forest industry research cooperatives

MANAGEMENT OF EUCALYPTS

SPACING OPTIONS FOR TASMAN FOREST INDUSTRIES

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Spacing Options for Tasman Forest Industries

by

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TASMAN FOREST INDUSTRIES LIMITED

Contents

1. Introduction

The Tasman Forest Industries Limited eucalypt tree farm estate has been developed since its inception in 1993 using an establishment stocking of 1200 stems per hectare for both *Eucalyptus nitens* and *E.fastigata* . This has been estimated to yield on average 250 m^3 per hectare with an approximate piece size of between 0.25 m^3 and 0.3 m^3 at age 10 years. At the start of the project, the existing series of *E.nitens* spacing trials of the NZ Eucalypt Management Co-operative were only three years old, so could not provide any useful data to determine whether this spacing was the most economic option.

With the trials now having had their seven year measurements, analysis of the data will allow a revision of the 1200 spha. practice. The most economic spacing must maximise the yield per ha. while minimising establishment and harvesting costs without compromising the health of the stand and final pulp and paper product quality.

Permission from co-operative members was given to TFIL to obtain the data for all current *E.nitens* spacing trials located at Mangakahia near Dargaville in Northland, Omataroa near Te Teko in the Bay of Plenty, Kinleith in the Waikato, Wainui east of Lake Taupo, Drumfern near Lumsden in Southland and Garden near Miller's Flat, Otago. A condition placed on acquisition of the data was that the co-op will receive a copy of this analysis.

After validation of the data, analysis has only been carried out on the Omataroa and Kinleith data sets as these would be most representative of the TFIL estate. Wainui data was prepared but not analysed due to irregularities with plot sizes.

Excel version 97, run on a 200 Mhz Pentium Computer with 32 Mb of RAM was used for the analysis.

2. Data

Data was received in two files in .DBF format namely FR137_SUM.DBF and FR137_TRE.DBF. These had been prepared by copying selected fields from the Forest Research PSP system on which all trial data is stored.

Each file had the following fields

FR137_SUM.DBF

- *PLOT_ID* - Trial Number, Location Number, Replicate Number and Regime Number. (eg. FR 137/ 2 1/ 5)
- *FOREST* - Forest Location. (eg. OMAT)
- *HT_ADJ_AGE* - Age at time of measurement .(eg. 3.5500)
- *MEAS_DATE* - Measurement Date. (eg. 22/11/93 00:00:00)
- *PLOT_SIZE* (eg. 0.0400)
- *HD_COEF_B1* – Petterson DBH/Height Coefficient B_1 (eg. 0.3762)
- *HD_COEF_B2* – Petterson DBH/Height Coefficient B_2 (eg. 20.9793)

FR137_TRE.DBF.

- *PLOT_ID* - Trial Number, Location Number, Replicate Number and Regime Number. (eg. FR 137/ 2 1/ 5)
- *TREENO* - Tree Number (eg. 9)
- *HT_ADJ_AGE* - Age at time of measurement .(eg. 3.5500)
- DBH - Diameter at Breast Height (cm.) (eg. 10.7)
- TOTAL_HT - Tree Height (eg. 8.4)
- STATUS - Tree Status (eg. A, X, W, F for alive , dead, windblown and felled respectively)
- DBH_CODE - Code for type of DBH (eg. U = unrepresentative)

The following operations were carried out on the data :

- Data was entered into an Excel file, and copied to worksheets FR137_SUM (FR137_SUM.DBF) and FR137_TRE (FR137_TRE.DBF).
- All data for Mangakahia, Gardens and Drumfern was deleted.
- Duplicate records were deleted (713 in FR137_TRE and 3 in FR137_SUM)
- Regimes were deleted to leave the following :
  - Omataroa - 2500, 1667, 1111 and 625 spha. all unthinned.
  - Kinleith - 2500, 1667, 1111 and 625 spha. all unthinned.
  - Wainui - 2500, 1667, 1111, 833 and 625 spha. all unthinned.

- The following were deleted :
  DBH_CODE field as there were no entries in this field in the amended data set.
  All dead trees (STATUS = "X").
  All trees with DBH = 0.
  All 4.4 year old data for Omataroa as there were no Petterson co-efficients.
  All 3.75 year old data for Wainui as there were no Petterson co-efficients.

- The following fields were inserted :
  FOREST field into FR137_TRE and names in the FOREST field of FR137_SUM were lengthened to full names.
  DBH_CLASS whereby diameters were put into 2cm diameter classes.

- The following calculations were made :
  All missing heights in the FR137_TRE worksheet were calculated using Petterson Coefficients using the equation :

$$\text{Height} = 1.4 + (B_1 + B_1/\text{Dbh})^{-2.5}$$

  Volumes were calculated using the equation in Co-op Report No. 9

$$\begin{aligned}\text{Volume} = {} & (\text{PI}()*\text{Dbh}^2*\text{Ht}^2/(40000*(\text{Ht}-1.4)^{2}))*(0.8066*((1-(((-0.2957*(1-1.4/\text{Ht})^{5.7928}) \\ & +(0.4963*(1-1.4/\text{Ht})^{32}))/(1-1.4/\text{Ht})^{2}))*\text{Ht}^{(2+1)}/(\text{Ht}^{(2)}*(2+1)) \\ & -0.2957*\text{Ht}^{(5.7928+1)}/(\text{Ht}^{(5.7928)}*(5.7928+1)) \\ & +0.4963*\text{Ht}^{(32+1)}/(\text{Ht}^{(32)}*(32+1)))+0.1309*((1-(((-0.2957*(1-1.4/\text{Ht})^{5.7928}) \\ & +(0.4963*(1-1.4/\text{Ht})^{32}))/(1-1.4/\text{Ht})^{2}))*\text{Ht}^{(2+2)}/(\text{Ht}^{(2+1)}*(2+2)) \\ & -0.2957*\text{Ht}^{(5.7928+2)}/(\text{Ht}^{(5.7928+1)}*(5.7928+2)) \\ & +0.4963*\text{Ht}^{(32+2)}/(\text{Ht}^{(32+1)}*(32+2))) \\ & -0.1231*((1-(((-0.2957*(1-1.4/\text{Ht})^{5.7928}) \\ & +(0.4963*(1-1.4/\text{Ht})^{32}))/(1-1.4/\text{Ht})\text{^}2))*\text{Ht}^{(2+9)}/(\text{Ht}^{(2+8)}*(2+9)) \\ & -0.2957*\text{Ht}^{(5.7928+9)}/(\text{Ht}^{(5.7928+8)}*(5.7928+9)) \\ & +0.4963*\text{Ht}^{(32+9)}/(\text{Ht}^{(32+8)}*(32+9))))\end{aligned}$$

3. Analysis

Pivot tables in Excel 7.0 were used extensively in the analysis of the data.

Analysis was only confined to age 7.05 results at both sites to reduce the confounding effect of time on results and because age 7 is the oldest complete set of spacing data for *E.nitens* closest to TFIL's target felling age of 10 years.

Results of the analysis are shown in the attached graphs :

4. Discussion

4.1 Diameter Distribution

- Graphs 1 & 2 – Stocking (SPHA) by DBH Class(2cm)
  - Both sites show a skewing of distributions for higher stockings to the smaller diameters and tailing off to the larger diameters. The opposite holds true for the lower stockings with a skewing to the larger diameters and tailing toward the smaller diameters.
  - The 1111 initial stocking shows an approximate normal distribution, more so at Omataroa.

4.2 Volume Distribution

- Graphs 3 & 4 – Volume (m^3/ha) by DBH Class(2cm)
  - As anticipated, the distribution of volume by diameter class mirrors the distribution of stems ie. more volume held on small stems for higher stockings and more volume held on large stems for lower stockings.
  - With 1111 spha. for Omataroa distribution is almost normal with some skewing towards the larger stems, but for Kinleith there is a marked skewing toward the larger stems.

4.3 Reverse Cumulative Volume and Stocking Distributions

- Graphs 5 to 12 : Reverse Cumulative Values % by DBH Class(2cm)
- Each graph reads as follows :
  For each diameter class, there are two values : volume % and stocking %. Because the distributions are reverse cumulative, for a given dbh class, the volume % of the stand volume is held in the largest stocking % of the stems. All the percentage volume will be of a diameter greater than the 2cm diameter class at which the percentages occur.
  Eg. For Graph 5 : 93 % of the volume is held in 75 % of the stems with a minimum diameter of 13cm.(Midway between 14cm and 12cm diameter class).
- Values for the graphs are shown in Tables 1 and 2 below.

Table 1 : OMATAROA at 7.05 years ***Reverse Cumulative Values % by DBH Class (2cm)***

	DBH Class											
Stocking	***4***	***6***	***8***	***10***	***12***	***14***	***16***	***18***	***20***	***22***	***24***	***28***
625 - Volume	100	100	100	99	95	93	88	72	50	45	25	0
625 - Stocking	100	98	95	93	79	76	67	48	28	24	12	0
1111 - Volume	100	100	100	98	94	81	66	50	35	16	7	2
1111 - Stocking	100	99	98	93	82	62	43	28	17	7	3	1
1667 - Volume	100	100	99	97	84	69	49	31	16	7	4	0
1667 - Stocking	100	98	93	88	64	44	26	14	6	2	1	0
2500 - Volume	100	100	100	91	79	66	48	26	18	18	0	0
2500 - Stocking	100	100	98	77	55	40	26	11	6	6	0	0

Table 2 : KINLEITH at 7.05 years ***Reverse Cumulative Stocking % by DBH Class (2cm)***

	DBH Class										
Stocking	***4***	***6***	***8***	***10***	***12***	***14***	***16***	***18***	***20***	***22***	***24***
625 - Volume	100	100	100	100	97	94	83	69	57	31	12
625 - Stocking	100	100	100	100	87	80	62	45	35	16	5
1111 - Volume	100	100	100	99	98	96	82	70	50	27	6
1111 - Stocking	100	99	93	89	85	82	59	45	28	13	2
1667 - Volume	100	100	100	99	96	88	72	55	31	20	4
1667 - Stocking	100	100	98	93	86	71	50	33	16	9	2
2500 - Volume	100	100	99	96	92	76	55	28	10	0	0
2500 - Stocking	100	98	95	80	73	51	32	15	5	0	0

- **Omataroa**
  Graphs 5 – 625 spha.
  Graphs 6 – 1111 spha.
  Graphs 7 – 1667 spha.
  Graphs 8 – 2500 spha.

  For the largest stems, the effect of increasing the stocking is to decrease the diameter at which the threshold volume is carried, ie. the sets of graphs

move down the diameter distribution with increasing stocking. See the shaded values in Table 1 for approximately 50 percent of the volume. It is carried by between 28 % (625 spha) and 26 % (2500 spha) of the largest stems. This reflects the leftwards skewed nature of higher stocking diameter distributions.
At Omataroa, the graph sets for 1667 spha (Graph 7) and 2500 spha (Graph 8) are very similar in shape and location. This is a function of the high degree of mortality which has occurred in the 2500 spha. plots – see Graph 13.

- **Kinleith**
  Graphs 9 – 625 spha.
  Graphs 10 – 1111 spha.
  Graphs 11 – 1667 spha.
  Graphs 12 – 2500 spha.

  Graphs for Kinleith show similar trends, but the differences between stockings are not as pronounced as for Omataroa.

  What is of interest is that the 625 spha (Graph 9) and 1111 spha (Graph 10) sets of graphs are almost identical in shape and location up to 80 percent of the stocking. The smallest 20 % of volume is carried in stems between 10 and 14cm for 625 spha, but in stems between 6 and 14 cm for 1111 spha. However, this does not imply that fewer stems can be planted to reduce the small diameter tail at higher stockings. The total volumes for Kinleith are 146 m^3/ha and 105 m^3/ha for 1111 spha and 625 spha respectively .

