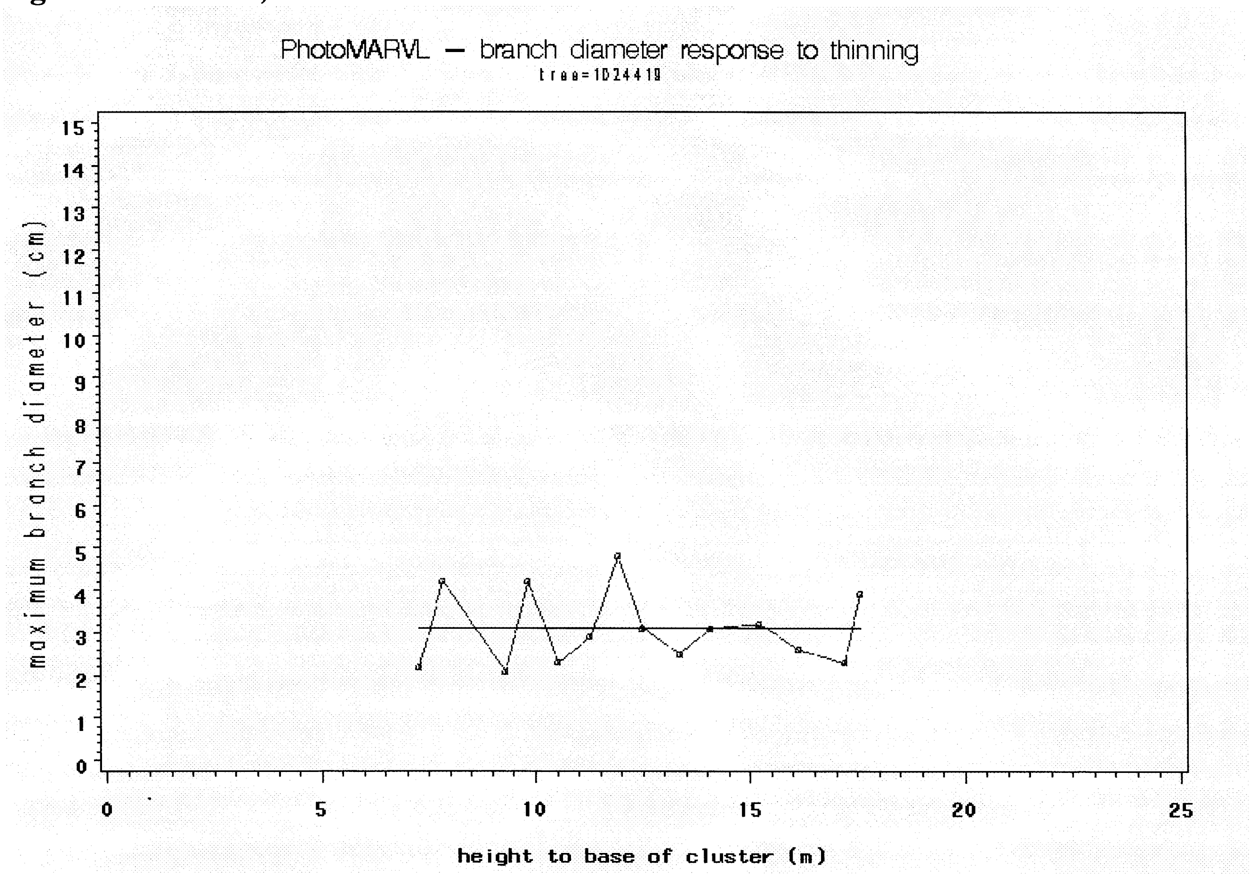

Figure 2. Tree 3/11, Plot 10/24 – unthinned.

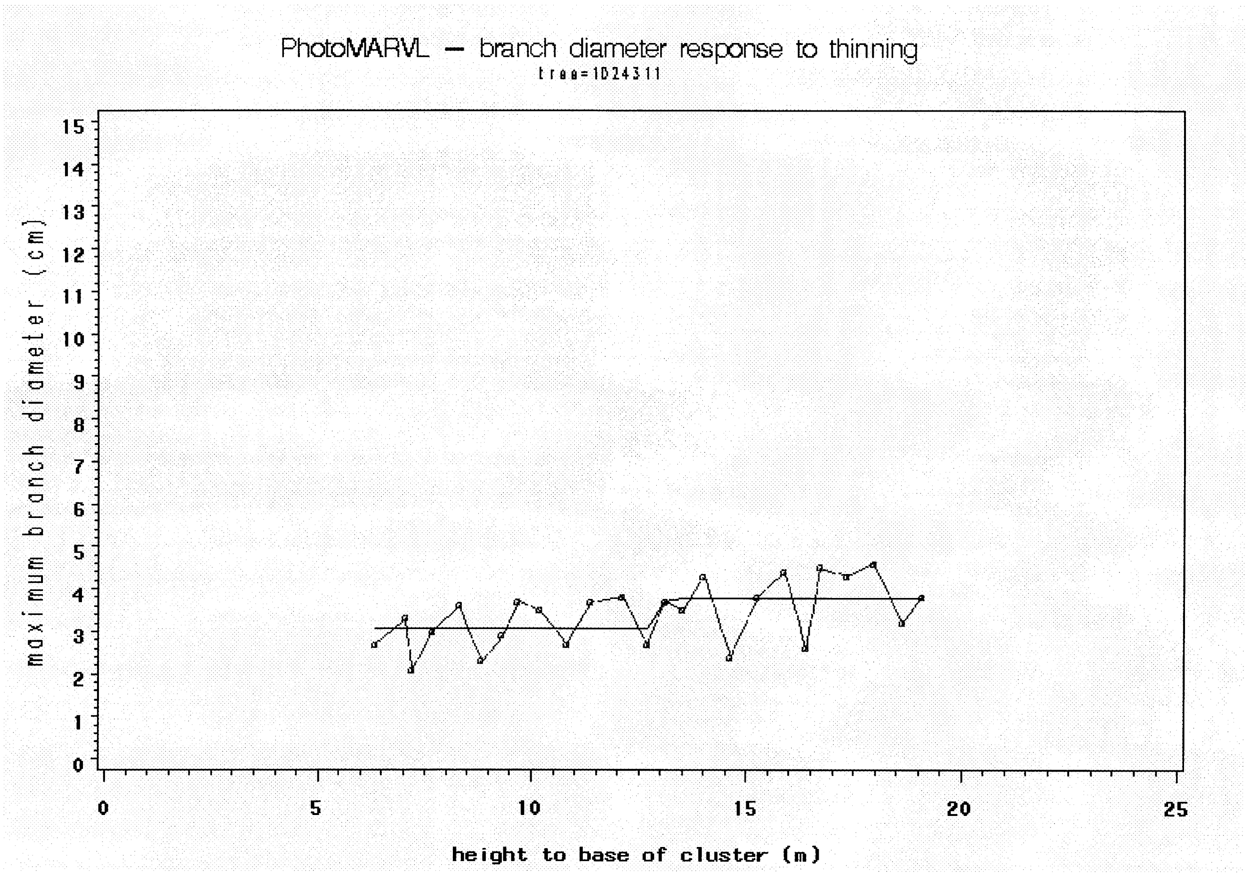

Figure 3. Tree 3/15, Plot 10/24 -unthinned.

