BRANCH DIAMETER GROWTH IN COMPARTMENT 905 (KAINGAROA) AND TARINGATURA (SOUTHLAND)

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EXECUTIVE SUMMARY

The branch diameter growth function is one of the thirteen functions that are currently used in a prototype version of the branch model being developed by the Stand Growth Modelling Cooperative (Grace and Pont 1998a). Grace (1996b) discussed the development of branch diameter growth for *Pinus radiata* in New Zealand. Further data have been collected from two new sites in New Zealand since Grace report (1996b). This study developed the equations that predict the change of branch diameter through time for Kaingaroa (Compartment 905) and Taringatura (Southland).

The non linear equations predict the branch diameter growth in Kaingaroa and Taringatura forests very well and they can be incorporated into the prototype version of the branch model.

Branch Diameter Growth in Compartment 905 (Kaingaroa) and Taringatura (Southland)

INTRODUCTION

The objective of this study is to develop the equations that predict the change of branch diameter through time for Kaingaroa (Compartment 905) and Taringatura (Southland) data sets. The branch diameter growth function is one of the thirteen functions that are currently used in a prototype version of the branch model being developed by the Stand Growth Modelling Cooperative (Grace and Pont 1998a). Grace (1996b) discussed the development of branch diameter growth for *Pinus radiata* in New Zealand. Further data have been collected from two new sites in New Zealand since Grace report (1996b).

DATA

Further data were collected in 1997 and they were separated into three groups:

1. Diallel Compartment 905 (Kaingaroa),
2. Uninodal Compartment 905 (Kaingaroa) and
3. Diallel Taringatura (Southland).

Grace *et al.* (1998c) discussed the data collection for Compartment 905 and its branching characteristics while Grace (in prep) discussed the selection of the diallel trees in Taringatura forest. Table 1 describes the details of tree sampled from Compartment 905, Kaingaroa forest and Taringatura forest and Tables 2-3 show the statistics of sample branches from the three strata.

Table 1. Diallel data sets from Kaingaroa and Taringatura forests and Uninodal data from Kaingaroa forest.

Site	Trial	Family Code	Tree No.	*Dbh*(cm)	MIL(m)
Compartment 905, Kaingaroa	Diallel	1	1	36.1	0.35
			2	57.7	0.51
		2	3	41.4	0.46
			4	46.0	0.34
		3	5	32.9	0.35
			6	57.0	0.87
		4	7	42.2	0.80
			8	52.4	0.35
-	Uninodal	5	9	37.0	0.34
			10	48.6	0.71
		6	11	29.0	0.64
			12	46.3	0.38
		7	13	33.5	1.27
			14	49.3	0.48
		8	15	29.2	0.64
			16	44.0	1.55
Taringatura	Diallel	1	5	47.7	0.41
			7	53.5	0.46
		2	6	36.3	0.59
			9	50.9	0.41
		3	10	35.7	0.54
			8	56.5	0.45
		4	3	31.8	1.55
			11	50.3	0.42

Note: Family code and tree number are as used in the analysis.
Dbh and Mean Internode Length (*MIL*) measurements are as recorded by Turner *et al.* (1997)

Table 2. Branch sample statistics per stratum.

Stratum	No. of sample		Branch Age (yrs)	Maximum branch diameter (mm)
Diallel Kaingaroa	137	Min	7	9
		Max	16	100
Uninodal Kaingaroa	127	Min	7	8
		Max	17	73
Diallel Taringatura	126	Min	7	8
		Max	17	92

Table 3. Number of branch sample selected according to the maximum branch diameter grouping.

Group	Diallel Kaingaroa	Diallel Taringatura	Uninodal Kaingaroa
Maxd < 20 mm	20	29	32
20 mm ≤ *Maxd* < 40 mm	59	46	58
40 mm ≤ *Maxd* < 60 mm	31	33	28
60 mm ≤ *Maxd* < 80 mm	20	15	9
Maxd > 80 mm	7	3	
Total branch sample	**137**	**126**	**127**

Note: *Maxd* is the under-bark maximum diameter attained by a particular branch.

METHODS AND RESULTS

The following non-linear function was used in Grace (1996b):

$$D = \frac{A}{\alpha M^{x_1} + \beta M^{-1} A + \gamma M^{x_2} A^{0.5}}$$ **Equation 1**

Where D is the branch diameter (mm).

M is the maximum diameter of the branch (mm).

A is the age of the branch (years).

α, β, γ, x_1, x_2 are the coefficients.

The function was tested by fitting the new data sets to the Equation 1 (Table 4) and the residuals were plotted (Figures 1-4). The residual in the estimated branch diameter was calculated as the actual minus the estimate.

Table 5 shows the Mean Square Error (*MSE*) and I^2 for the three strata.

Table 4. The coefficients of the fitted equations

Stratum	α	β	γ	x_1	x_2
Uninodal Kaingaroa	0.991479 *(0.074750)*	1.951323 *(0.028010)*	-1.967994 *(0.105446)*	-0.443295 *(0.017775)*	-0.725352 *(0.010603)*
Diallel Kaingaroa	0.569895 *(0.053881)*	1.924156 *(0.037441)*	-1.403330 *(0.105103)*	-0.296996 *(0.020315)*	-0.640595 *(0.013426)*
Diallel Taringatura	1.093734 *(0.115868)*	1.835413 *(0.042991)*	-1.834820 *(0.157506)*	-0.465099 *(0.023412)*	-0.723106 *(0.015610)*
General	0.741781 *(0.039980)*	1.897223 *(0.021383)*	-1.595252 *(0.067528)*	-0.366053 *(0.011855)*	-0.678005 *(0.007719)*
Experiment RO696[1]	0.990000	1.920000	-1.910000	-0.440000	-0.720000

Note: The standard error of the respective coefficient is in italic.

Table 5. The Mean Square Error and Coefficient of Determination of the fitted equations.

Stratum	*MSE*	I^2
Uninodal	4.7012	97.82%
Diallel Kaingaroa	10.4219	96.85%
Diallel Taringatura	9.6369	96.81%
General	8.5719	97.03%

Where $I^2 = 1 - \frac{SS(Residual)}{SS(Corrected\ Total)}$

Figures 5-8 show examples of the branch growth using the new fitted equations for 16 year-old branches with maximum branch diameters between 25mm - 100 mm. Figure 9 illustrates the maximum differences between the growth curves. Finally, Figure 10 shows the age when the branch first reaches the maximum diameter.

DISCUSSION

The branch diameter growth equations give little overall bias for Kaingaroa and Taringatura forests. *MSE* for the two diallel strata (Table 5) are twice the value for the uninodal stratum. Figures 1-4 clearly show the sections where the large residuals occurred the most; that is where the maximum branch diameter is larger than 60 mm. The sample statistics (Table 3) also show that the number of sample branches with maximum diameter more than 60 mm from the Diallel strata in Kaingaroa and Taringatura were at least two times the number of samples from the Uninodal Kaingaroa. For illustration, Figure 7 shows the maximum

[1] The equation for this stratum was fitted by Grace (1996b) and the standard errors are not available.

distances between the predicted curves of the four strata ranged from 0.1 mm to 3.4 mm for the branches with maximum diameter less than 75 mm. The range is small considering the variation of branch sizes. The larger branches with maximum diameter around 100 mm were not well presented in the sample (6 branches in total), especially the sample branches from the Uninodal Kaingaroa. Figure 4 shows that this particular branch size had the highest maximum differences between the predicted curves. If the problem is due to the sample selection then it might be resolved by selecting more sample of this category in the future collection. However it might also be the fact that the branch occurrence for this particular category is rare in the field.