Table 3 : Kinleith Total Volume at 7.05 years

Volume m^3/ha	625 Spha	1111 Spha	Difference
Stems smaller than 14 cm	21	29	8
Stems larger than 14 cm	84	116	32
Total	105	145	40

By reducing stocking from 1111 spha to 625 spha, the volume of stems below 14 cm is reduced by 8 m^3/ha but further reduced for stems over 14cm by 32 m^3/ha.

This shows that the same volume is not carried in the same number of large stems, regardless of the stocking. Generally, at lower stockings less volume is carried in fewer, larger stems than at comparatively higher stockings.

4.4 Stocking

- For both stocking graphs the stocking shown is higher than actual stocking due to forking of trees. The data set received from Forest Research did not differentiate between two or more stems on one stump. Hence for Omataroa all stockings except for 625 spha are higher at age 2 than the nominal stockings of 2500, 1667 and 1111 stems per ha.

- Graph 13 - Omataroa Stocking
  Omataroa displays classic mortality over time. From age 6, there has been a large amount of mortality for the 2500 and 1667 spha plantings.

- Graph 14 - Kinleith Stocking
  Kinleith shows similar trends to Omataroa, but as expected of a cooler and slower growing site , mortality is not as severe for the higher stockings. Of note is the low true initial stocking of the nominal 1667 spha. plots. Establishment mortality has reduced initial stocking to approximately 1500 spha. This is mirrored in some of the following graphs where the values for nominal 1111 spha and nominal 1667 spha are similar.

4.5 Average DBH

- Graph 15 - Omataroa Average of DBH
  As expected, over time the lower stockings have larger average diameters. However what is strange is that at age 2.25, the 2500 spha. stocking had the largest average DBH. By age 7.05 though, the expected trend has developed with it having the smallest average DBH.

- Graph 16 – Kinleith Average of DBH
  Kinleith shows the classic trend with largest diameters belonging to the lowest stockings for all ages. Of note is the similarity in diameter between the 1667 spha and 1111 spha. diameters. This is due to the lower stocking of the 1667 spha plots as mentioned in 4.4 above.

4.6 Average Height

- Graph 17 - Omataroa Average of Height.
  No surprises – higher stockings being taller due to less effort going into diameter increment through competition effects.

- Graph 18 – Kinleith Average of Height
  Kinleith by comparison shows some unusual trends. The 1667 spha is the tallest, followed by the 625 spha, then the 1111 spha and last being the 2500 spha.

4.7 Average Piece Size

- Graph 19 – Omataroa Piece Size
  The 1111 spha piece size should project to approximately 0.25 m^3 by age 10.

Piece sizes for 1667 spha and 2500 spha are similar due to similar mean diameters and the heavy mortality of small stems suffered by the 2500 spha plots.

- Graph 20 – Kinleith Piece Size
  For all stockings, Kinleith piece sizes are smaller than for Omataroa. An approximate projected piece size for 1111 spha to age 10 would be 0.2 m^3.

4.8 Total Volume

- Graph 21 – Omataroa Sum of Volume
  The heavy mortality suffered by the higher stockings has caused the 2500 spha volume to decline from around age 6 and the 1667 spha volume to decline. At age 7.05 the 1667 spha and 1111 spha stockings have similar volumes, although the 1667 spha plots have a smaller piece size and more stems per ha. The two graphs are in the process of crossing over due to continued mortality in the 1667 spha plots.

- Graph 22 – Kinleith Sum of Volume
  Once again due to Kinleith being a cooler, slower growing site, all stockings are continuing to increase volume, even at the higher stockings. There have been no crossovers of volume by age 7, but the expected trend is for the 1111 spha graph to cross over the 1667 spha graph by age 9.

- The 1111 spha has only achieved 145 m3/ha at Kinleith versus 155 m3/ha at Omataroa.

4.9 Mean Annual Increment (MAI) and Current Annual Increment (CAI)

- Graph 23 – Omataroa CAI & MAI
  CAI is expected to peak earlier with higher stockings. This has occurred at Omataroa even though the graphs don't show it too well. What is unusual is that the CAI has started increasing after age 6, particularly for 1111 spha and 625 spha. Possibly weather conditions during the 6th year caused a premature slowing in growth, which improved during the 6th year when conditions improved.
  The MAI peaks where the MAI equals CAI for any given stocking. The 1111spha MAI has peaked between ages 5 and 6 at a value of 24 m^3/ha/annum.

- Graph 24 – Kinleith CAI & MAI
  Kinleith shows more of a classic form of CAI and MAI curves. The higher stocking plots have shown an earlier decrease in CAI and MAI curves have correspondingly peaked earlier.
  1111 spha's MAI has not peaked by age 7. MAI at age 7 is 21 m^3/ha/annum.

4.10 Volume loss by reducing from 1200 to 1100 spha.

In order to determine what the effect of reducing the TFIL standard of planting 1200 spha to 1100 spha, MAI values were interpolated between 1111spha and 1667 spha for each age of measurement to estimate MAI values for 1200 spha.. The MAI volume difference was then calculated for each age and expressed as a percentage loss from the MAI for 1200 spha.

Using regression analysis, coefficients for a function of the form
Volume Loss = $\exp(B0+B1* \log(Age)+B2*\log(Age)^2)$ were derived for Omataroa and Kinleith.
These are :

Omataroa	
B0	-0.82726
B1	1.425473
B2	-0.6320
R^2	0.1772

Kinleith	
B0	-1.51145
B1	4.726832
B2	-1.80697
R^2	0.9583

The original volume loss values and regression lines are depicted in the following two graphs:

- Graph 25 – Omataroa Volume Loss – 1200 to 1100 spha
  For Omataroa the volume loss is rather erratic, hence the poor fit of the function (R^2 = 0.1772). However, the loss by planting 1100 spha, at age 10 years is projected to be only 0.4 % which approximates 10 m^3 at harvesting for an MAI of 25.
- Graph 26 – Kinleith Volume Loss – 1200 to 1100 spha
  The data for Kinleith is much more predictable, with a good fit of the regression line (R^2 = 0.9583). The final MAI difference at age 10 is approximately 0.8% or 20 m^3 .

Both these values (10 m^3 loss for Omataroa and 20 m^3 for Kinleith) are well within the confidence limits of estimation for total recoverable volume and when run through the TFIL Economic model for two rotations, despite the loss in revenue, the

IRR is increased due to cost savings on establishment costs.
For Omataroa there is a 0.05 % increase in IRR for a 0.8 % volume loss and for Kinleith a 0.08 % increase in IRR for a 0.4 % volume loss.

4.11 Growth Projections

To get some idea of what the total volume for each site would yield, for each level of stocking, it was decided to use the *E.nitens* growth model developed by Steve Candy of Forestry Tasmania. This model has been encapsulated into a user friendly interface , developed by Forest Research and available to all members of the Eucalypt Management Co-operative.

For each of the sites, mean top height, basal area and stocking values were calculated for age 7.05 and then fed into the growth model. The results of projections from age 7 to age 10 for total volume, and estimates of observed volumes up to age 7 are depicted in the following graphs :

- Graph 27 – Omataroa Sum of Volume (grown on to 10 years)
- Graph 28 – Kinleith Sum of Volume (grown on to 10 years)

The growth model does not fit the data very well.

Actual growth for the higher stockings is on the decline at age 7.05 years. The growth model then projects that growth will increase from age 7 to age 10.

The fit is not as bad for the lower stockings, but still shows a relative over projection.

For Kinleith there is an added complication in that the basal area, mean top height and stocking starting values for the model yield different volumes than the actual estimates of volumes using the Eucalypt Management Co-operative developed volume function. The difference is also there for Omataroa, but is not as apparent.

In order to test the overall effectiveness of the growth model, growth data (Basal area, mean top height and stocking) were fed into the model at age 3.55 and projected through to age 10.55 years. The results of this are shown in the following graph:

- Graph 29 – Omataroa Sum of Volume (grown on from 3.55 to 10.55 years)

Once again, the model does not fit the data very well, with over projections for all volumes, particularly for the higher stockings. The projected curves do not take on the sigmoidal form assumed by actual growth.

5. Conclusion

The analysis shows that in relative terms, it is economically viable to decrease the initial stocking from 1200 to 1100 spha. This is achieved by saving more on establishment costs than is lost through volume reductions by having less stems per ha to harvest.
The effect of thinning on the economics of the TFIL operations was not modelled. It is unlikely that it would be economically viable, but should be given some consideration.

The current growth model does not fit at all well with observed growth trends. Further validation of the model with TFIL's older PSP data for Settlers, Te Kapua and Knights tree farms will be undertaken. If similar trends are confirmed then interim adjustments must be made to allow for over estimated growth projections.

In the longer term TFIL will pursue the development of regional growth models for Taupo and the Bay of Plenty to supercede the currently used model. This will involve acquisition of further data through the Eucalypt Management Co-operative. Development should include the development of a fibre resource model, in conjunction with resource fibre and pulp property sampling, to assist the mill and TFIL with harvesting and production planning.

6. References

Gordon A., Hay E., Milne P. – A Volume and Taper Equation for New Zealand Grown *Eucalyptus nitens*. - Management of Eucalypts Co-operative Report No 9 – November 1990.

Nitens Growth Model Version 2.0 – 1997 – New Zealand Forest Research Institute Limited.

PSP Users Manual – New Zealand Forest Research Institute Limited.

MicroSoft Excel 97 Copyright 1985-1997 Microsoft Corporation.

Excel Files used :