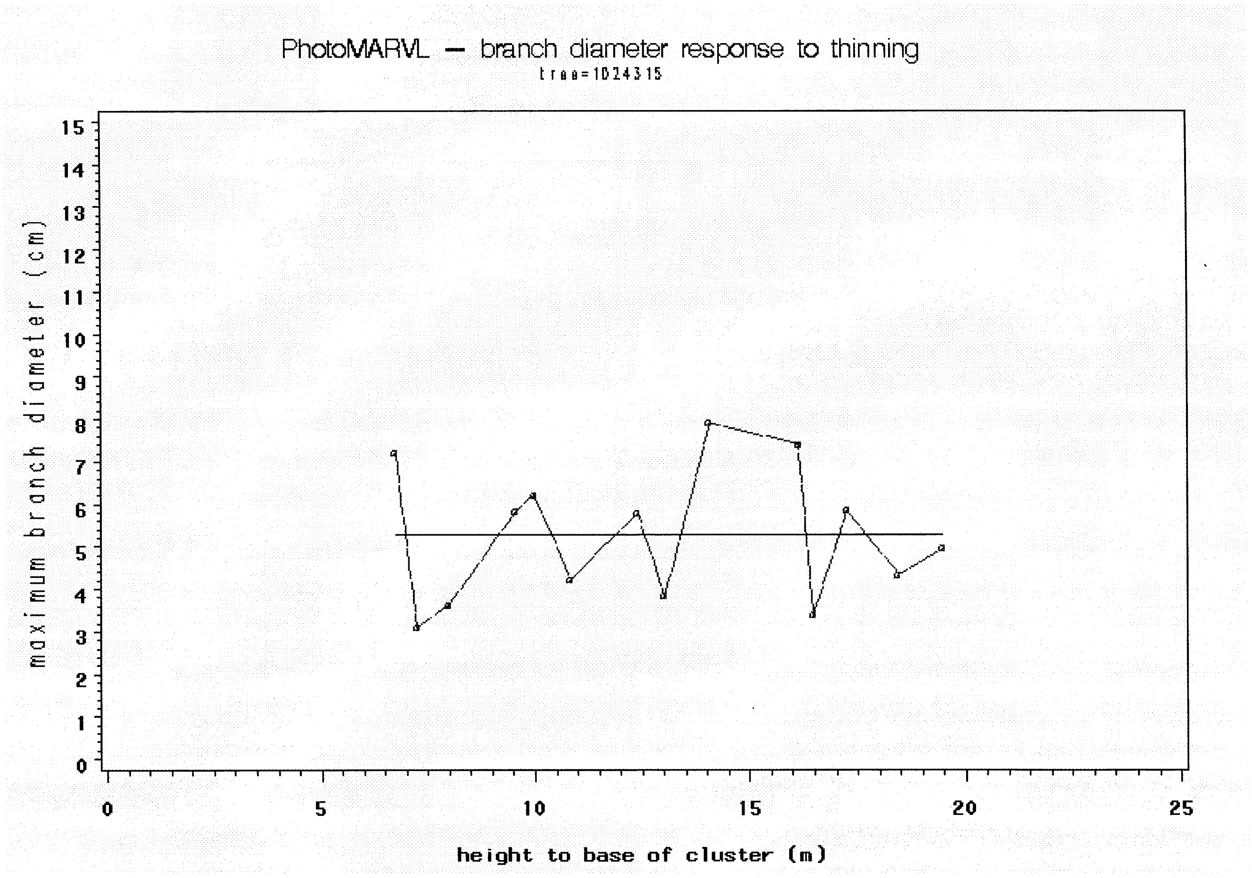

Figure 4. Tree 0/22, Plot 5/12 thinned to 200 stems/ha at 12 m.

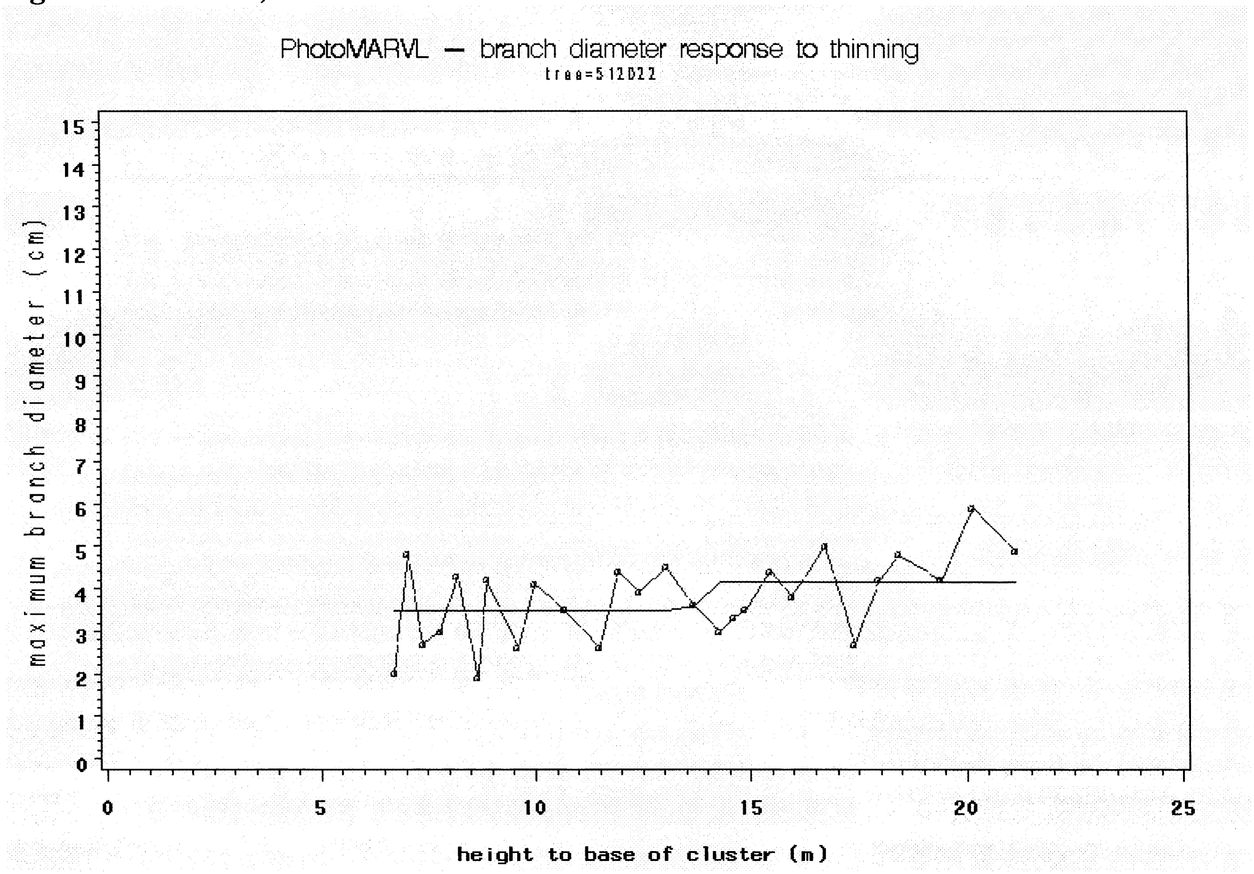

Figure 5. Tree 0/53, Plot 5/12 – thinned to 200 stem/ha at 12 m.

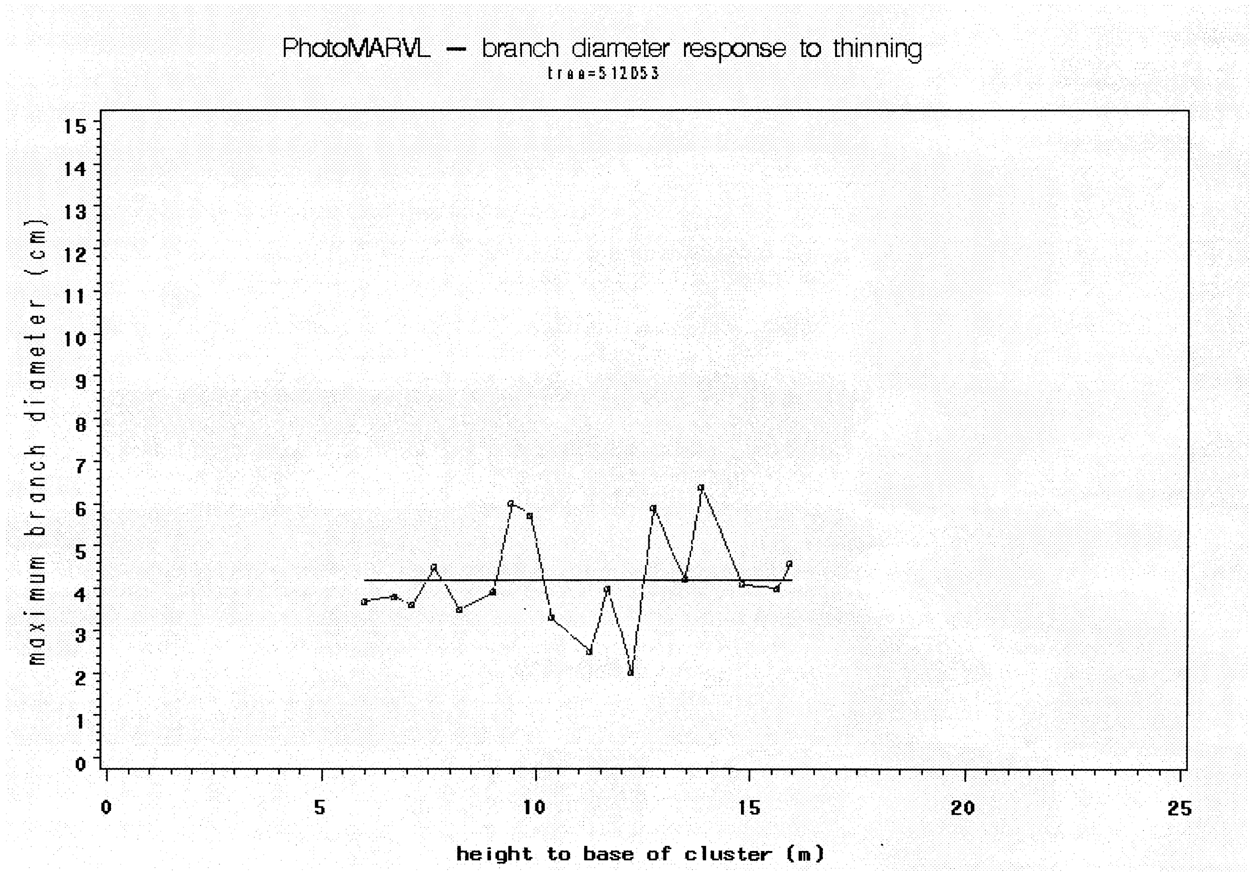

Figure 6. Tree 0/18, Plot 5/12– thinned to 200 stem/ha at 12 m (original analysis).