The coefficient of determination (I^2) showed a minimum of 96% fit in all strata. Figure 9 shows the maximum distances between the predicted branch diameter curves for four different sizes of 16 year old branches. The maximum distance between the predicted curves is only 1-1.5 mm. Hence the general equation can be used to predict the branch diameter growth from the three sites.

The branch growth equation was tested by calculating the estimates of the branch diameter for the yearly growth. The residuals were grouped by branch age and the mean and 95% confidence interval for each group calculated. These residuals were plotted over the branch age on figures 11-14 . The branch diameter was well predicted for all strata.

CONCLUSION

The non linear equations developed here predict the branch diameter growth in Compartment 905 (Kaingaroa) and Taringatura (Southland) very well and they can be incorporated into the prototype version of the branch model.

Future Direction

Although the non-linear equation that predicts the change in branch diameter with time gives a good estimation, it is not as flexible as a function that predicts branch diameter increment from current branch diameter, tree and stand condition. Such a function will be particularly useful for predicting branch response to thinning (Grace 1998b) and it may also explain the wide variability in relative branch diameter within a cluster (Grace 1996a).

REFERENCES

Grace, J.C. 1996a: Diameter of branches within a cluster in Experiment RO696. Stand Growth Modelling Co-operative Report No. 50 (unpublished).

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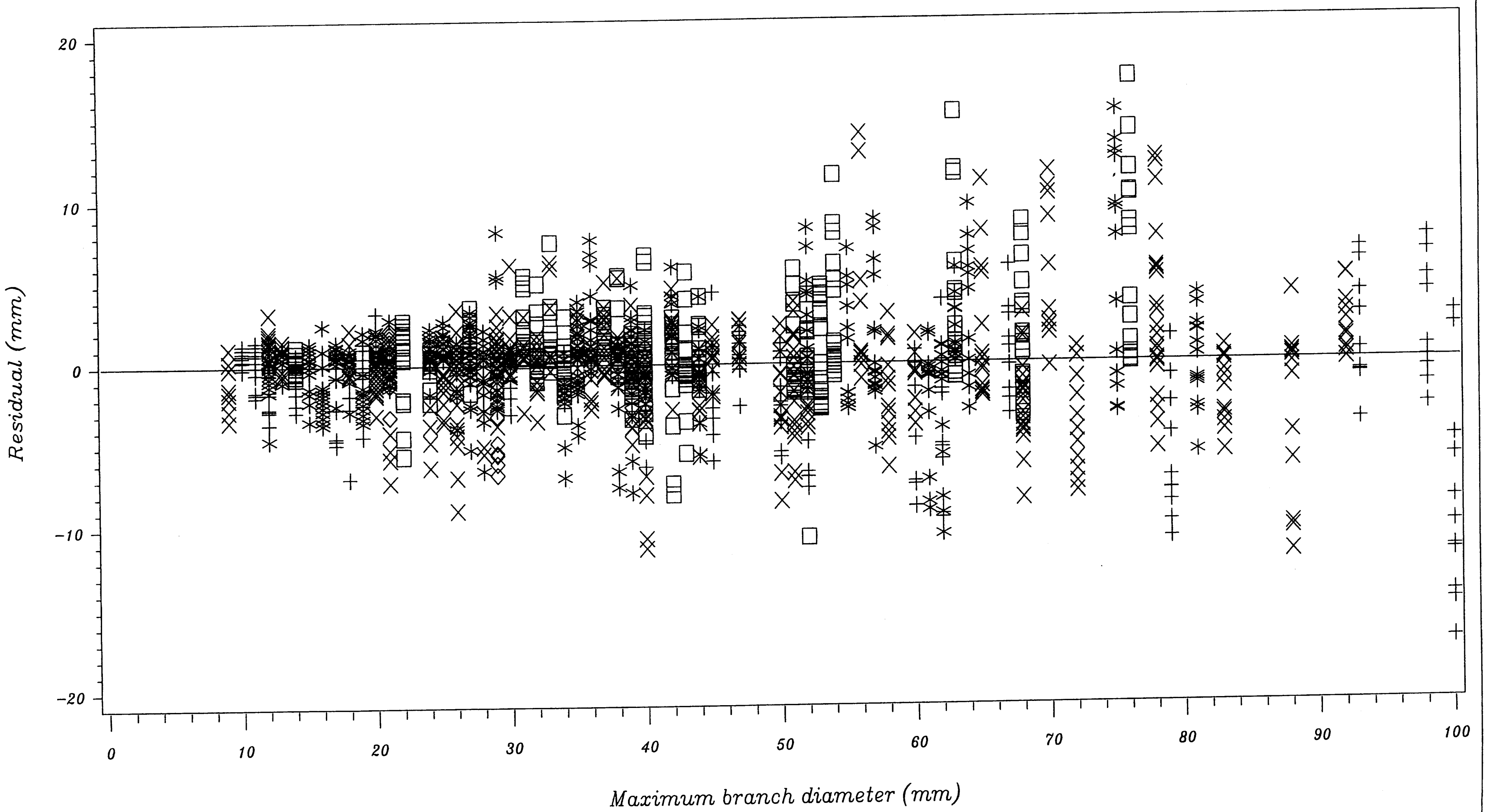
Grace, J. C; Pont, D; Blundell, W; Duyvesteyn, D and Budianto, M. 1998c: Branching characteristics of radiata pine in Compartment 905, Kaingaroa. Data Collection. Stand Growth Modelling Co-operative Report No. 63 (unpublished).

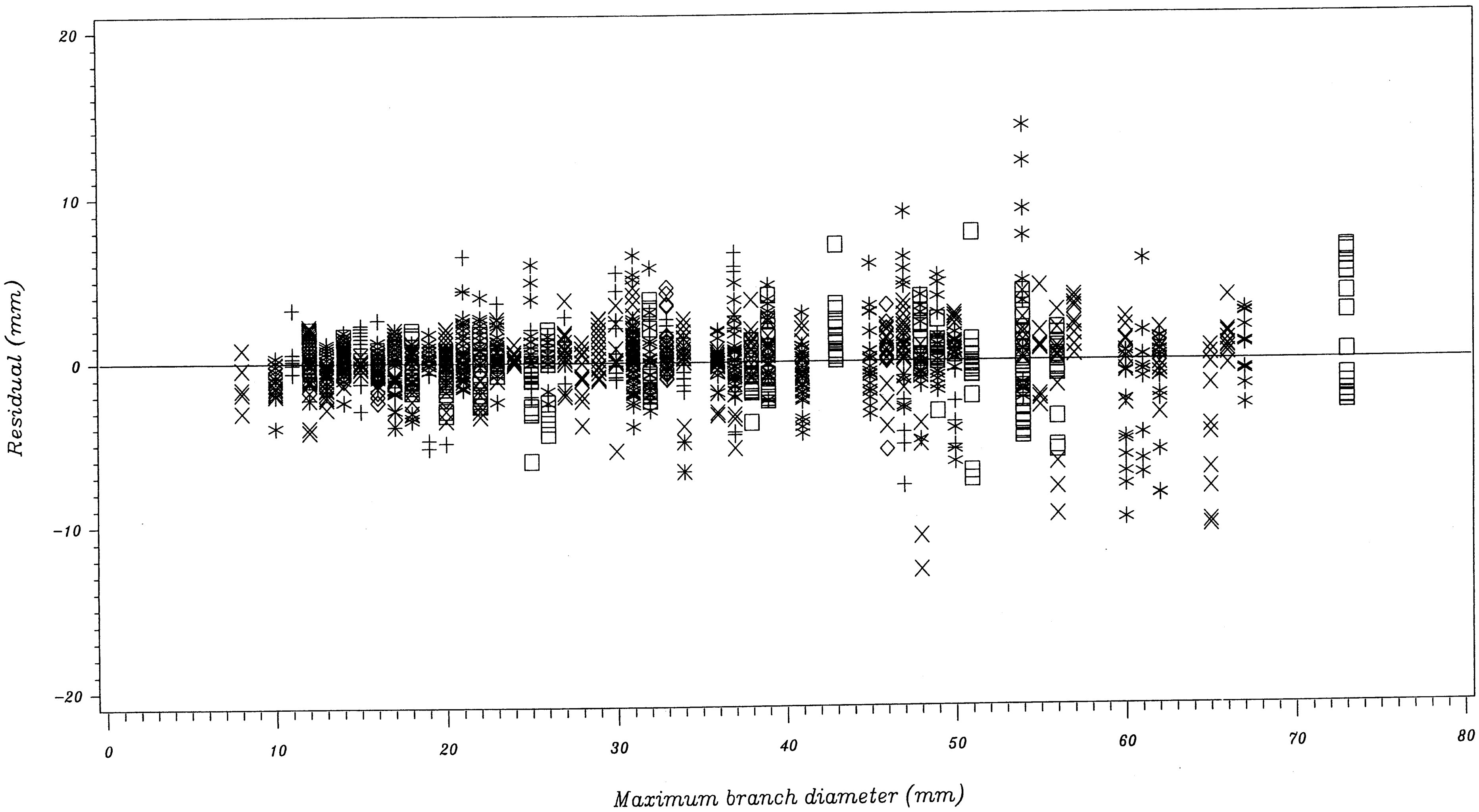
Residuals in Branch Diameter Estimate against Maximum Branch Diameter