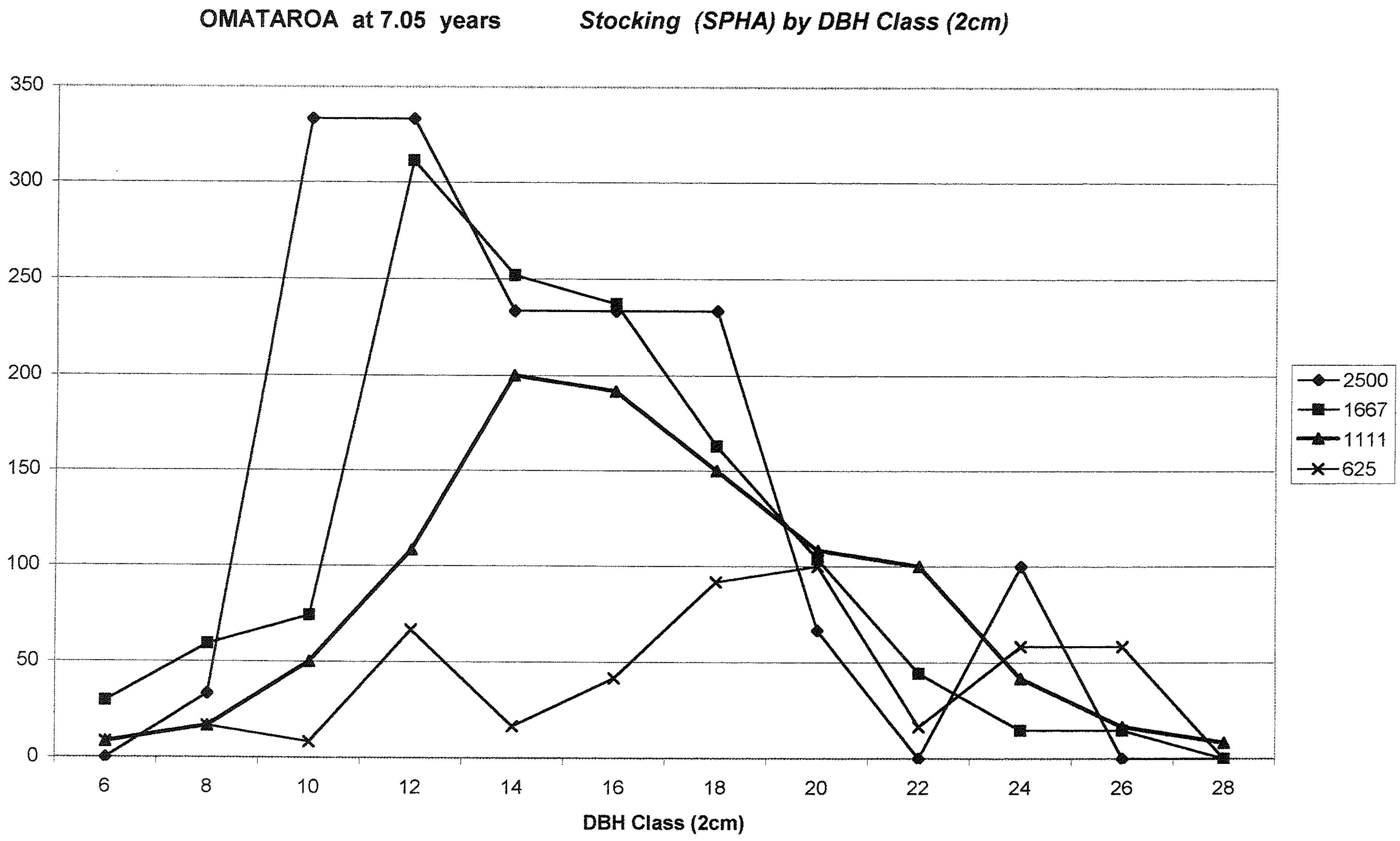
F137 Analysis.xls

F137 Analysis Version 2.xls

TFIL Economic Model – 2 Rotations.xls

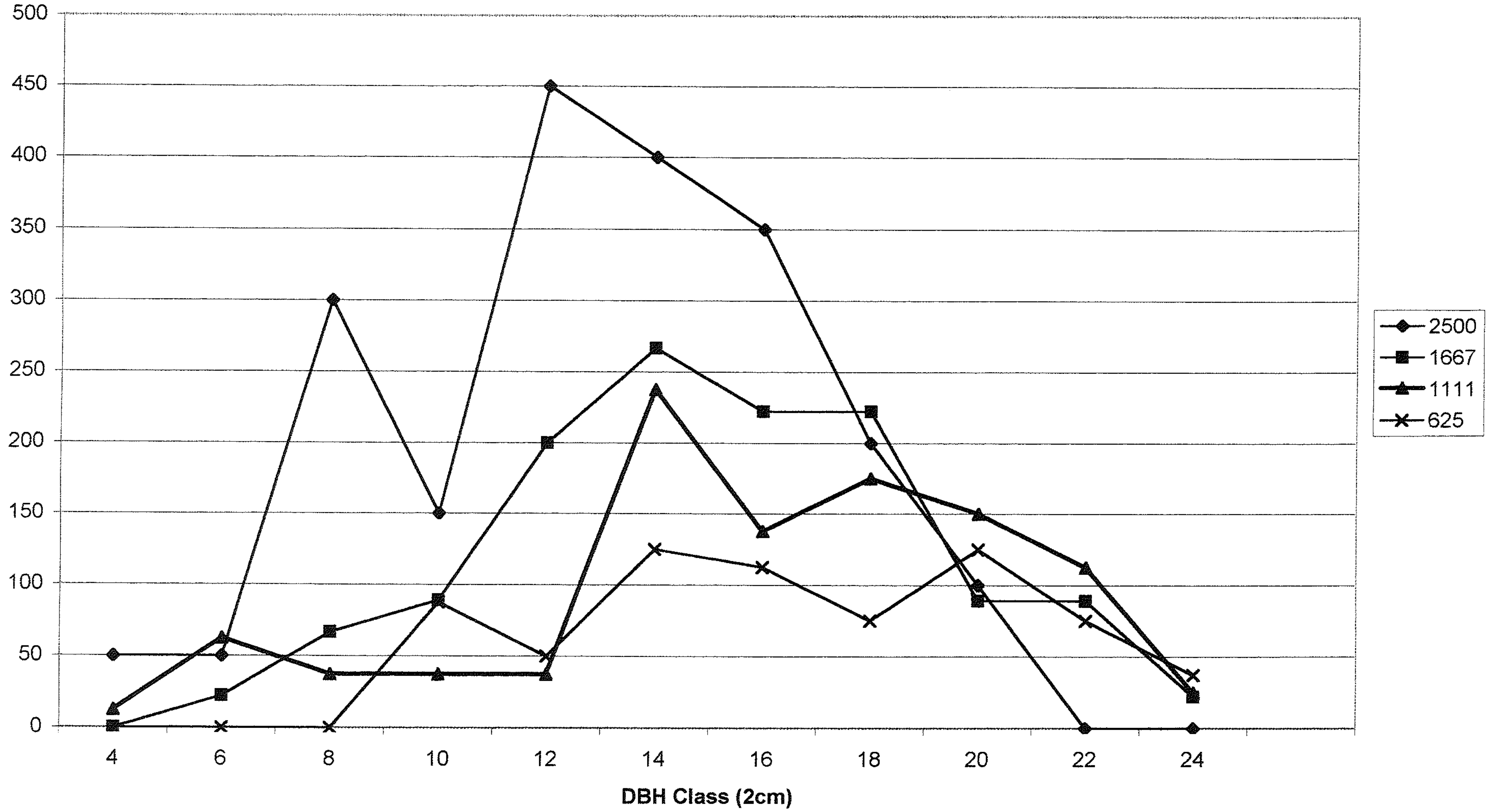
7. References

See Attached Graphs.

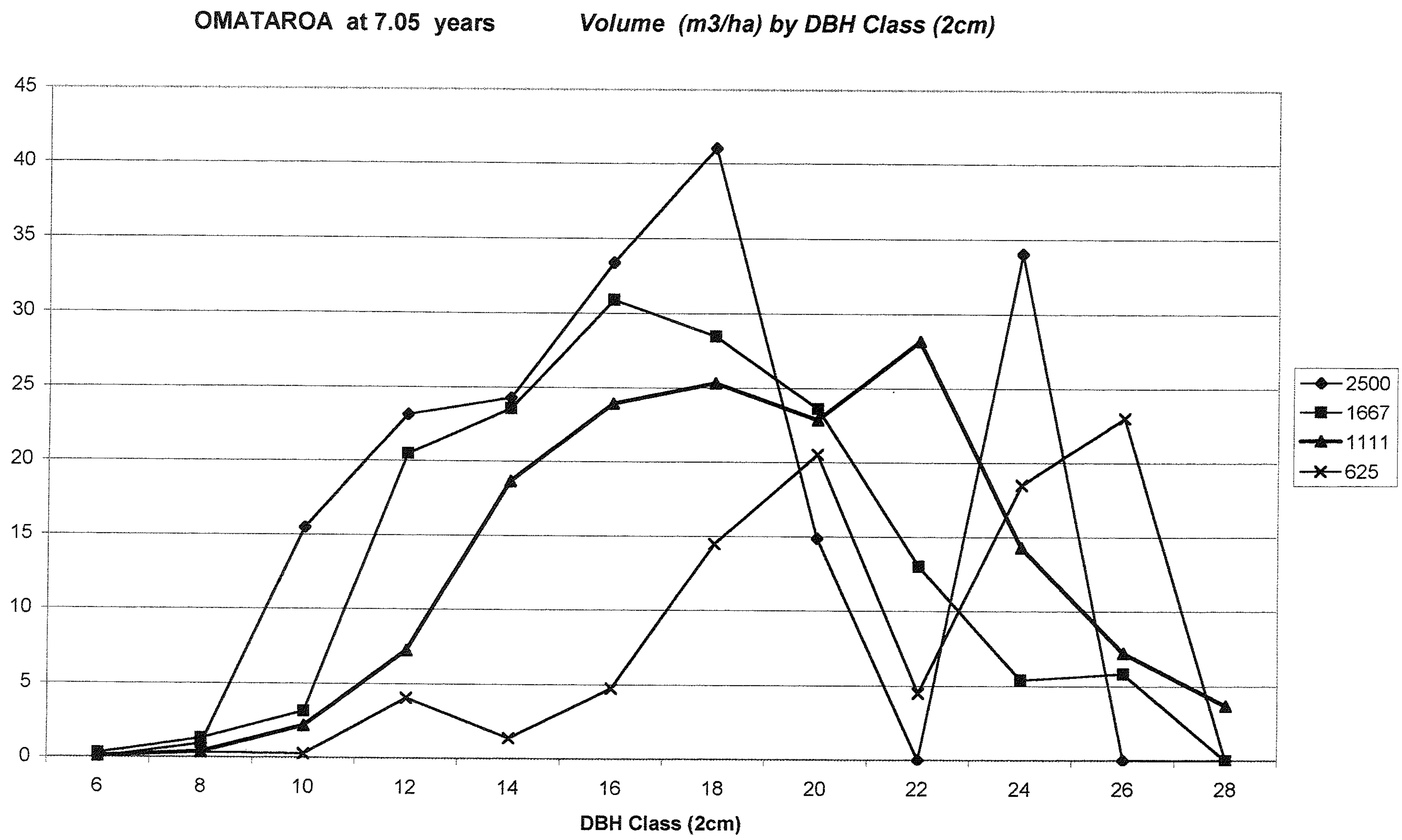

OMATAROA at 7.05 years
Stocking (SPHA) by DBH Class (2cm)
350
300
250
200
150
100
50
0
6
8
10
12
14
16
18
20
22
24
26
28
DBH Class (2cm)
2500
1667
1111
625