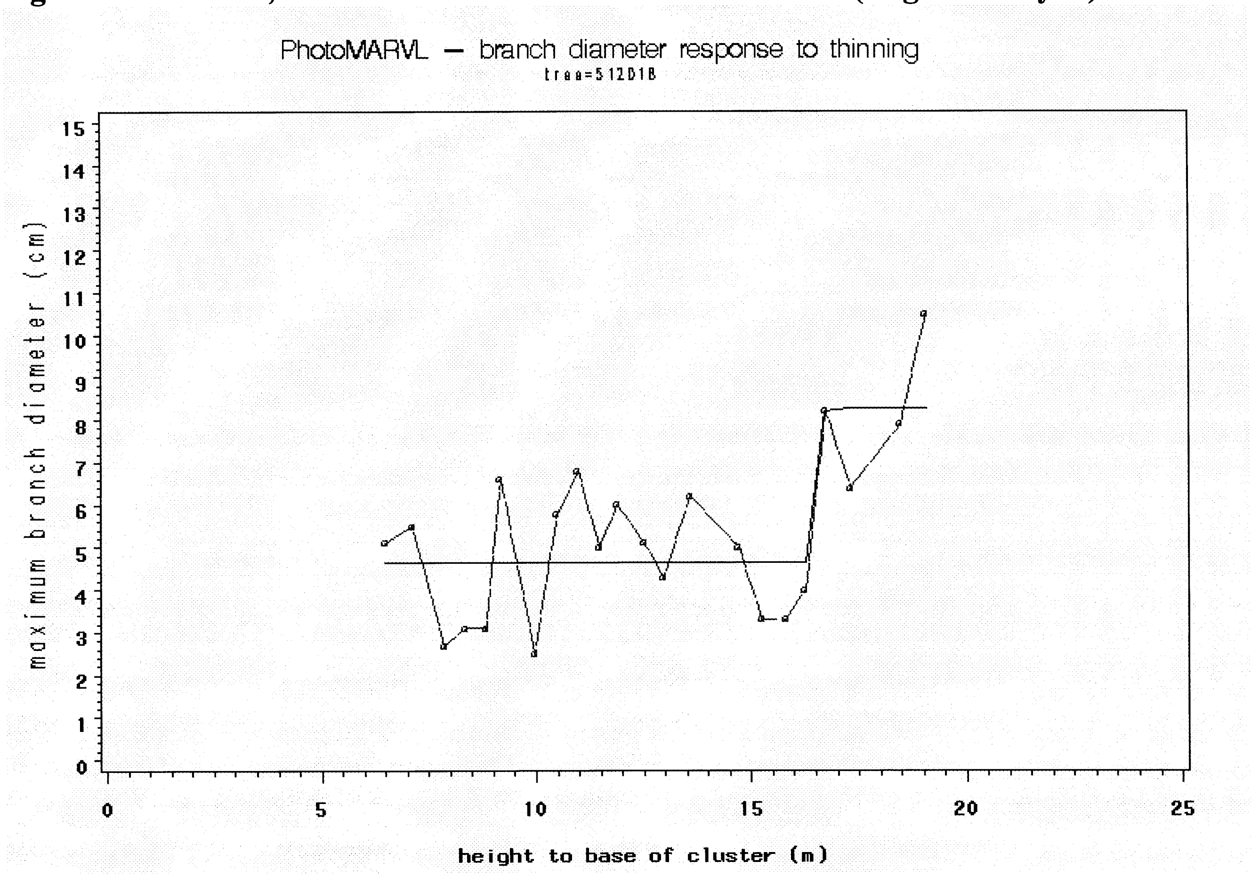

Figure 7. Tree 0/18, Plot 5/12– thinned to 200 stem/ha at 12 m (amended analysis).

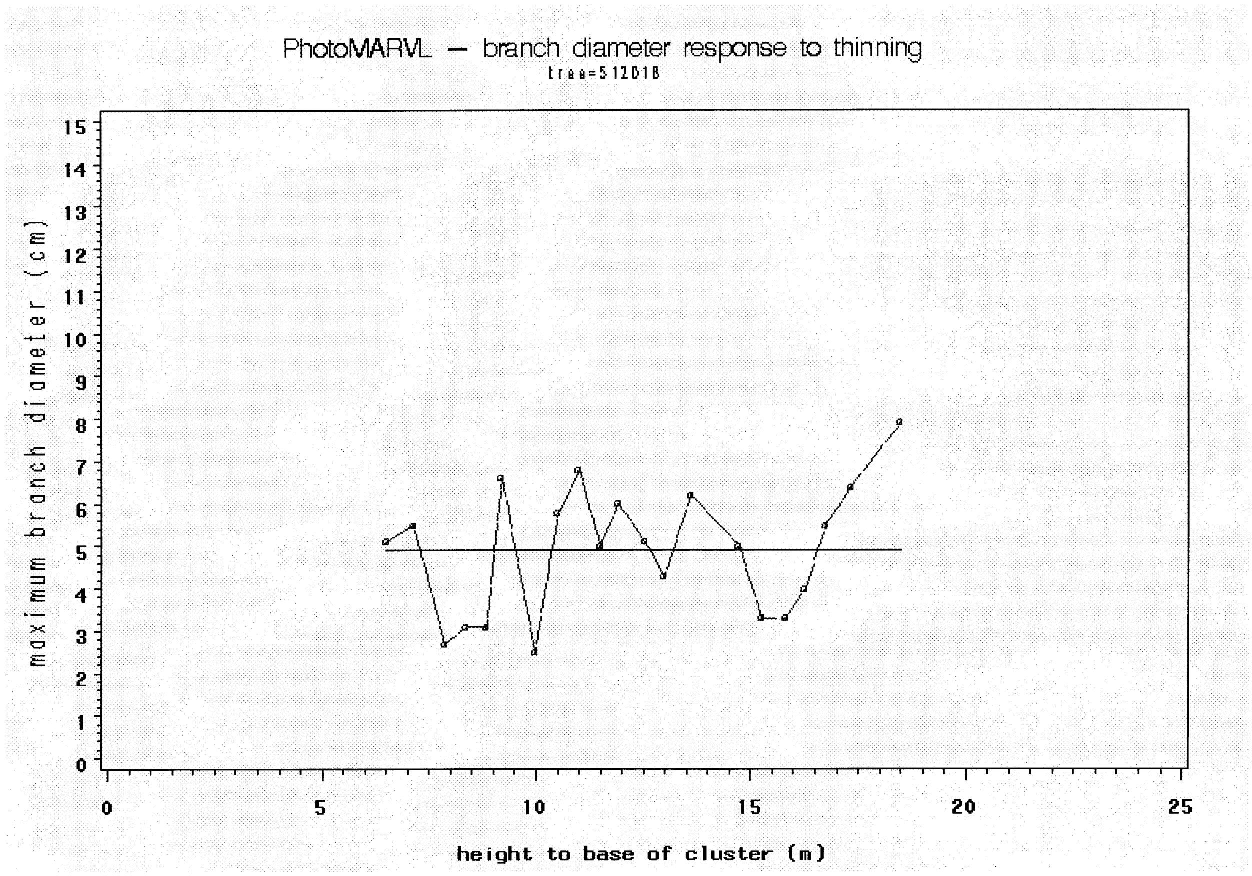

Figure 8. Tree 0/3, Plot 5/12 – thinned to 200 stem/ha at 12 m.