Figure 1 STRATUM=diall905



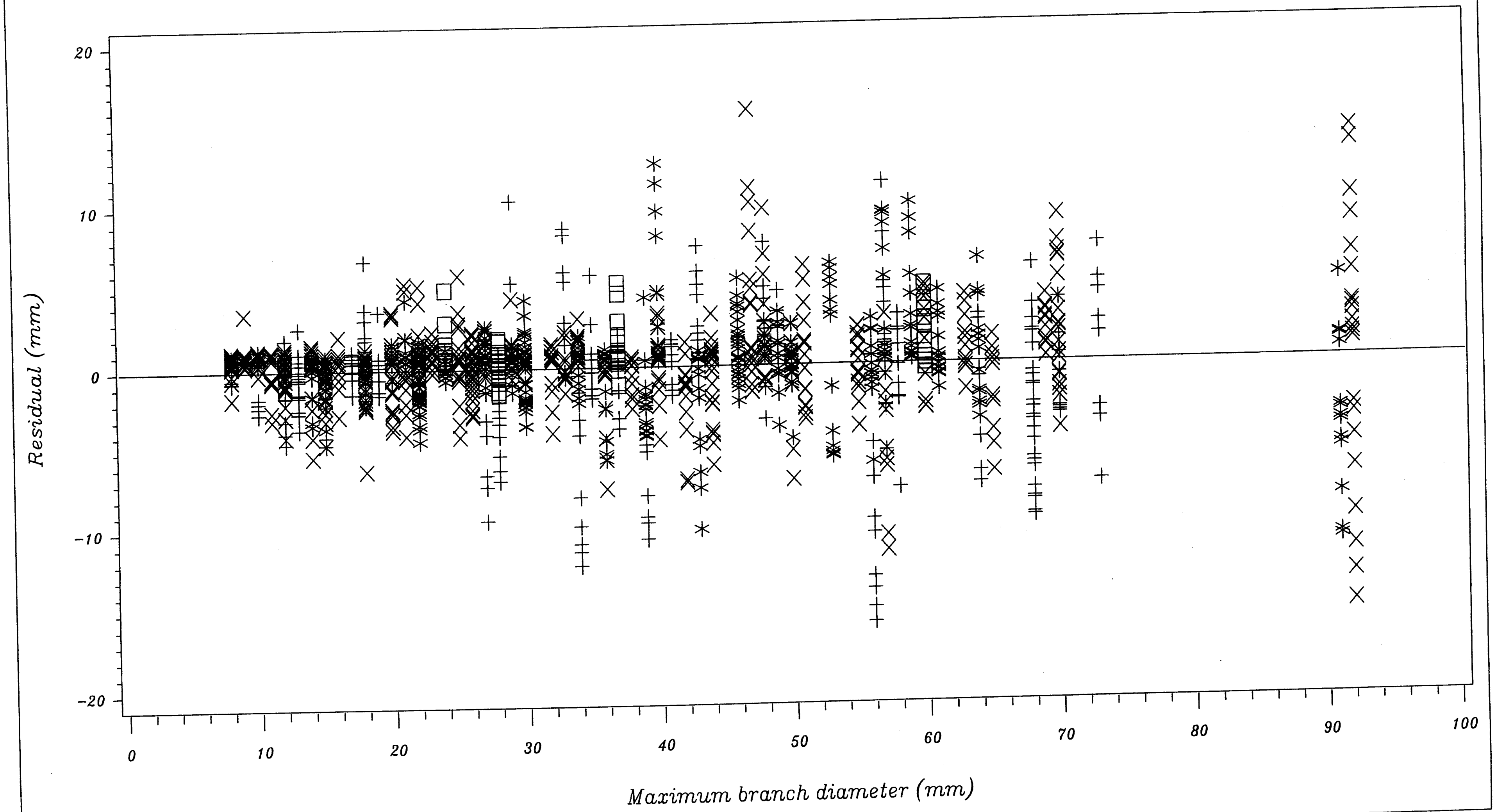
Residuals in Branch Diameter Estimate against Maximum Branch Diameter

Figure 2 STRATUM=uni905



Residuals in Branch Diameter Estimate against Maximum Branch Diameter

Figure 3 STRATUM=taring



Residuals in Branch Diameter Estimate against Maximum Branch Diameter
Figure 4. All Strata. General equation