Graph 1

KINLEITH at 7.05 years *Stocking (SPHA) by DBH Class (2cm)*

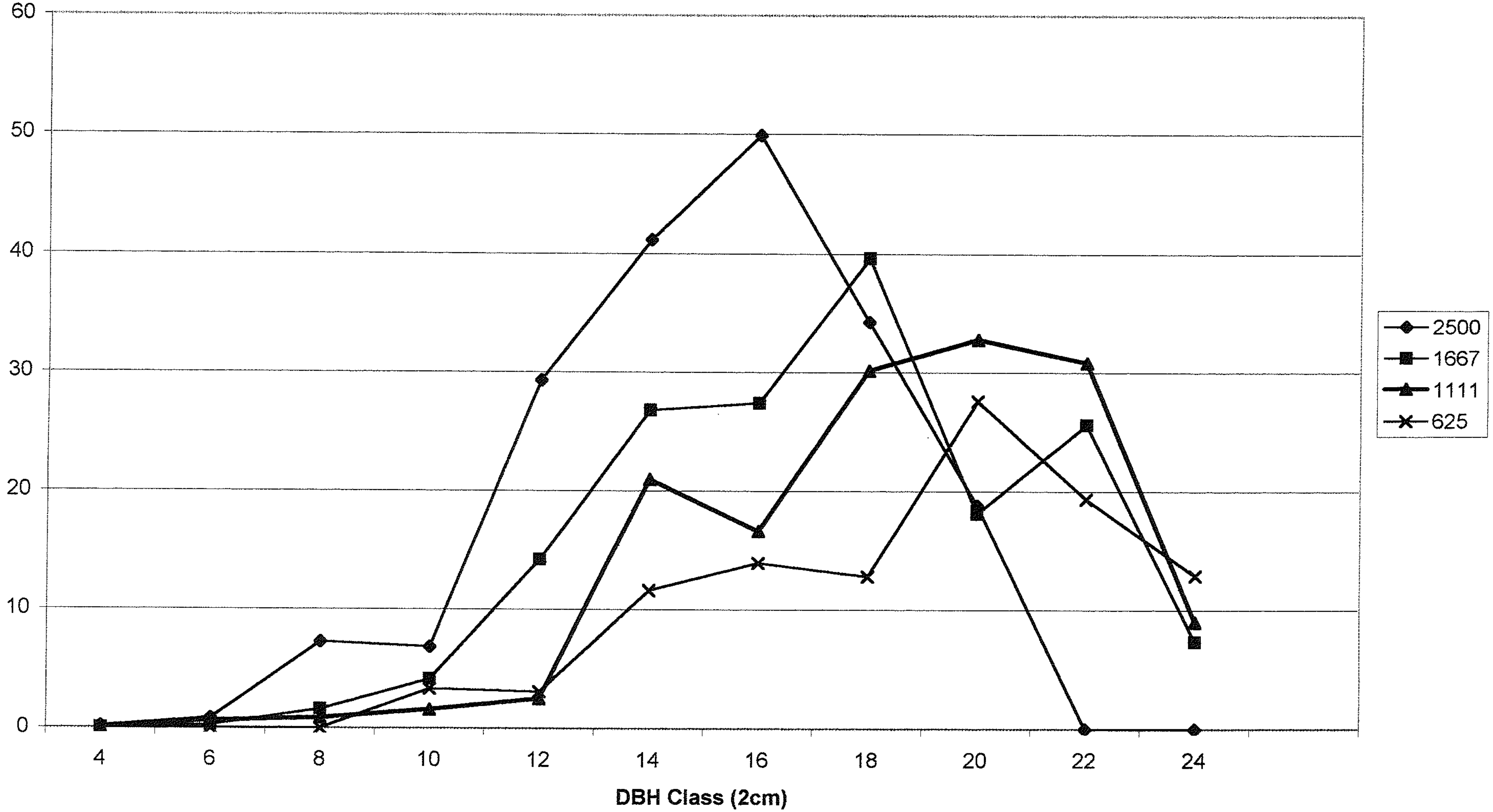


Graph 2

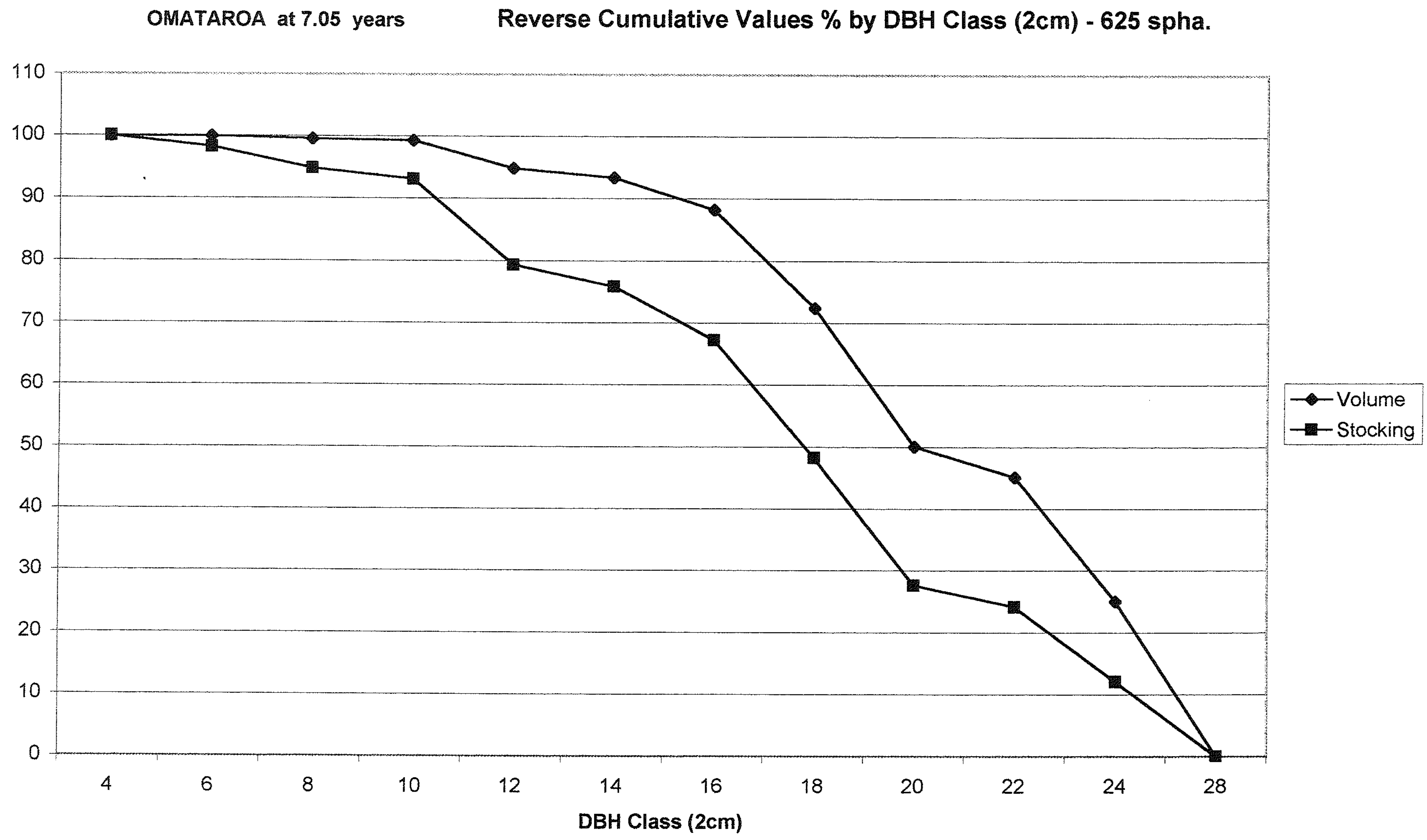

OMATAROA at 7.05 years
Volume (m3/ha) by DBH Class (2cm)
45
40
35
30
25
20
15
10
5
0
6
8
10
12
14
16
18
20
22
24
26
28
DBH Class (2cm)
2500
1667
1111
625

Graph 3

KINLEITH at 7.05 years *Volume (m3/ha) by DBH Class (2cm)*

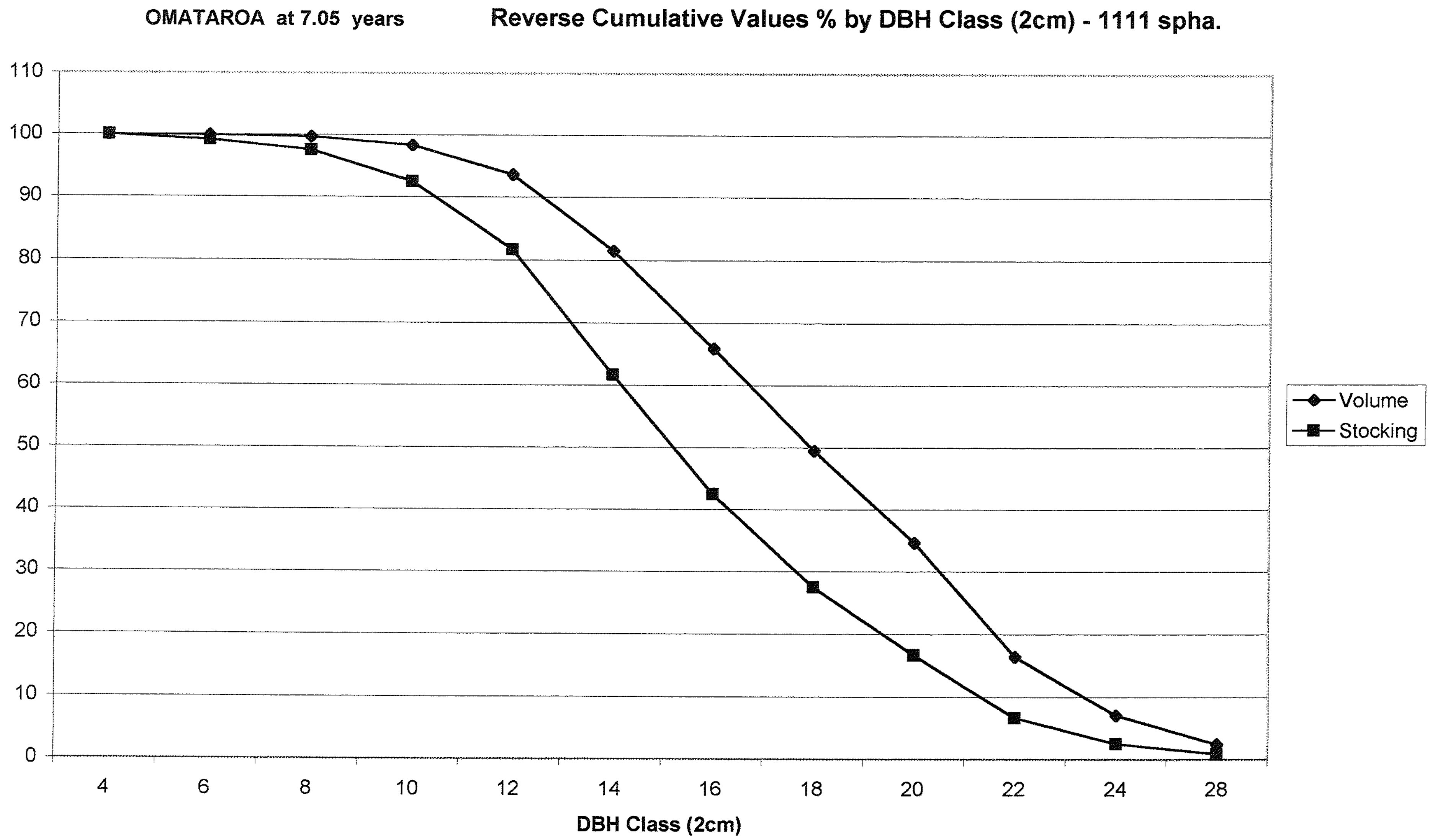


Graph 4



OMATAROA at 7.05 years
Reverse Cumulative Values % by DBH Class (2cm) - 625 spha.
110
100
90
80
70
60
50
40
30
20
10
0
4
6
8
10
12
14
16
18
20
22
24
28
DBH Class (2cm)
Volume
Stocking