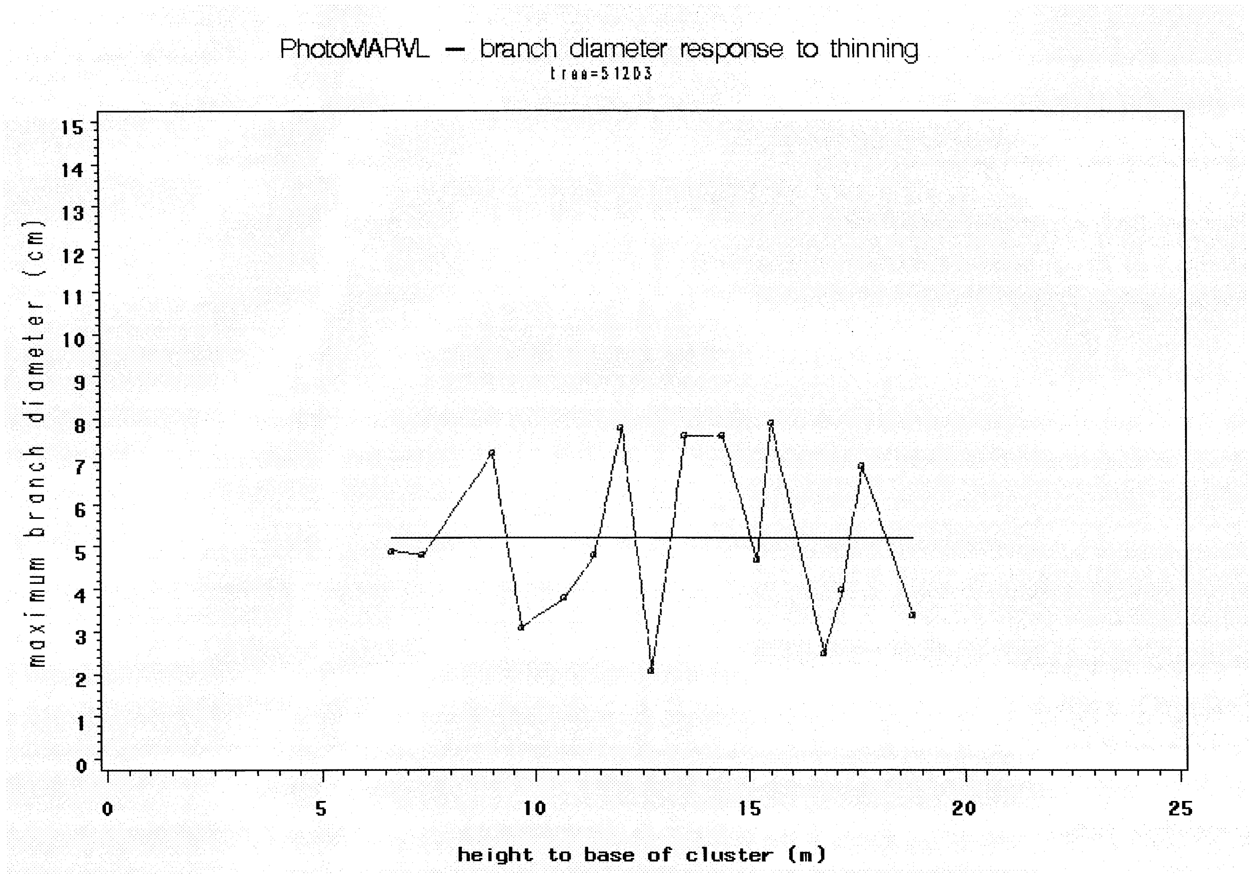

Figure 9. Tree 0/5, Plot 6/13 – thinned to 400 stems/ha at 12 m.

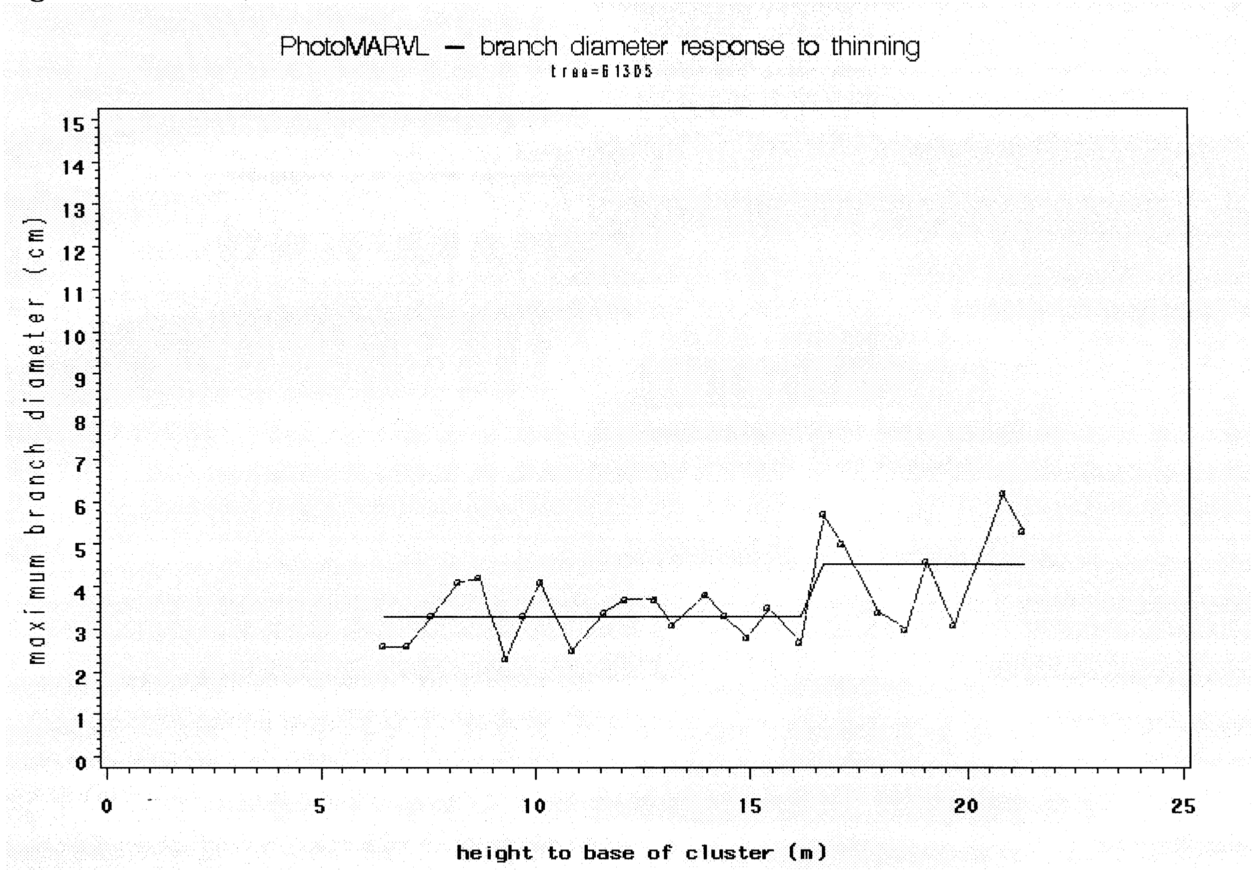

Figure 10. Tree 0/13, Plot 6/13 – thinned to 400 stems/ha at 12 m.