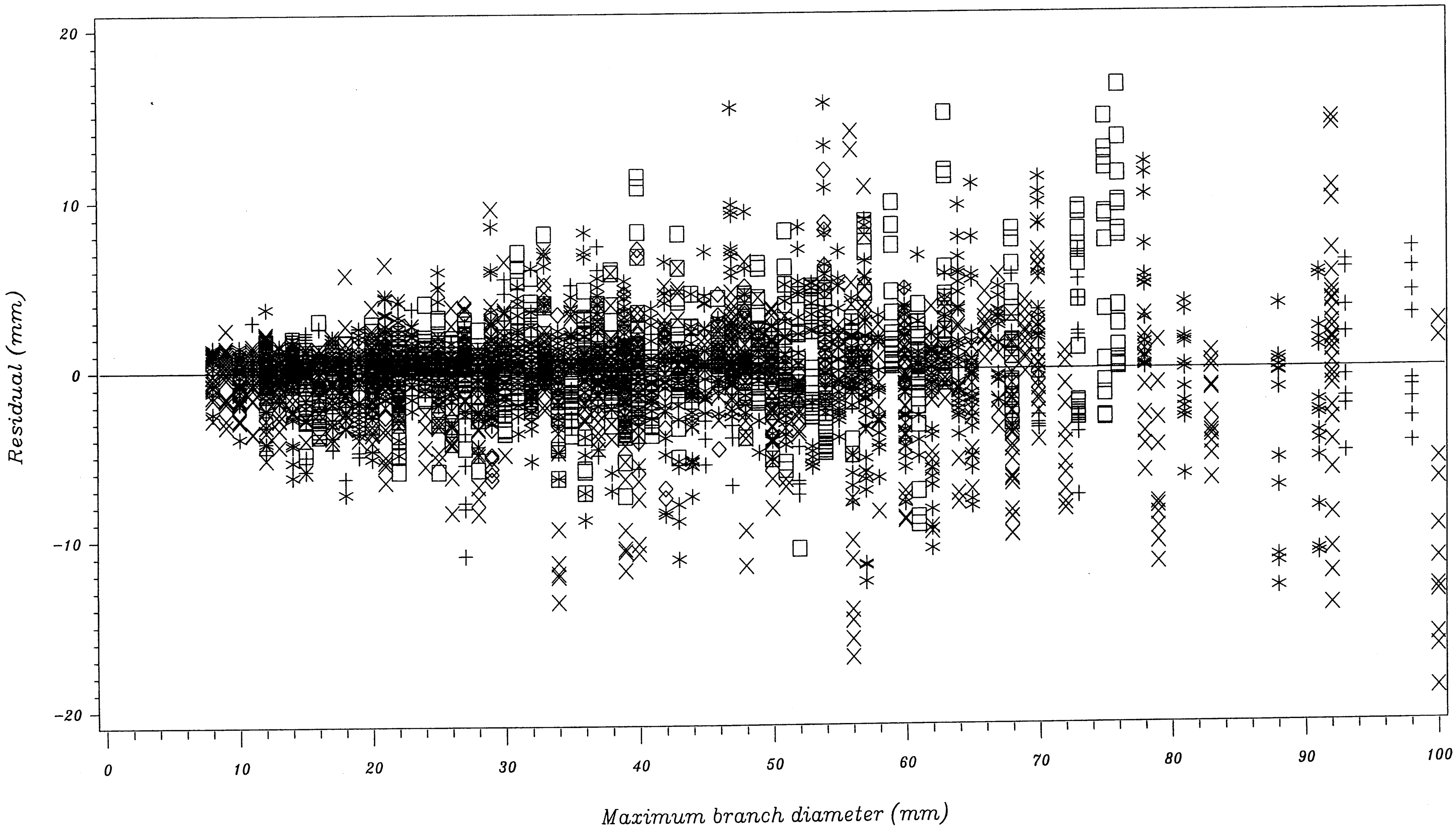


Figure 5

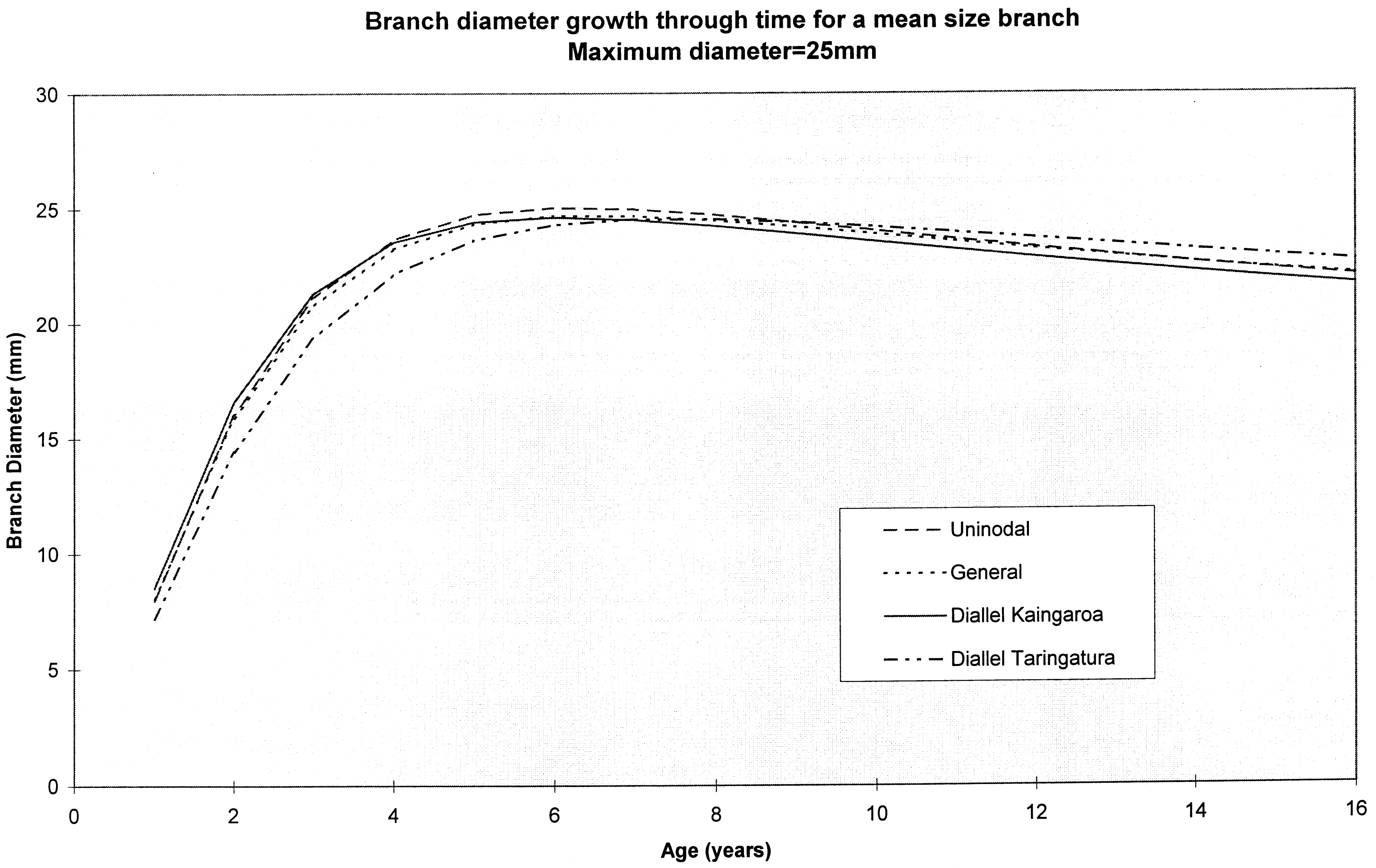