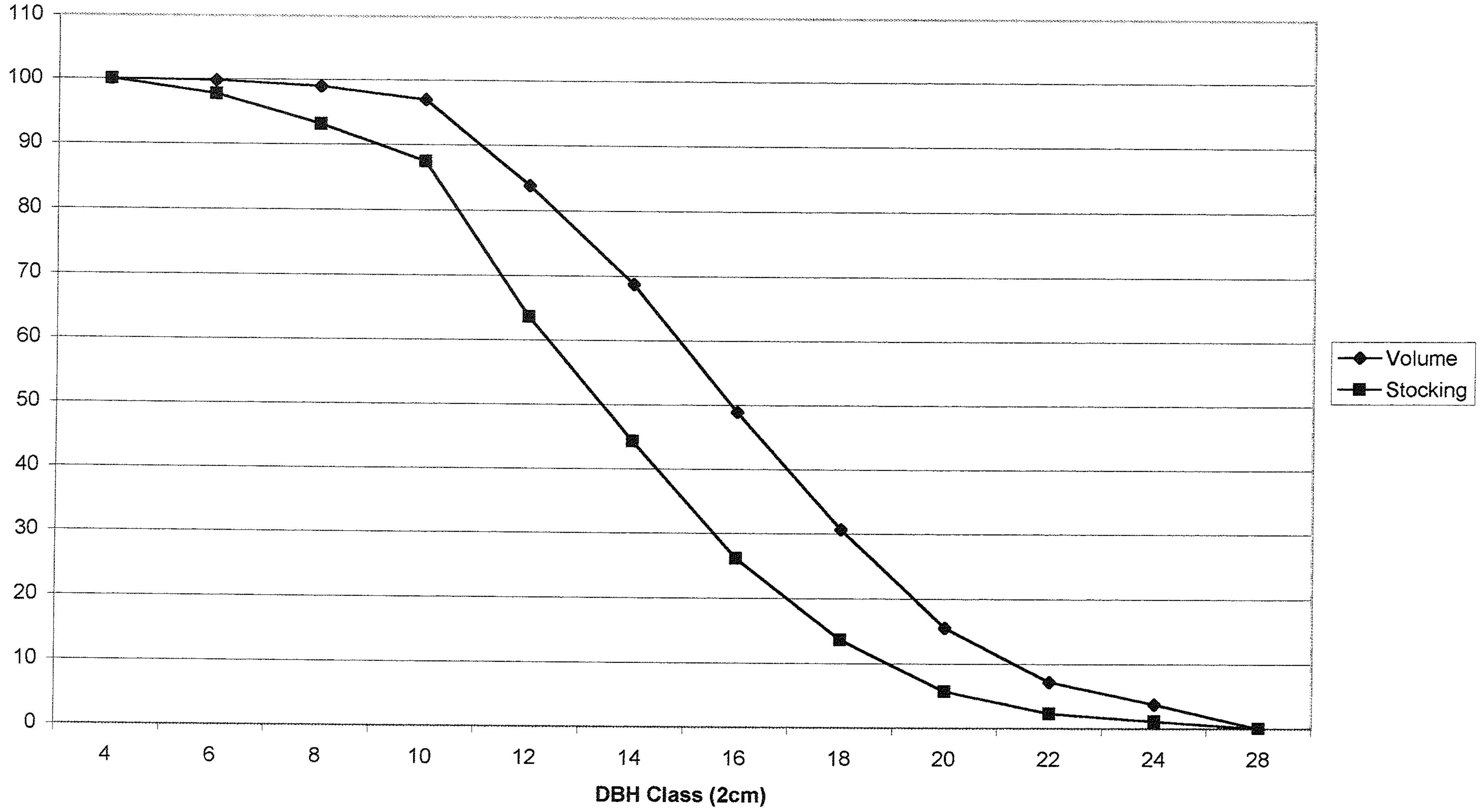
Graph 5


OMATAROA at 7.05 years
Reverse Cumulative Values % by DBH Class (2cm) - 1111 spha.
110
100
90
80
70
60
50
40
30
20
10
0
4
6
8
10
12
14
16
18
20
22
24
28
DBH Class (2cm)
Volume
Stocking

Graph 6

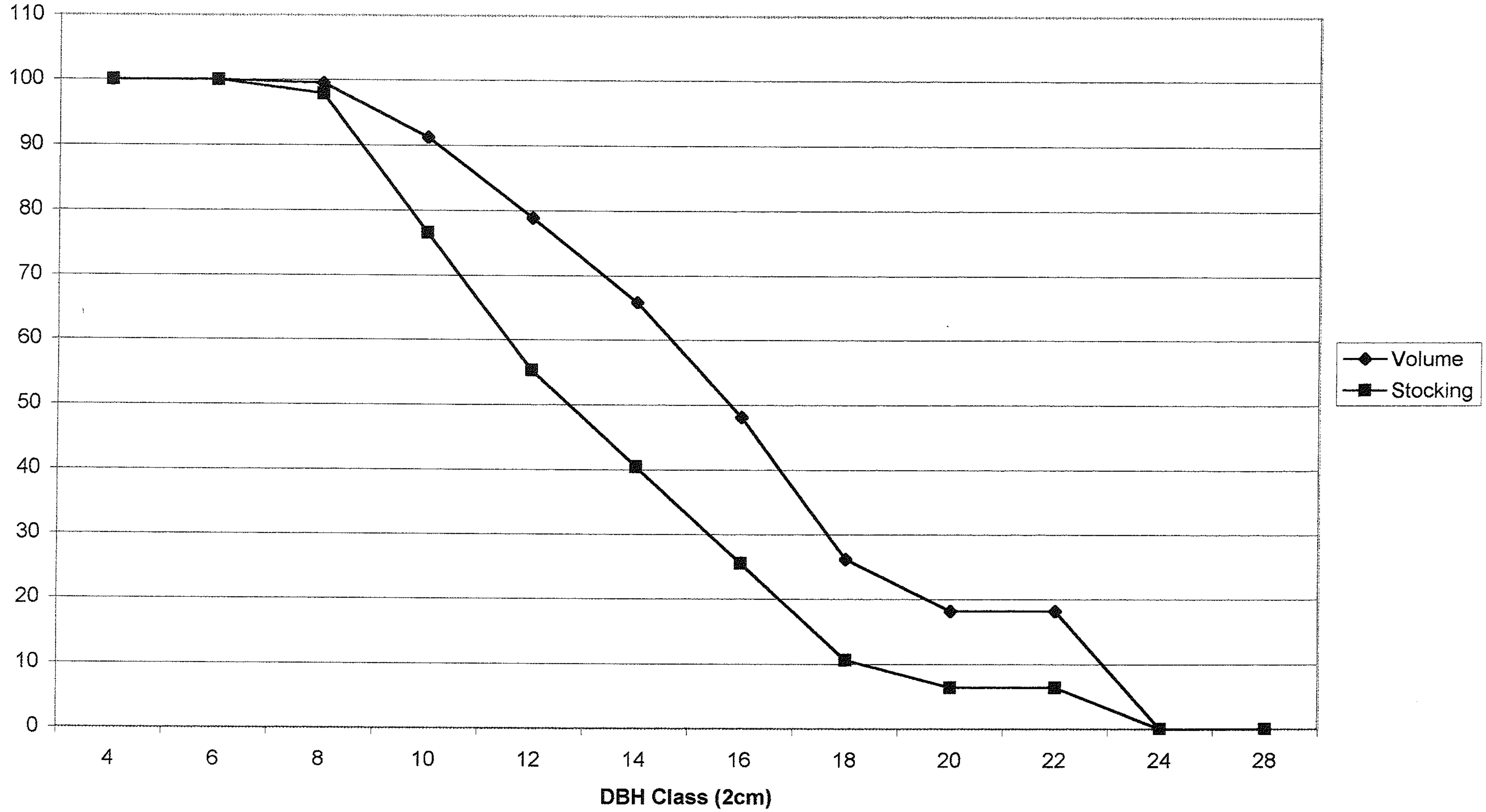
OMATAROA at 7.05 years

Reverse Cumulative Values % by DBH Class (2cm) - 1667 spha.



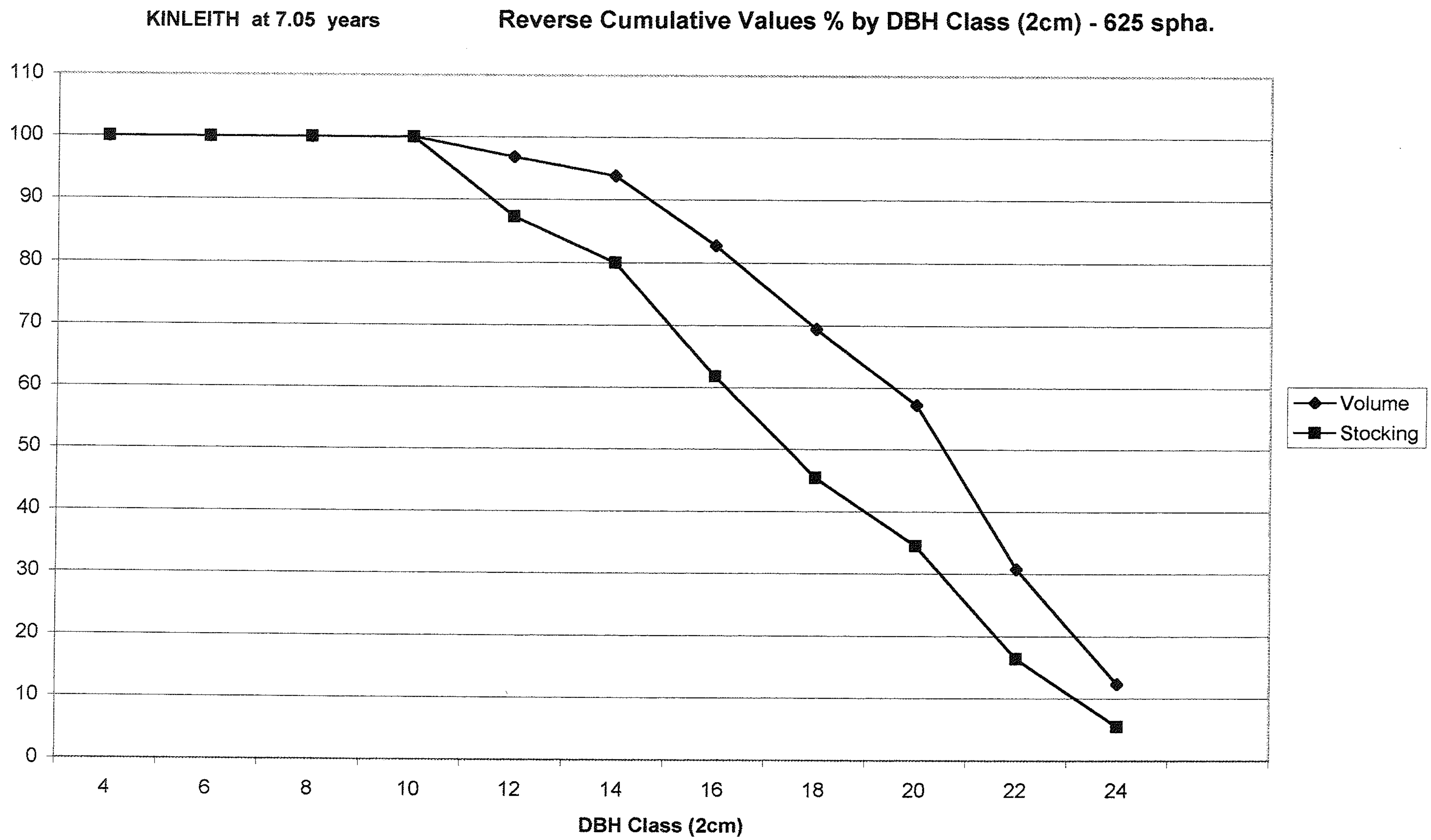
Graph 7

OMATAROA at 7.05 years ***Reverse Cumulative Values % by DBH Class (2cm) - 2500 spha***