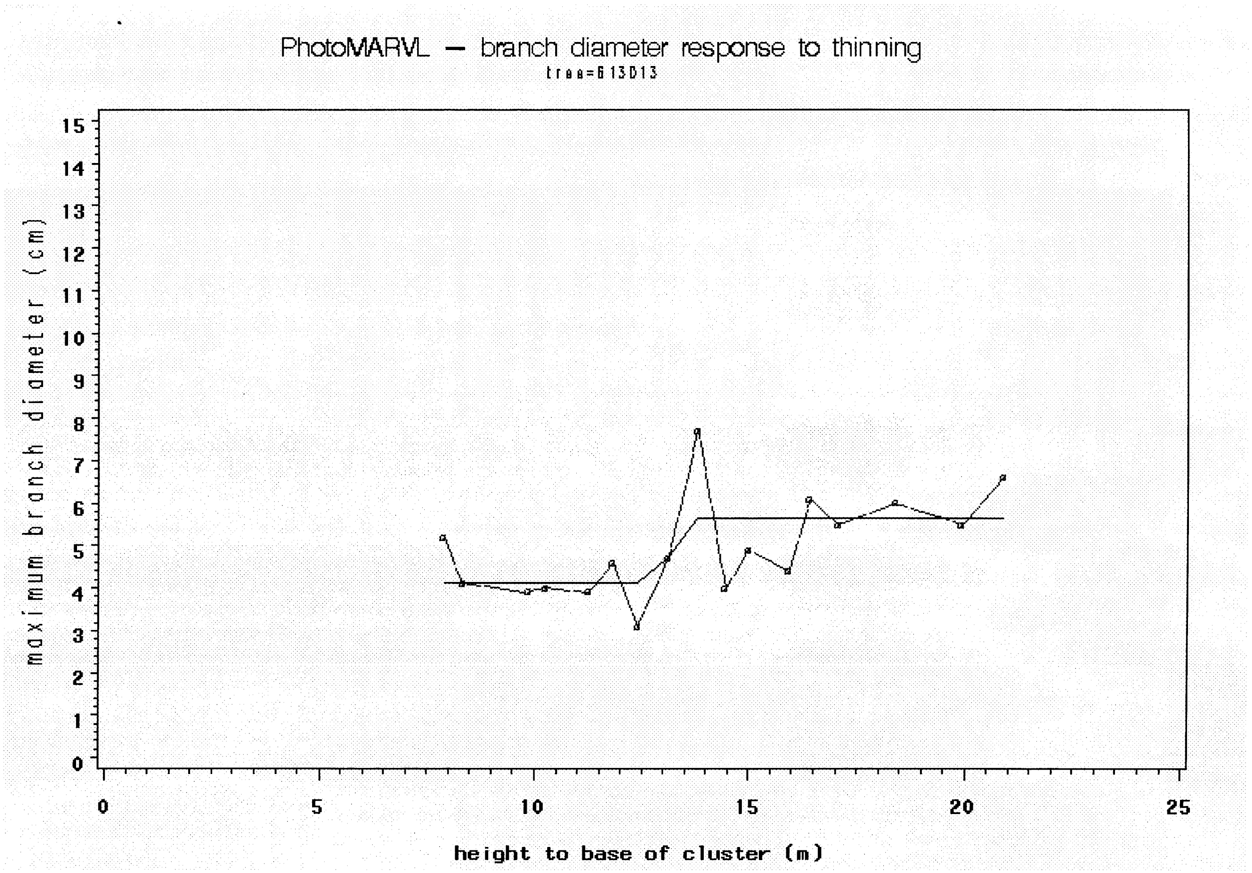

Figure 11. Tree 4/27, Plot 6/13 – thinned to 400 stems/ha at 12 m.

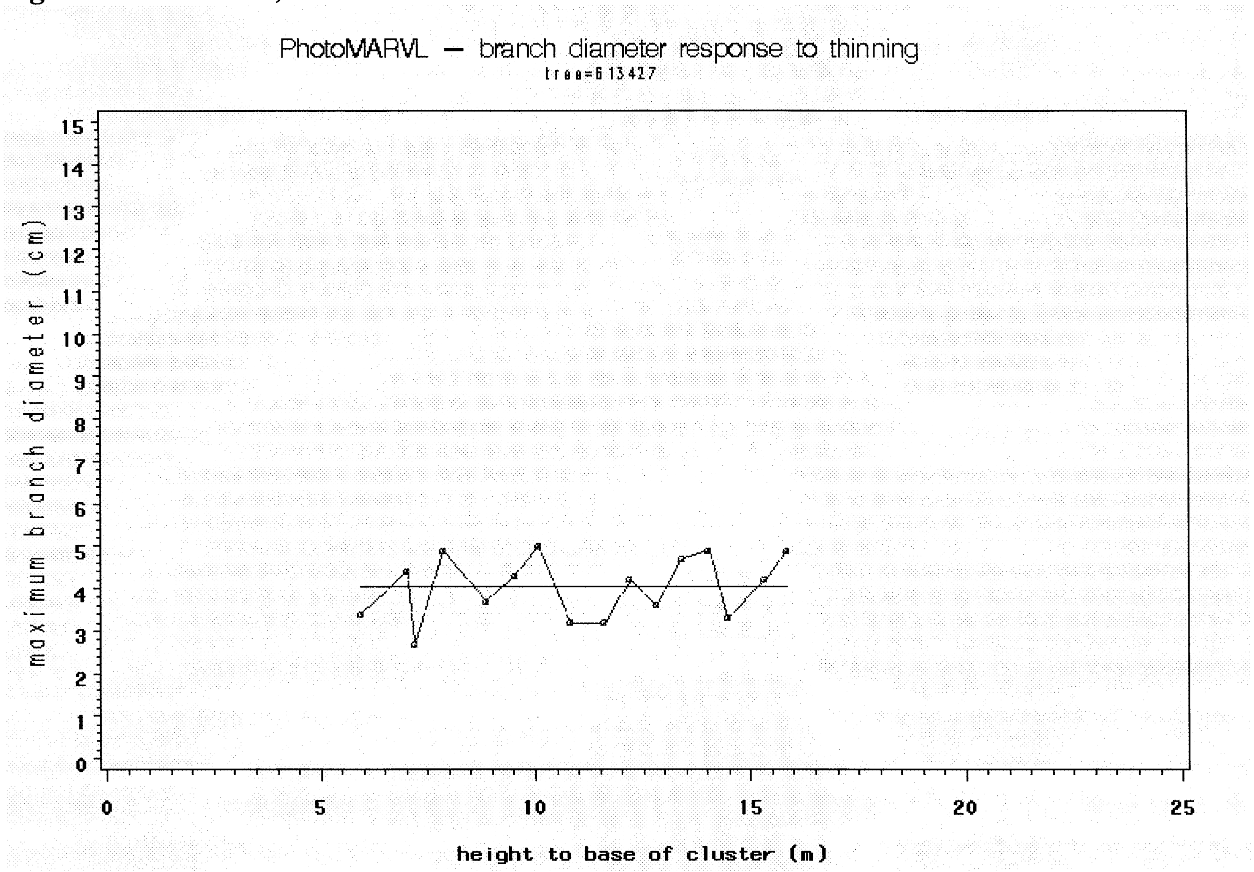

Figure 12. Tree 1/7, Plot 6/13 – thinned to 400 stems/ha at 12 m.

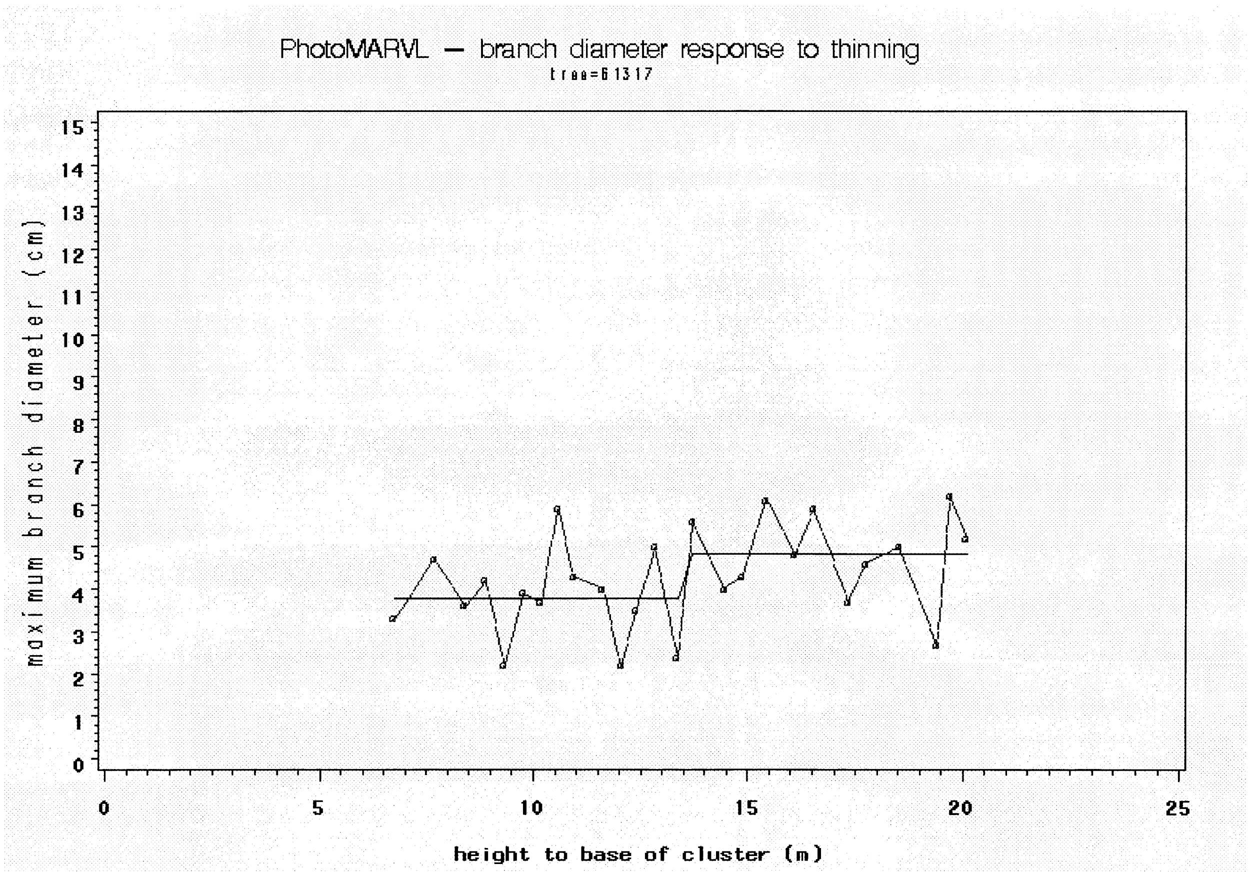

Figure 13. Tree 4/50, Plot 19/36 – thinned to 200 stems/ha at 20 m.