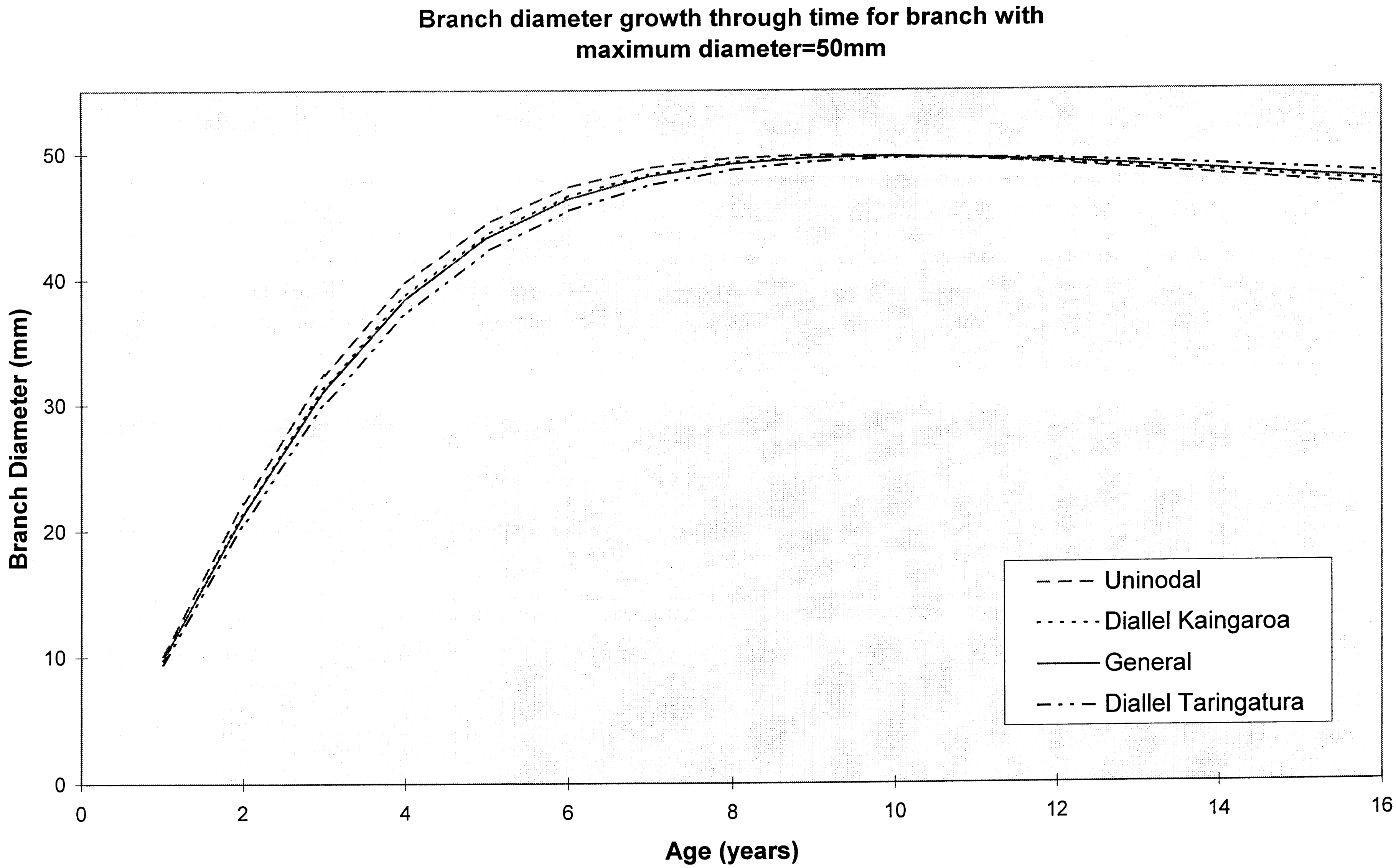
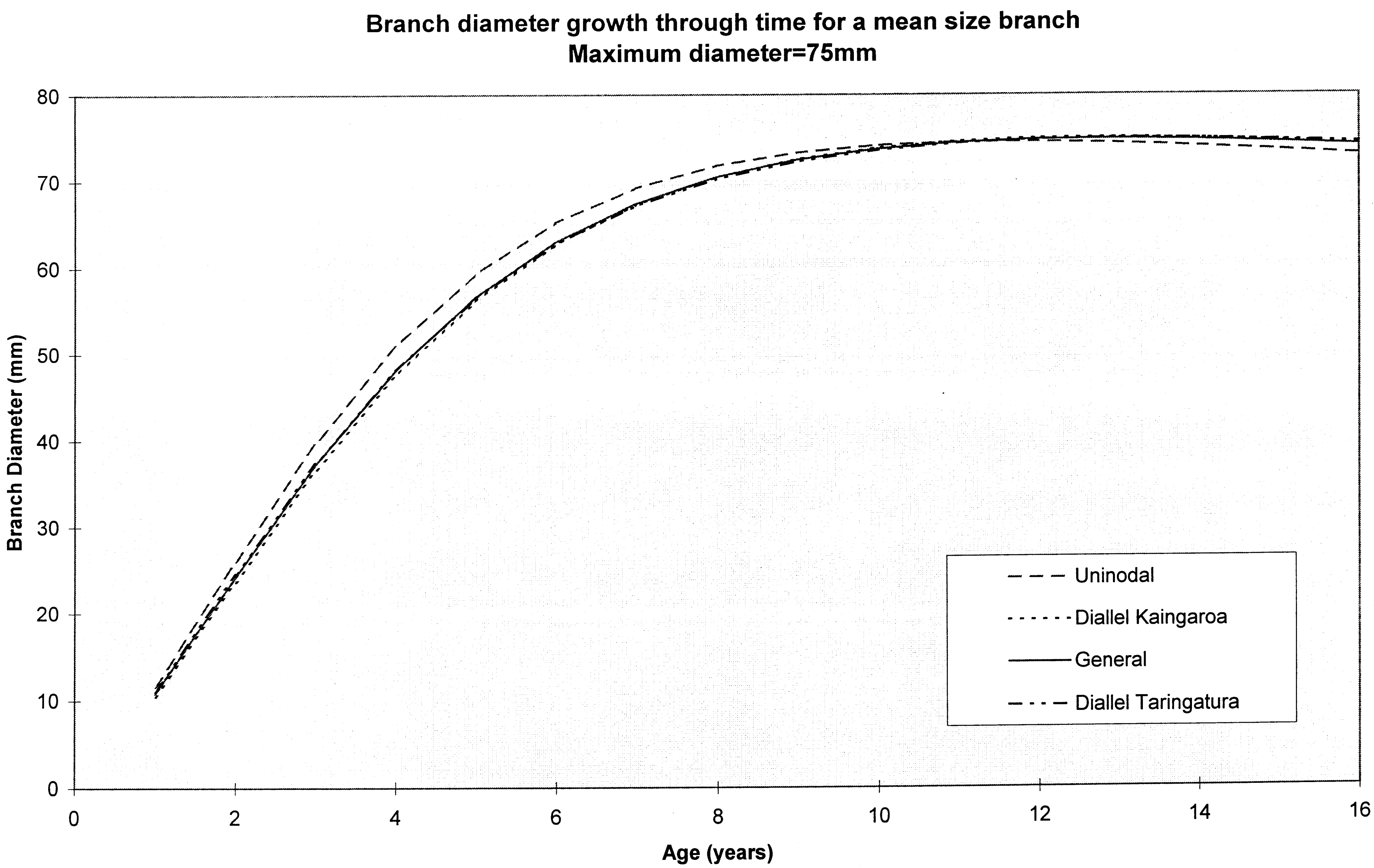