Graph 8

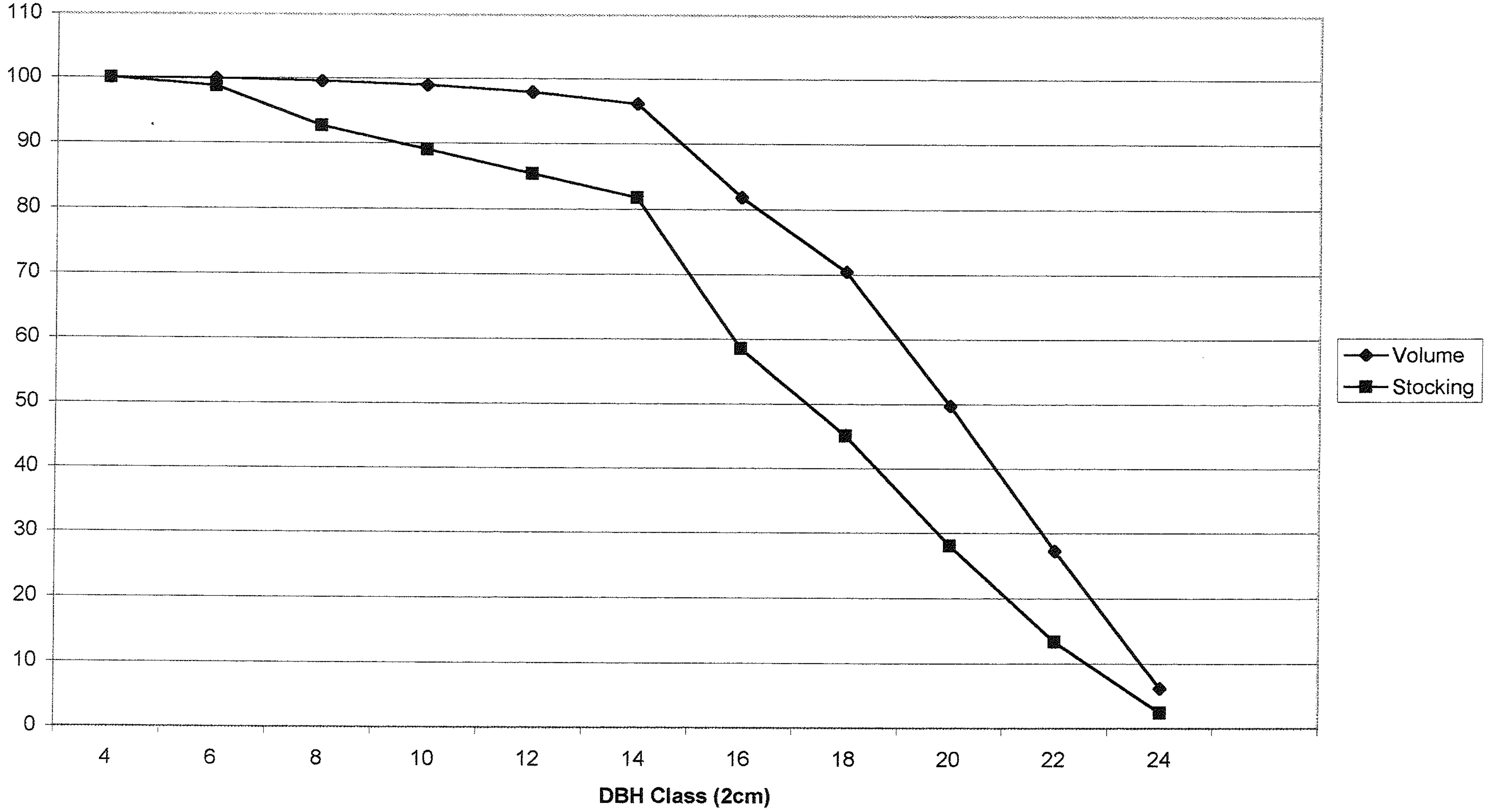
KINLEITH at 7.05 years



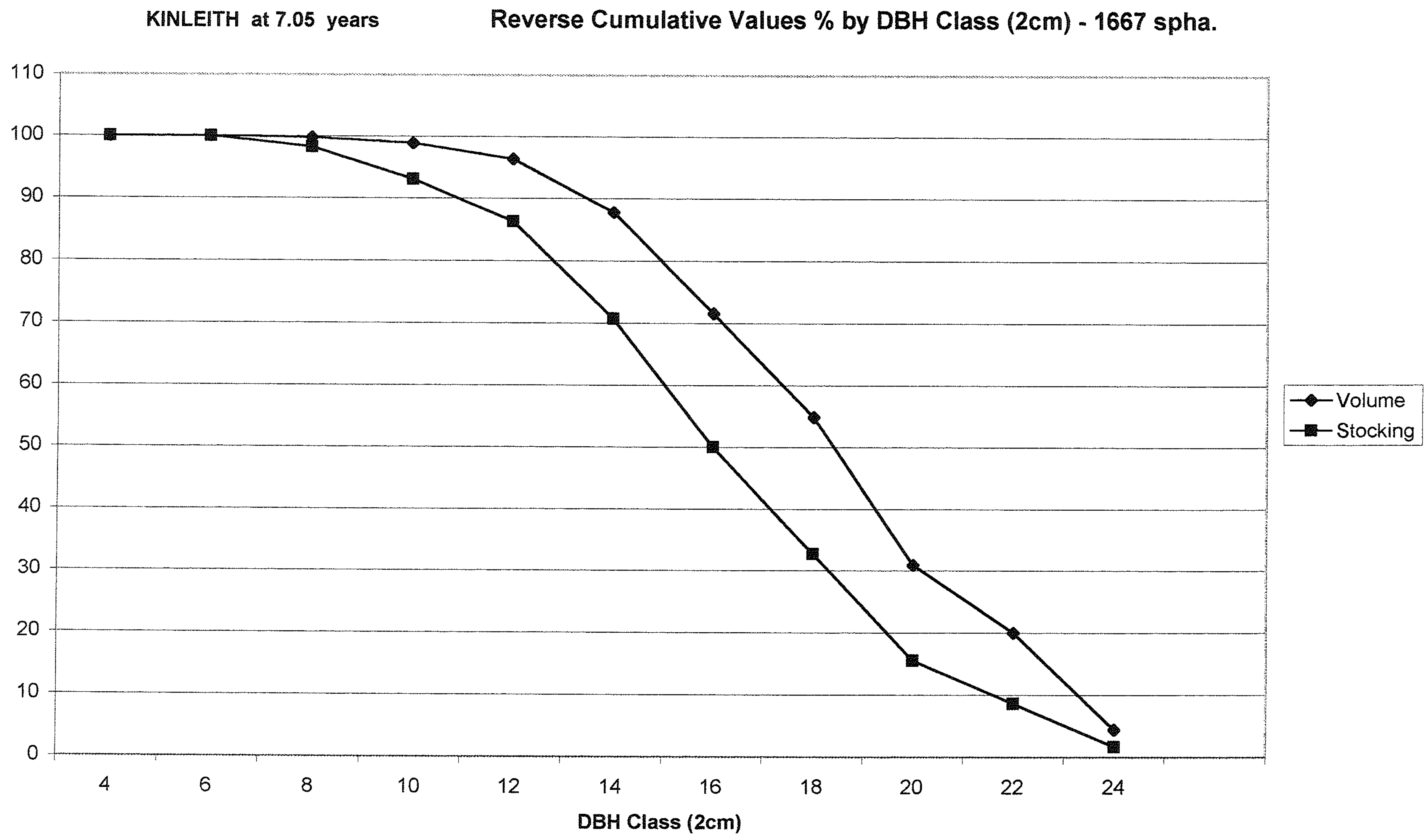
Graph 9

KINLEITH at 7.05 years

Reverse Cumulative Values % by DBH Class (2cm) - 1111 spha.



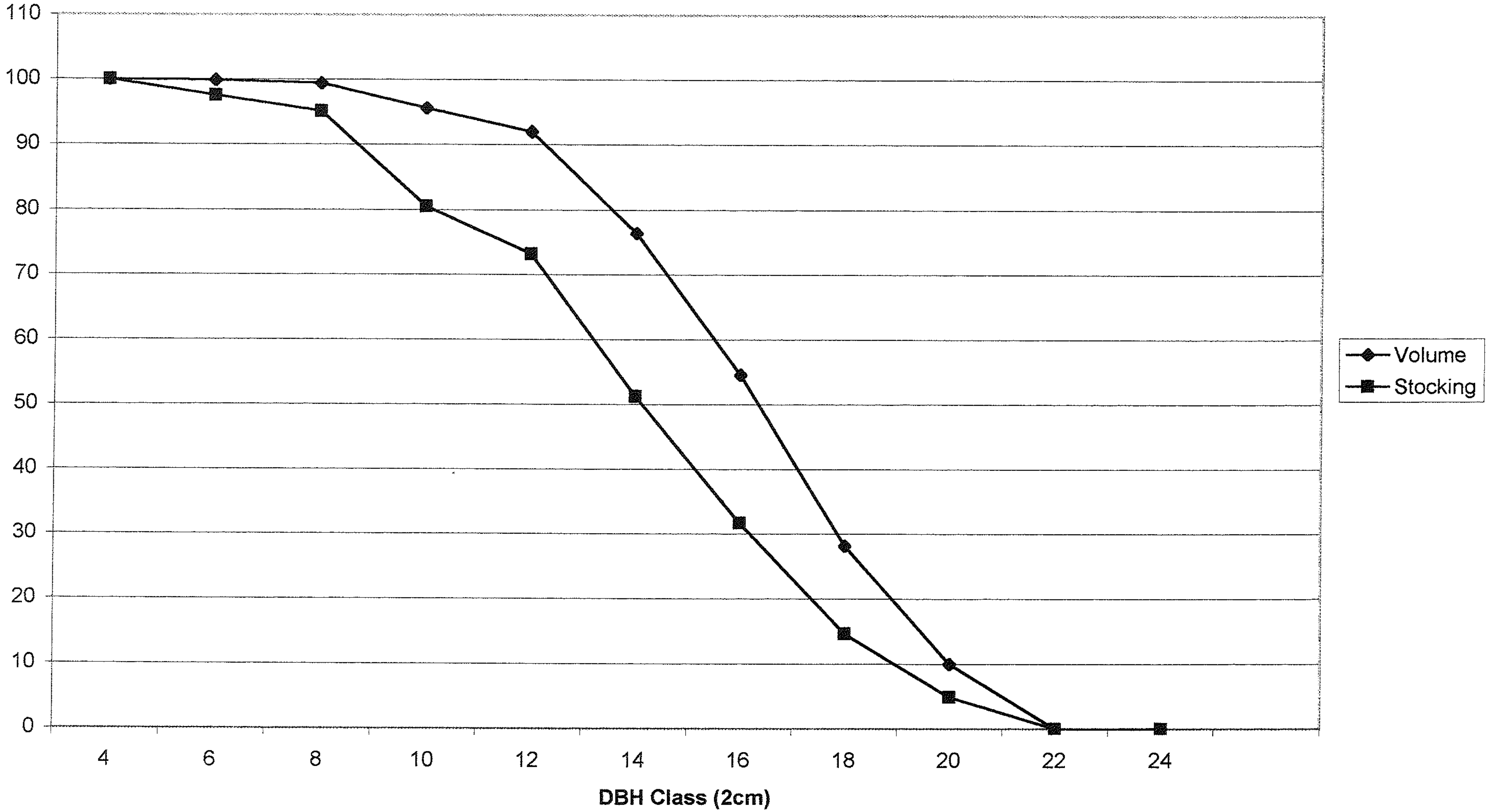
Graph 10


KINLEITH at 7.05 years
Reverse Cumulative Values % by DBH Class (2cm) - 1667 spha.
110
100
90
80
70
60
50
40
30
20
10
0
4
6
8
10
12
14
16
18
20
22
24
DBH Class (2cm)
Volume
Stocking