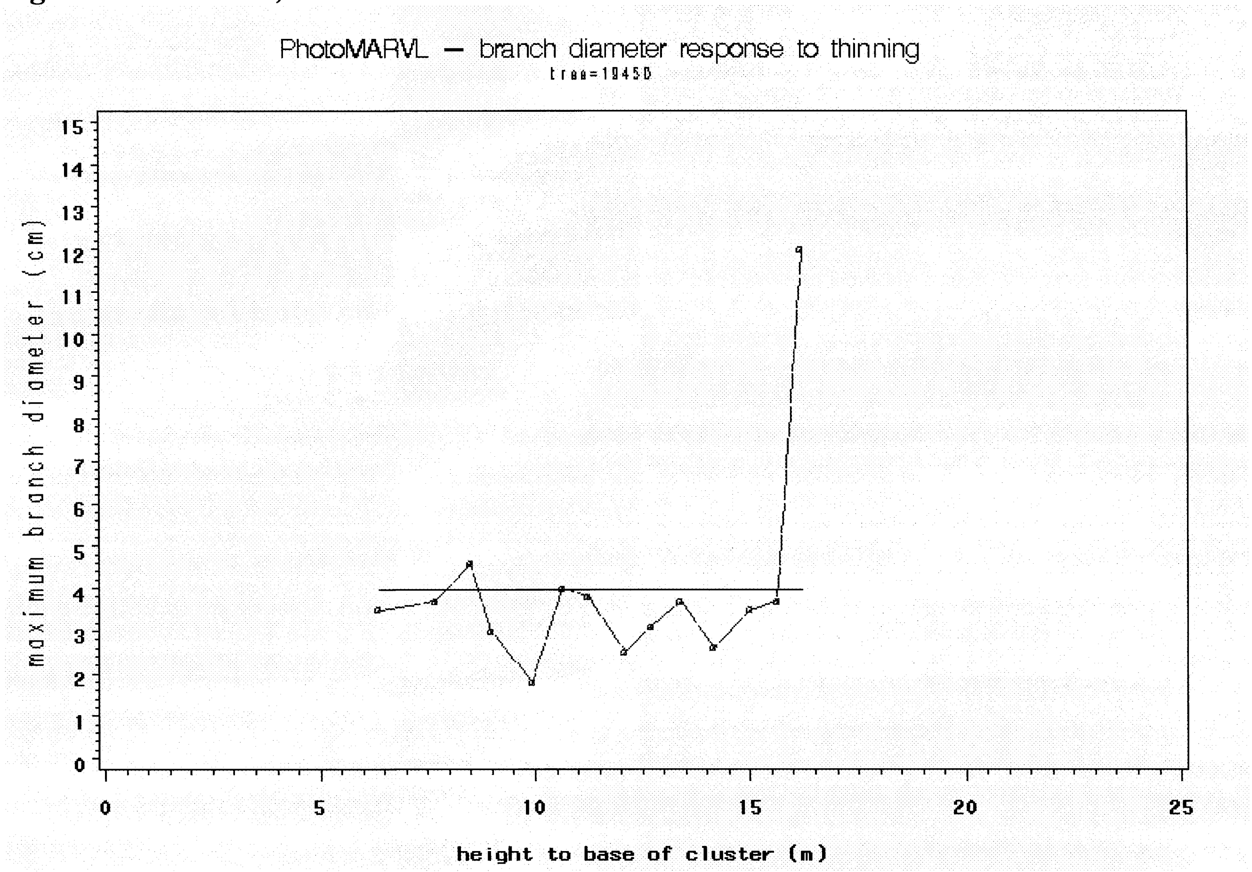

Figure 14. Tree 4/49, Plot 19/36 - thinned to 200 stems/ha at 20 m.

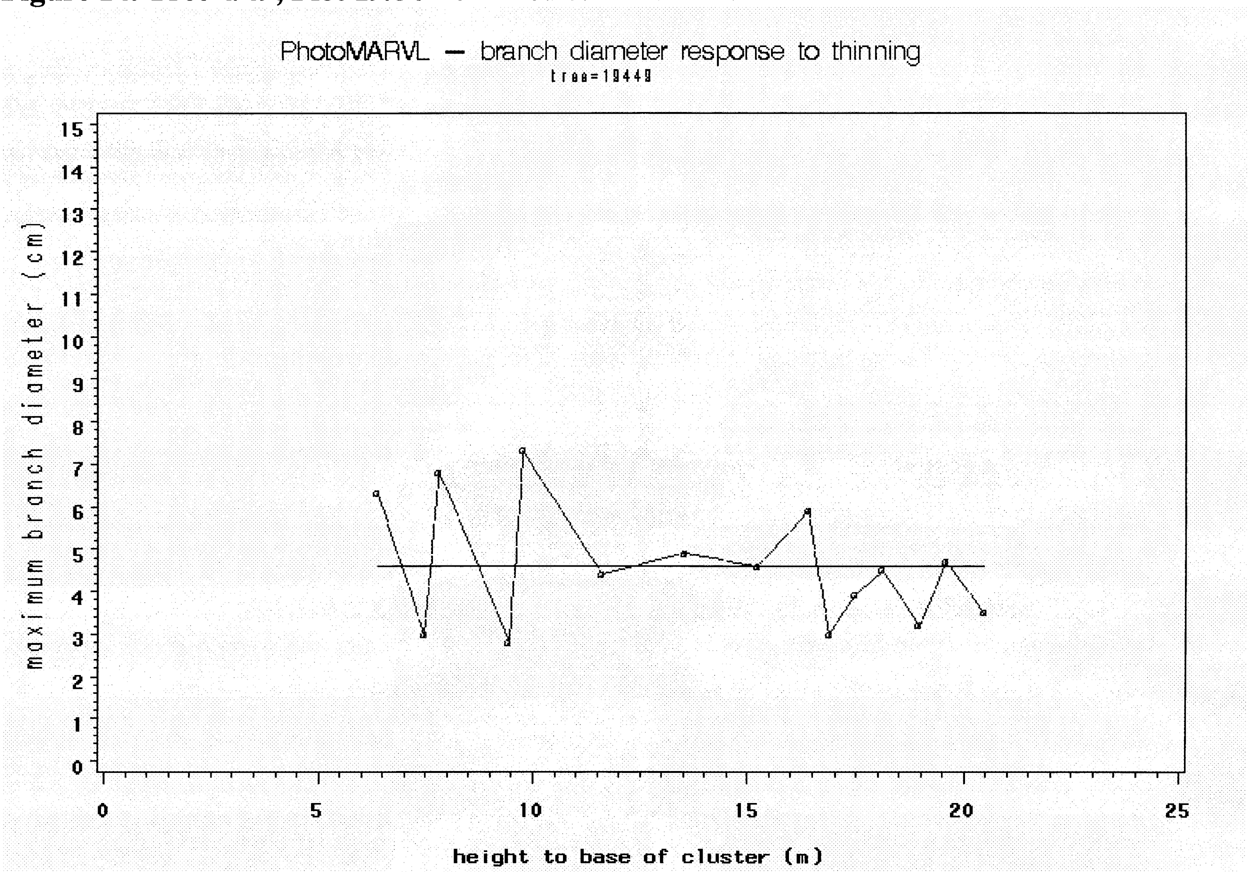

Figure 15. Tree 0/29, Plot 19/36 - thinned to 200 stems/ha at 20 m.