Branch diameter growth through time for a mean size branch
Maximum diameter=25mm
30
25
20
15
10
5
0
Branch Diameter (mm)
0
2
4
6
8
10
12
14
16
Age (years)
Uninodal
General
Diallel Kaingaroa
Diallel Taringatura

Figure 6



Branch diameter growth through time for branch with maximum diameter=50mm
Branch Diameter (mm)
0
10
20
30
40
50
Age (years)
0
2
4
6
8
10
12
14
16
Uninodal
Diallel Kaingaroa
General
Diallel Taringatura

Figure 7



Branch diameter growth through time for a mean size branch
Maximum diameter=75mm
Branch Diameter (mm)
Age (years)
0
10
20
30
40
50
60
70
80
0
2
4
6
8
10
12
14
16
Uninodal
Diallel Kaingaroa
General
Diallel Taringatura

Figure 8

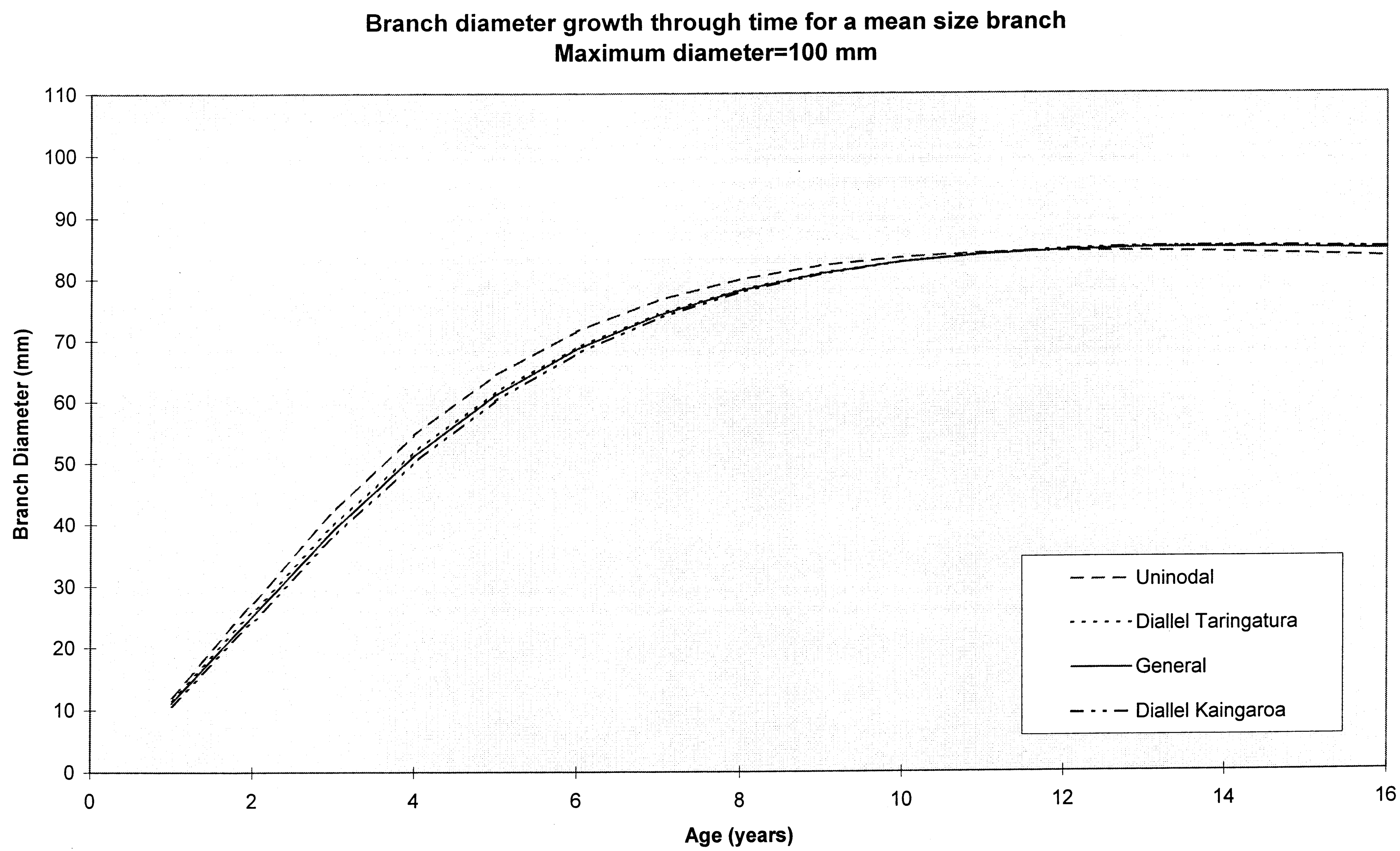
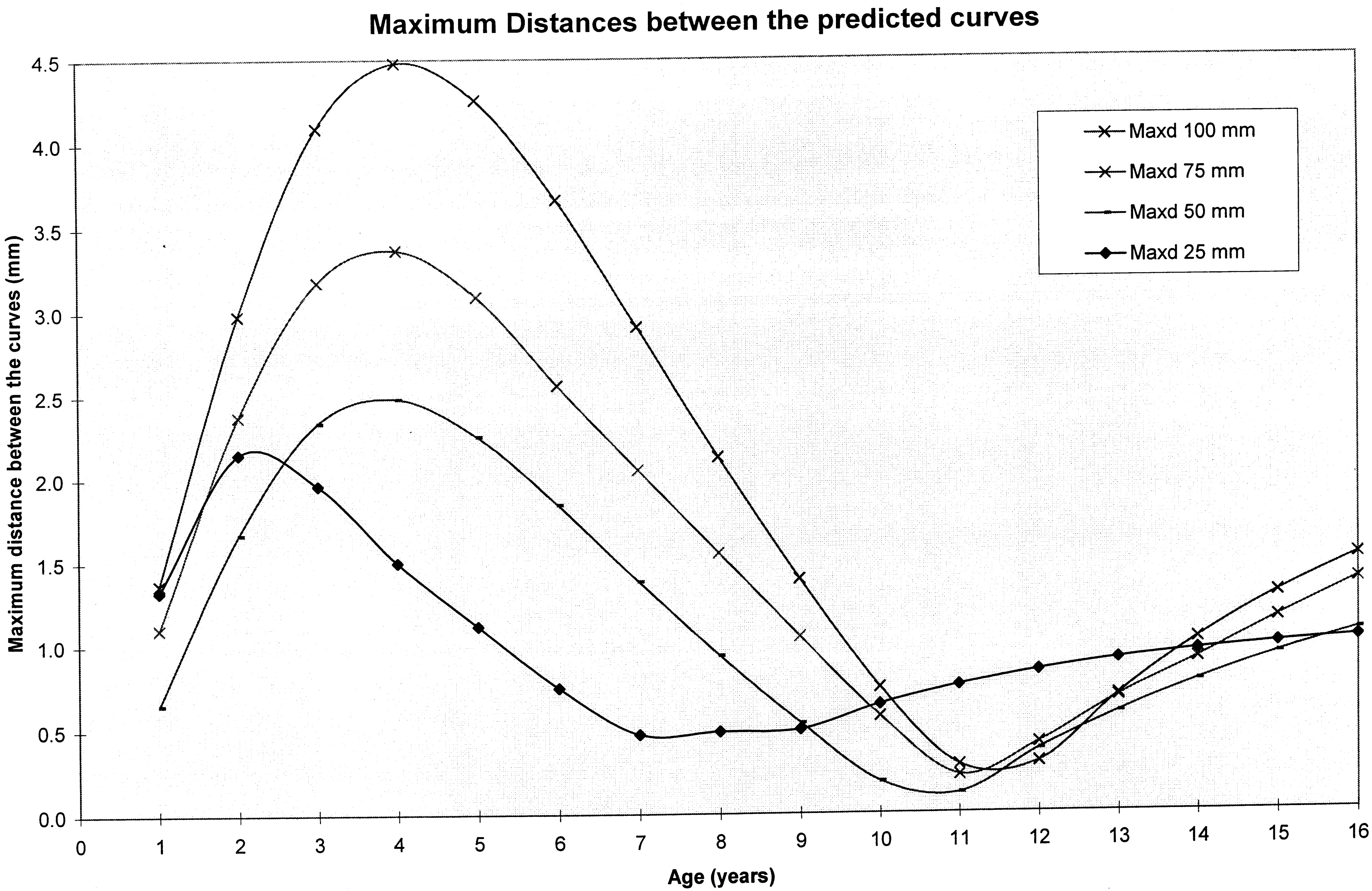
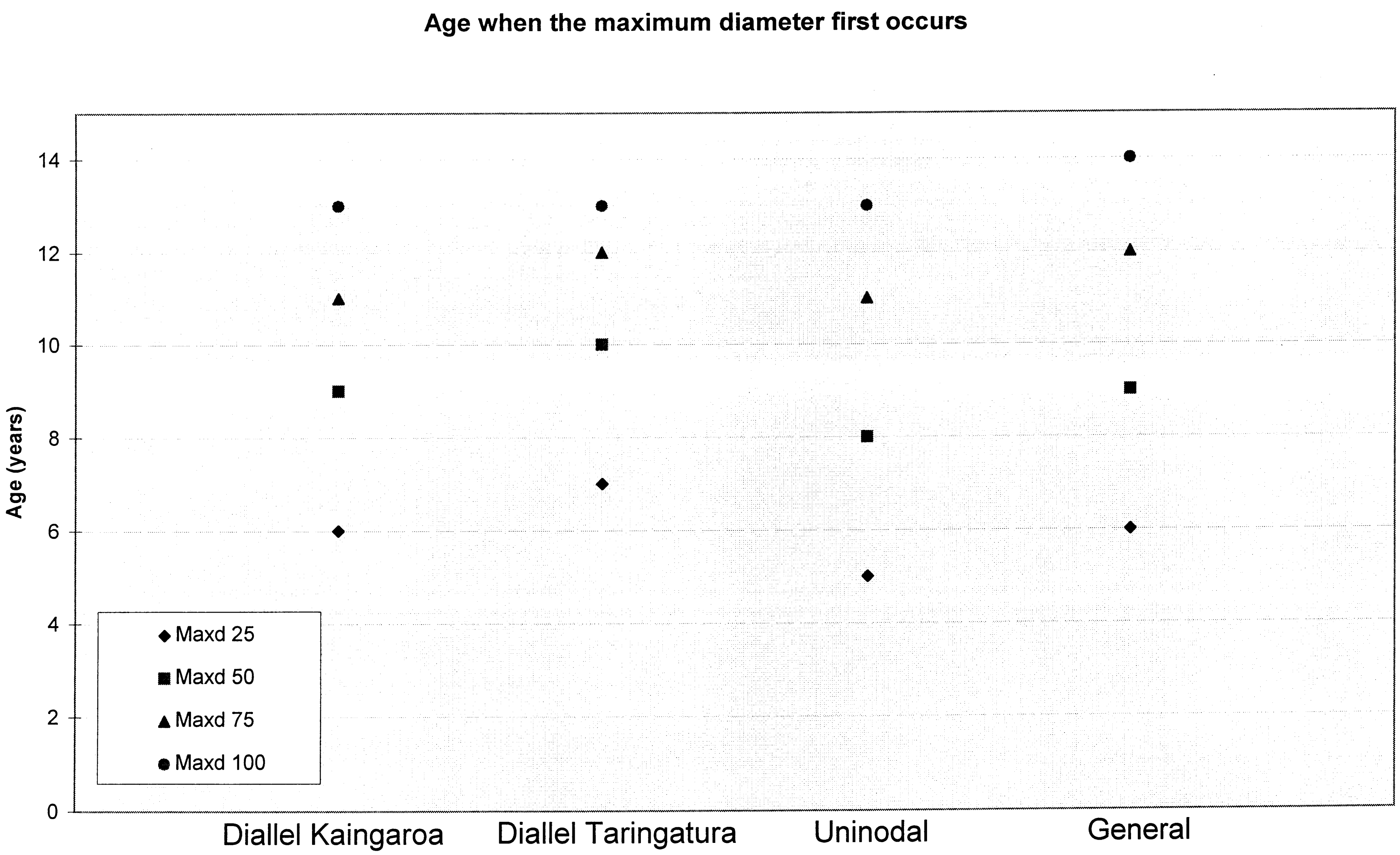