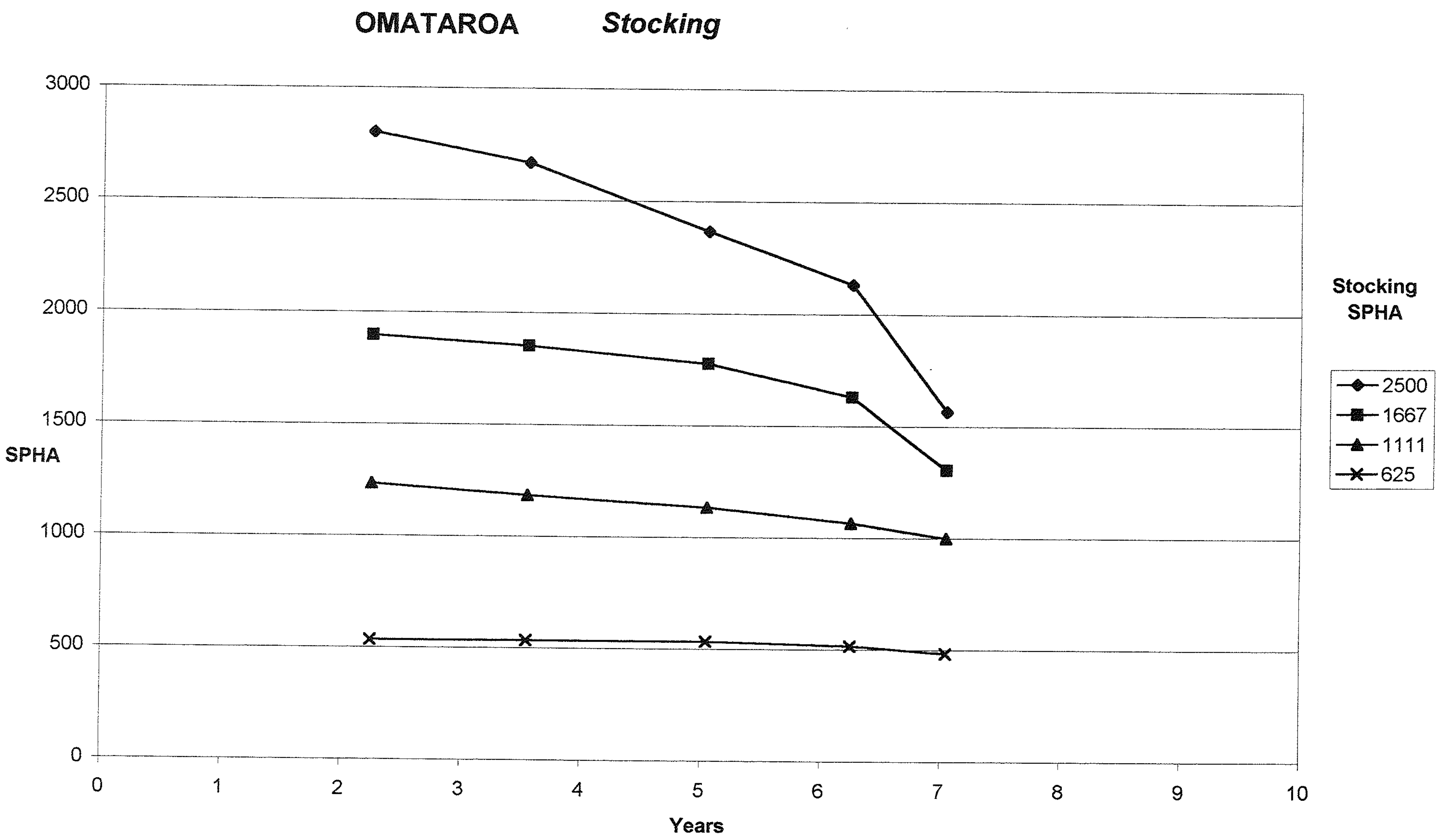
Graph 11

KINLEITH at 7.05 years

Reverse Cumulative Values % by DBH Class (2cm) - 2500 spha.

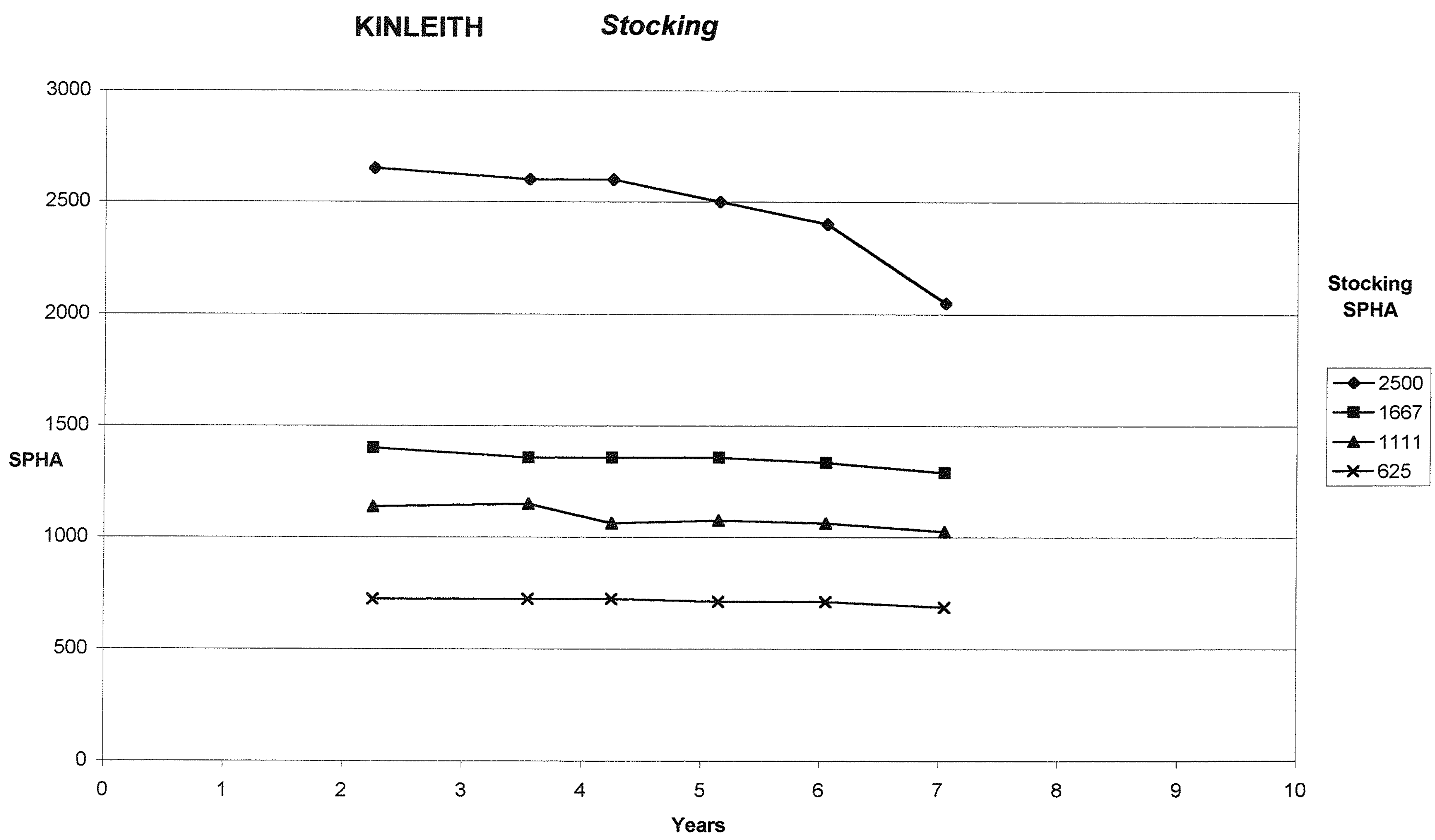


Graph 12

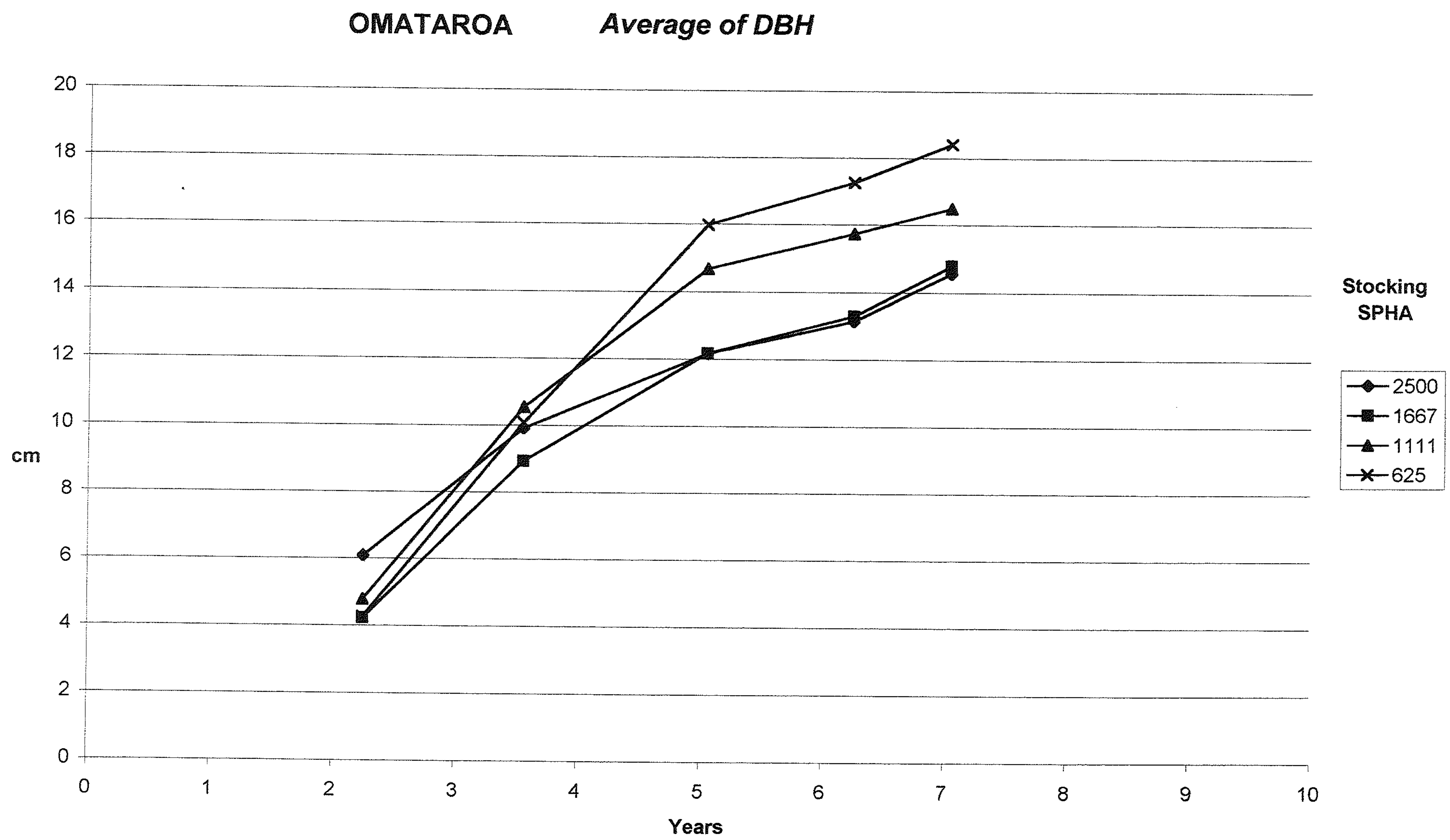


OMATAROA Stocking
3000
2500
2000
1500
1000
500
0
SPHA
0
1
2
3
4
5
6
7
8
9
10
Years
Stocking SPHA
2500
1667
1111
625