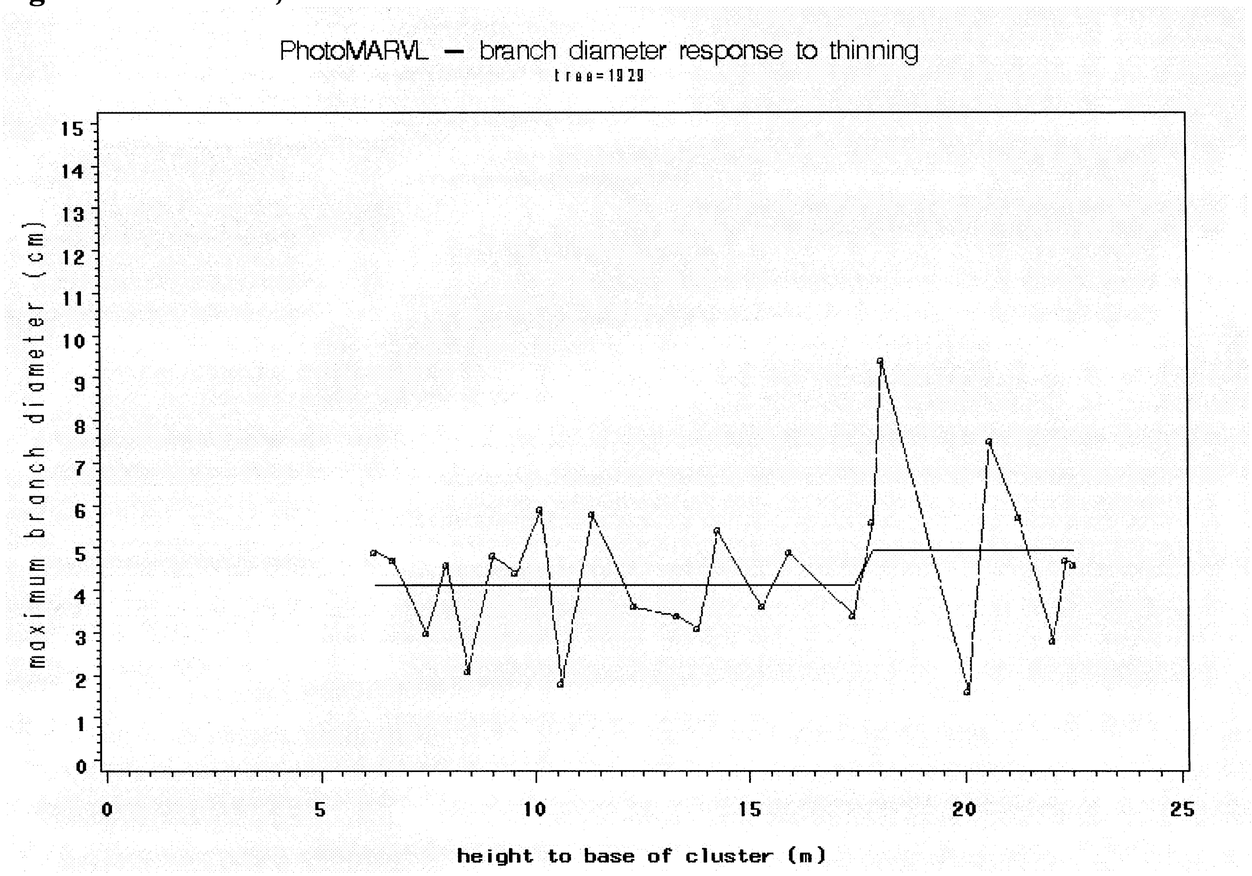

Figure 16. Tree 1 / 2, Plot 19/36 - thinned to 200 stems/ha at 20 m.

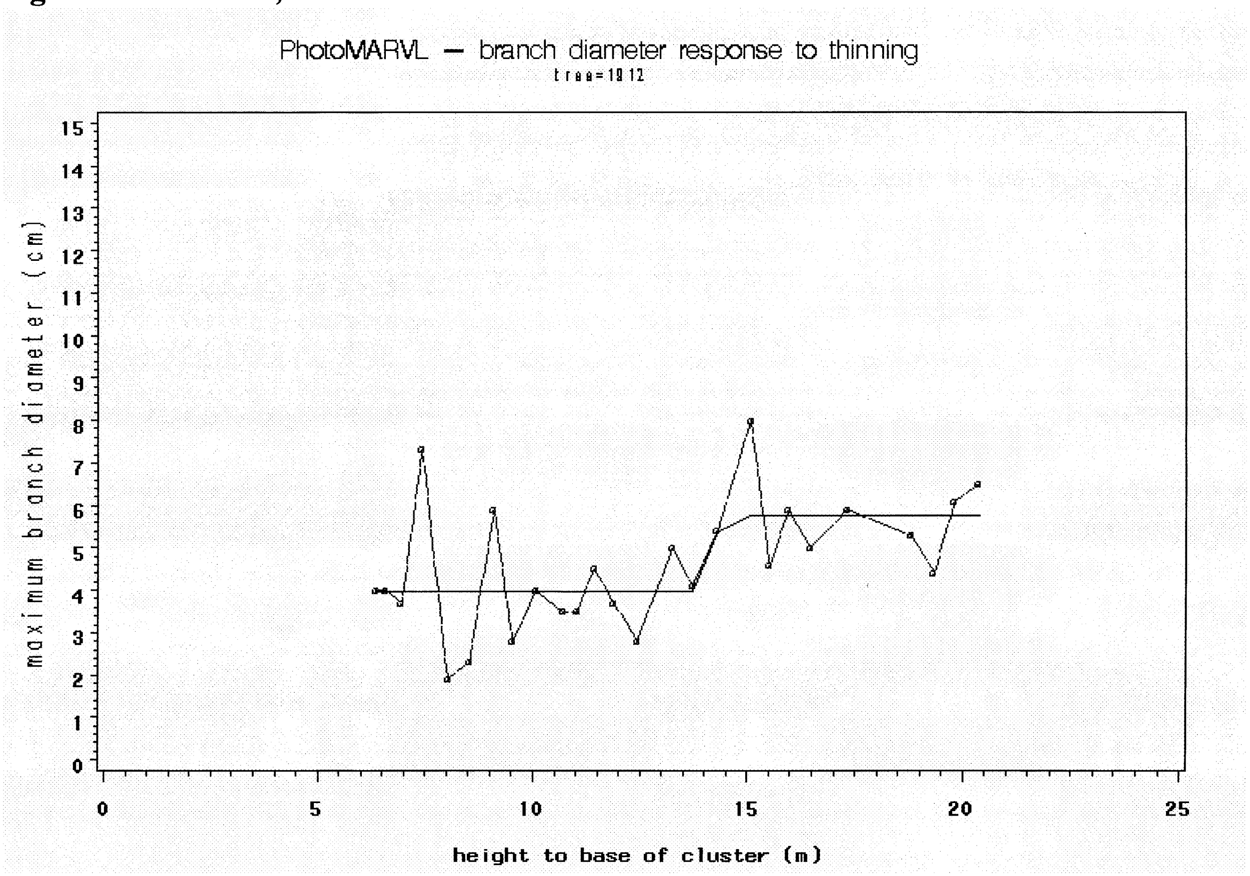

Figure 17. Tree 2/15, Plot 15/27 – thinned to 400 stems/ha at 20 m.