Branch diameter growth through time for a mean size branch
Maximum diameter=100 mm
Branch Diameter (mm)
110
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
Age (years)
Uninodal
Diallel Taringatura
General
Diallel Kaingaroa

Figure 9



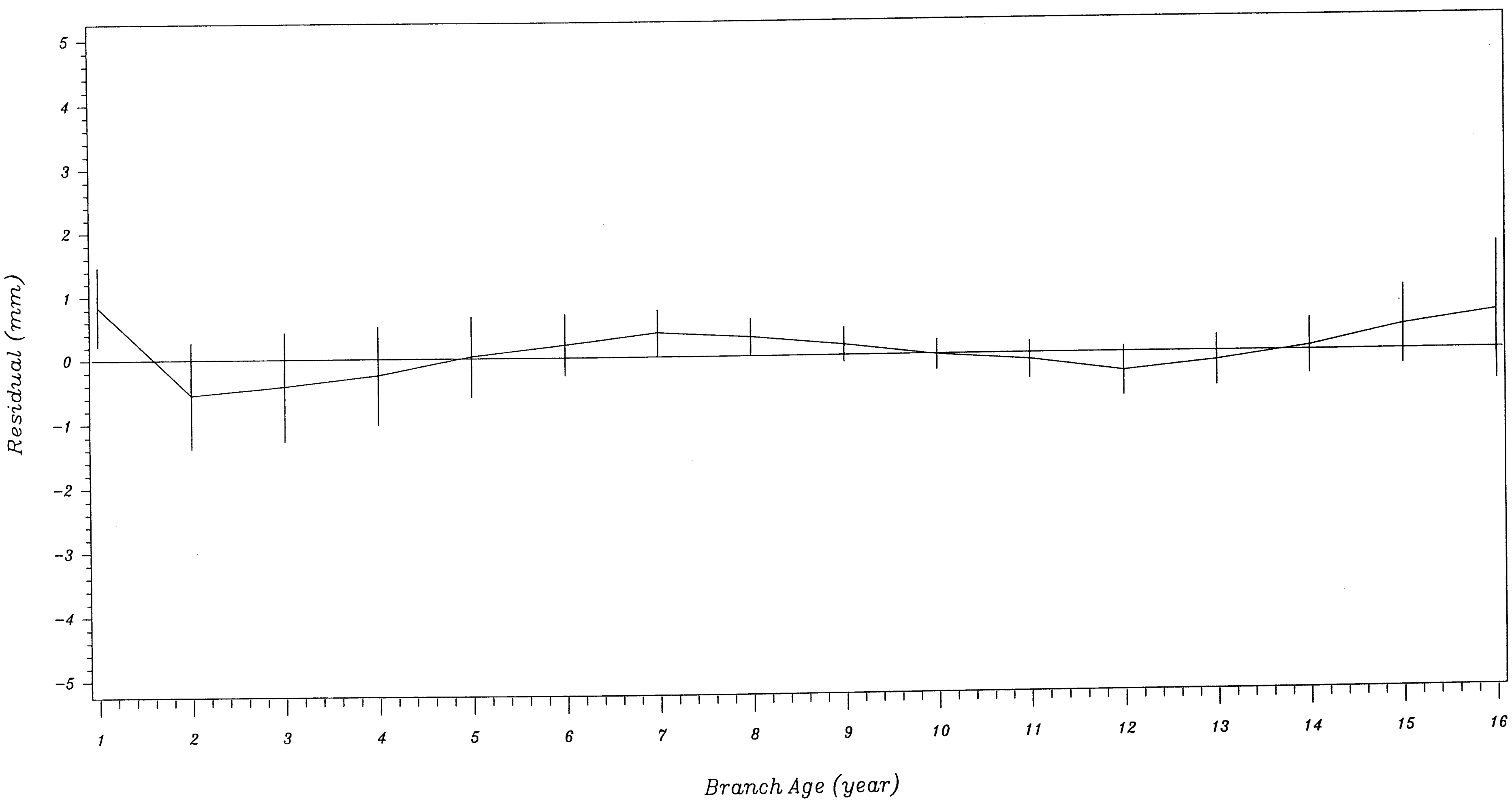
Maximum Distances between the predicted curves
Maxd 100 mm
Maxd 75 mm
Maxd 50 mm
Maxd 25 mm
Maximum distance between the curves (mm)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Age (years)

Figure 10


Age when the maximum diameter first occurs
Age (years)
14
12
10
8
6
4
2
0
Maxd 25
Maxd 50
Maxd 75
Maxd 100
Diallel Kaingaroa
Diallel Taringatura
Uninodal
General

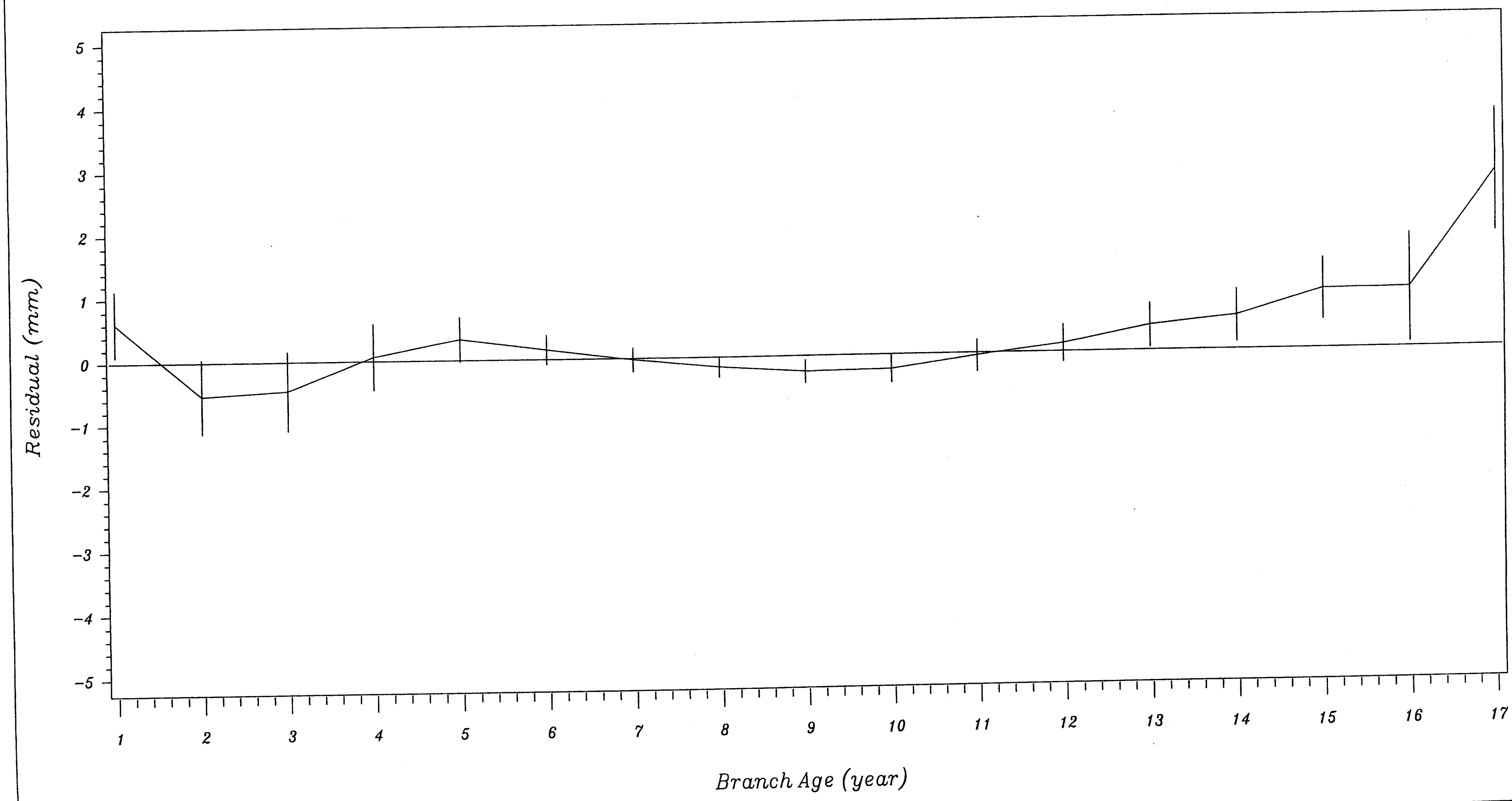
Residuals in Branch Diameter Estimate against Branch Age
Approximate confidence intervals are shown.

Figure 11 STRATUM=diall905



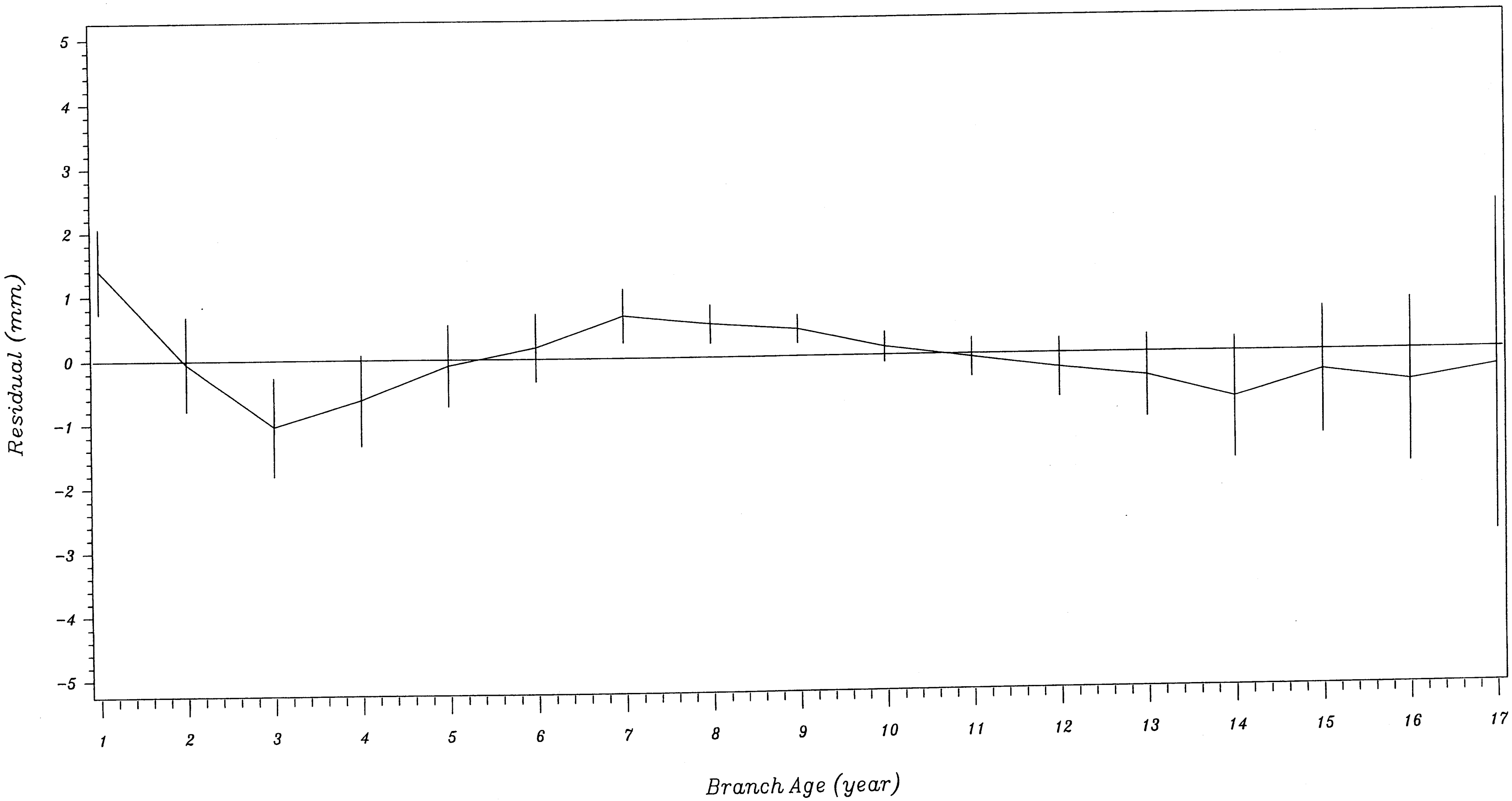
Residuals in Branch Diameter Estimate against Branch Age
Approximate confidence intervals are shown.

Figure 12 STRATUM=uni905



Residuals in Branch Diameter Estimate against Branch Age
Approximate confidence intervals are shown.

Figure 13 STRATUM=taring



Residuals in Branch Diameter Estimate against Branch Age
Approximate confidence intervals are shown.
Figure 14. All Strata. General equation