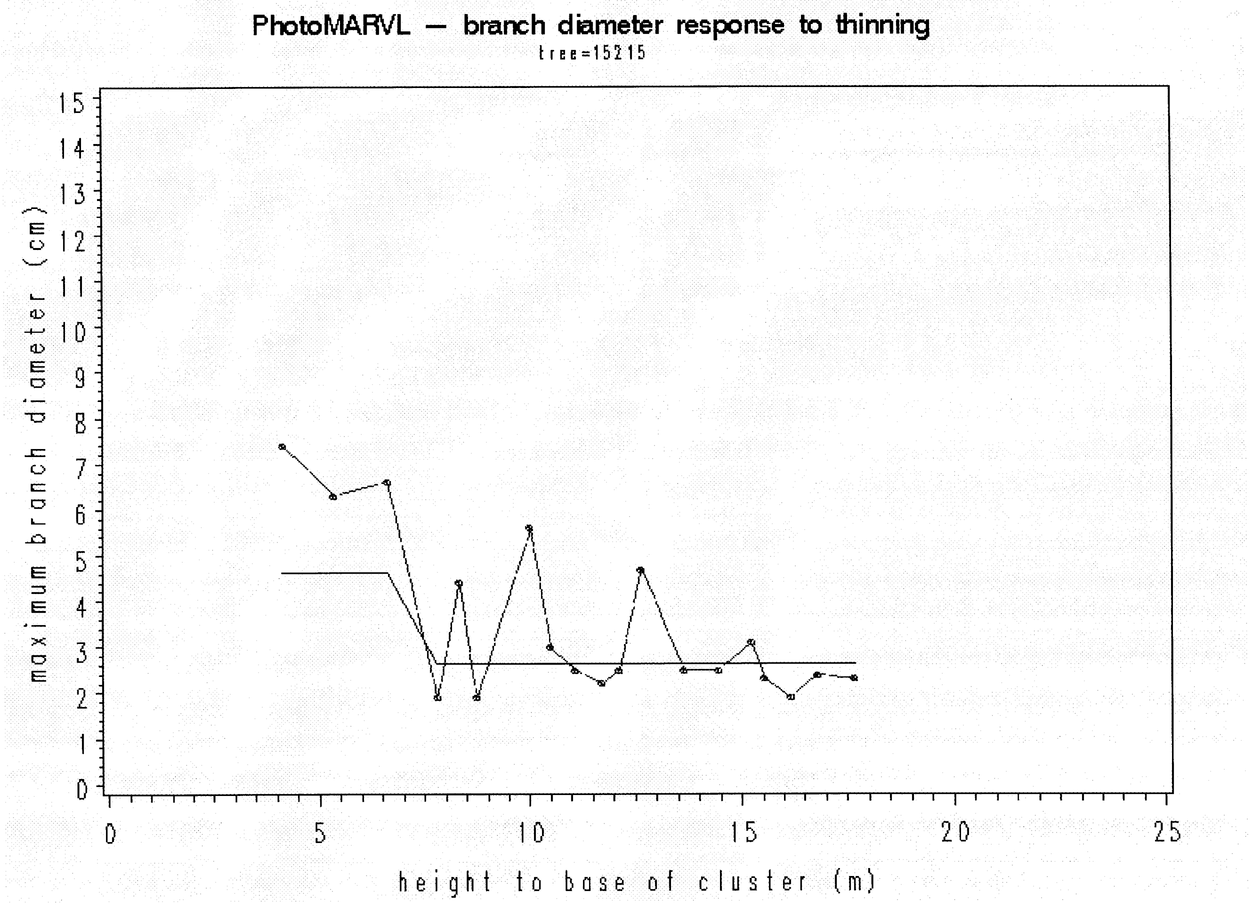

Figure 18. Tree 4/30, Plot 15/27 – thinned to 400 stems/ha at 20 m.

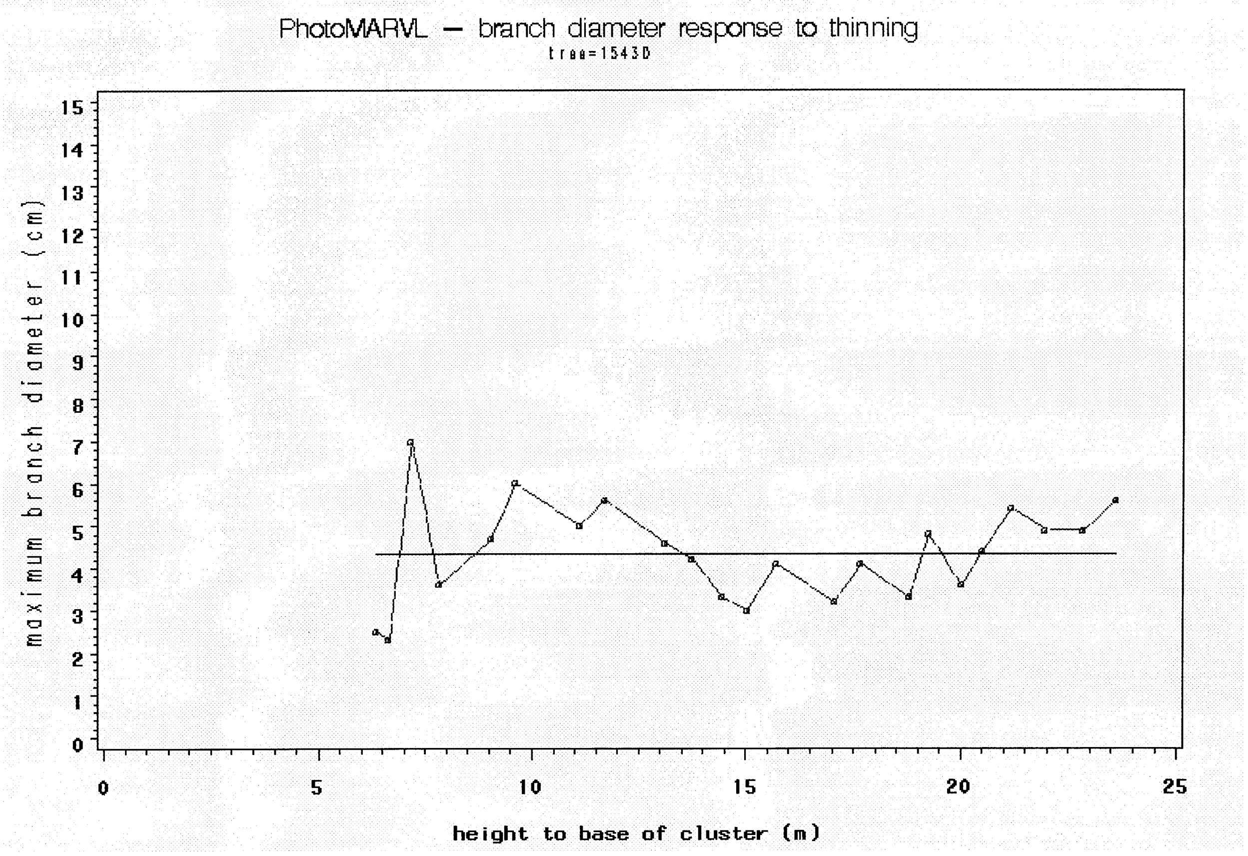

Figure 19. Tree 1 / 4, Plot 15/27 – thinned to 400 stems/ha at 20 m.

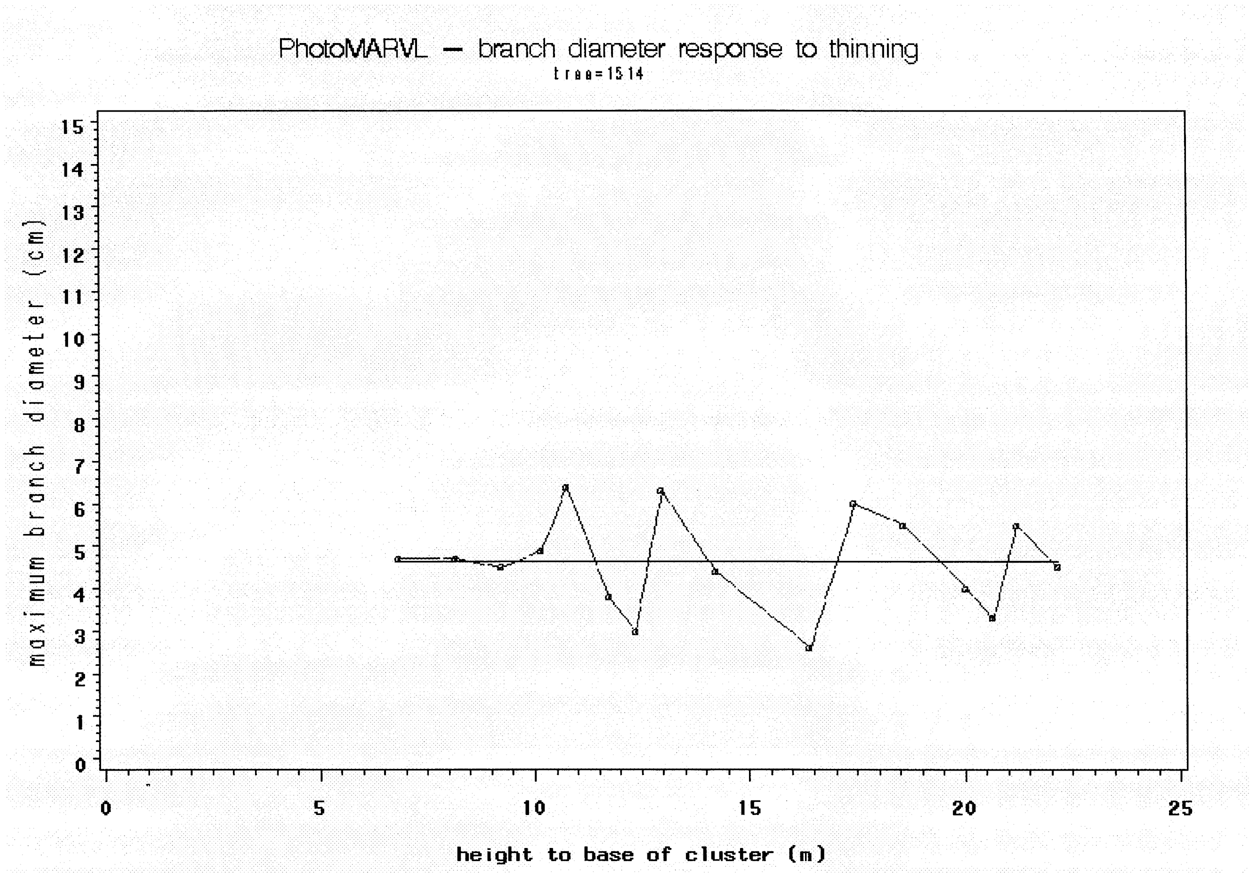

Figure 20. Tree 0/21, Plot 15/27 – thinned to 400 stems/ha at 20 m.