Graph 13

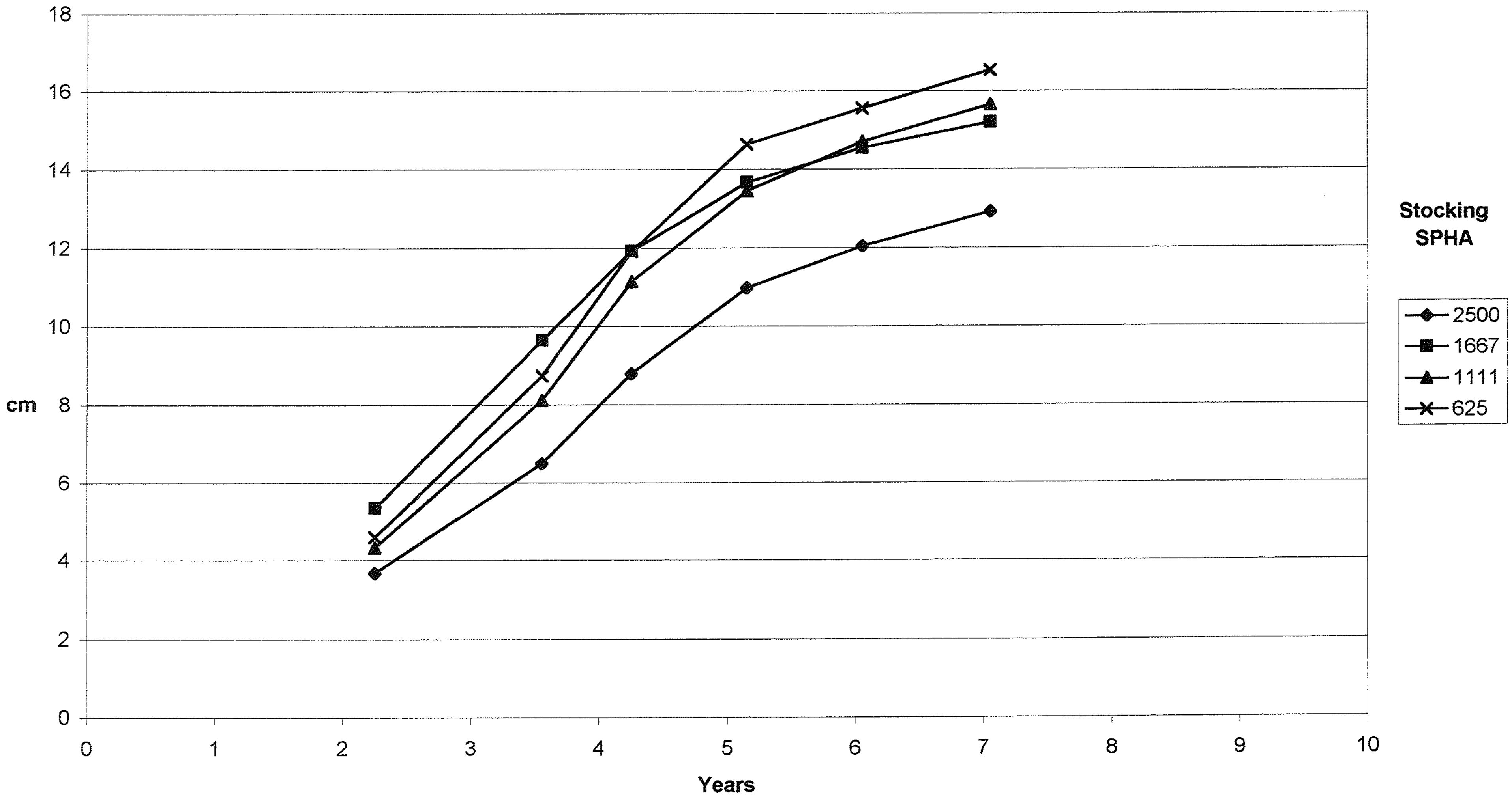

KINLEITH
Stocking
3000
2500
2000
1500
1000
500
0
SPHA
0
1
2
3
4
5
6
7
8
9
10
Years
Stocking SPHA
2500
1667
1111
625

Graph 14

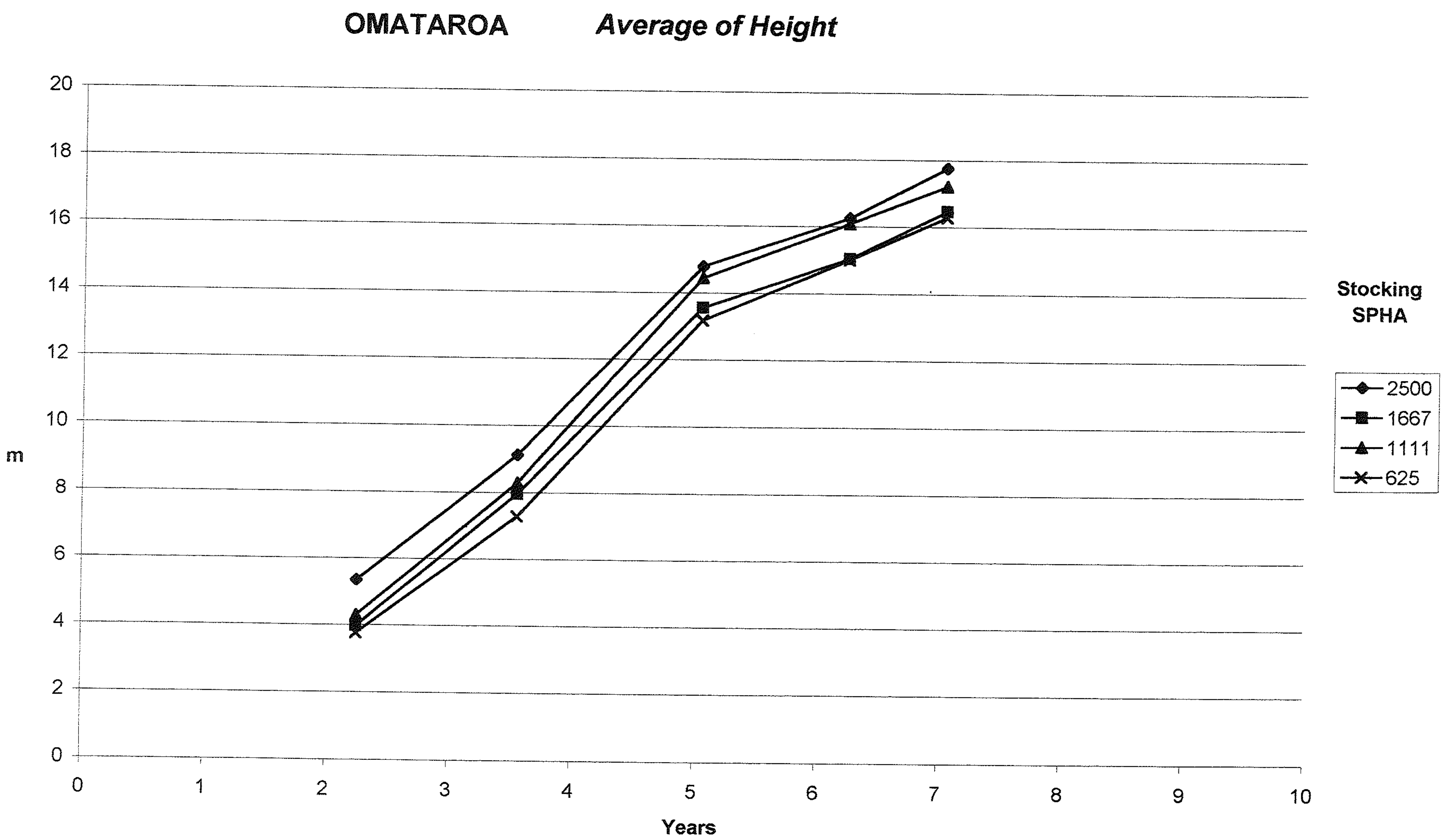

OMATAROA Average of DBH
cm
Years
Stocking SPHA
2500
1667
1111
625
0
2
4
6
8
10
12
14
16
18
20
0
1
2
3
4
5
6
7
8
9
10

Graph 15

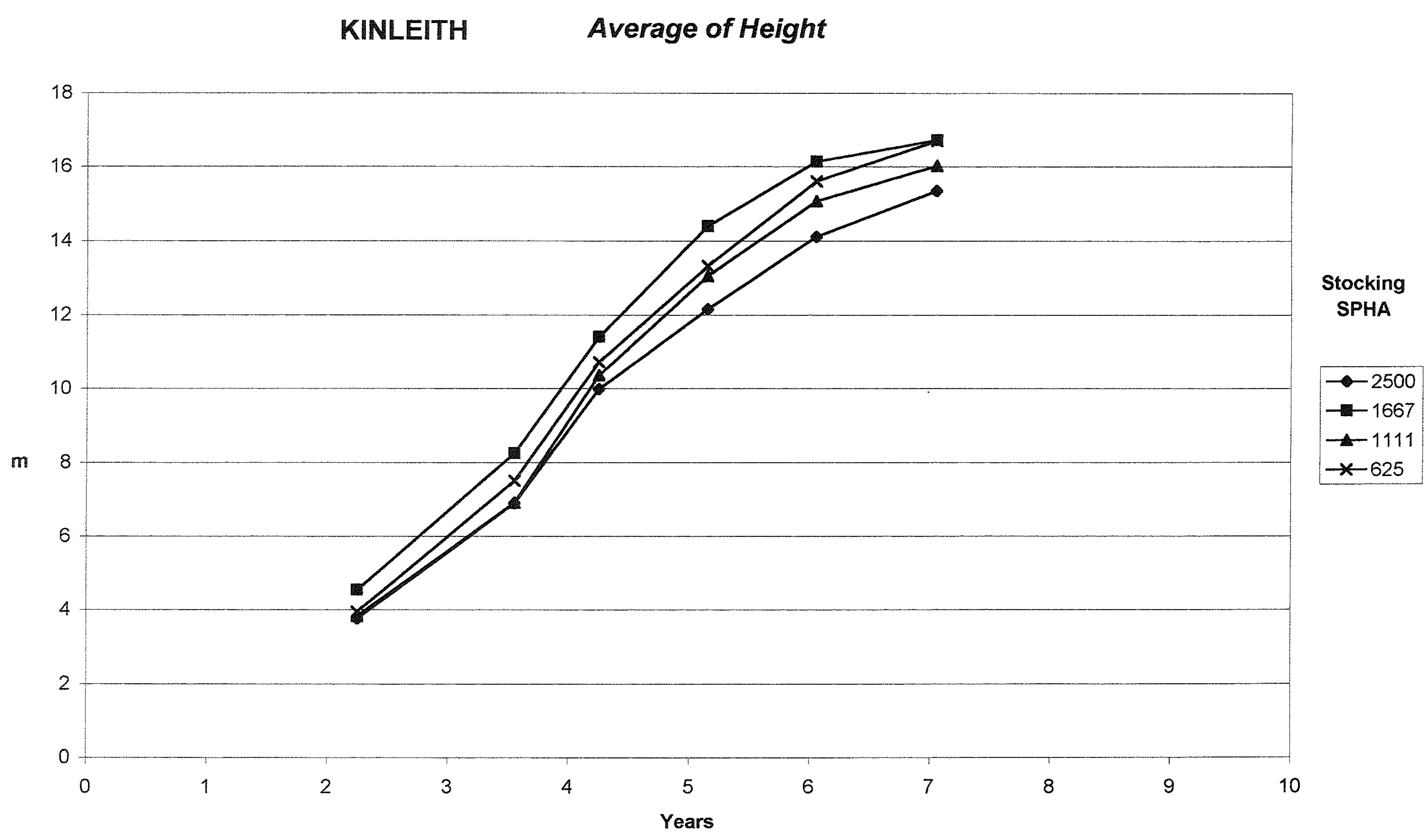
KINLEITH *Average of DBH*



Graph 16

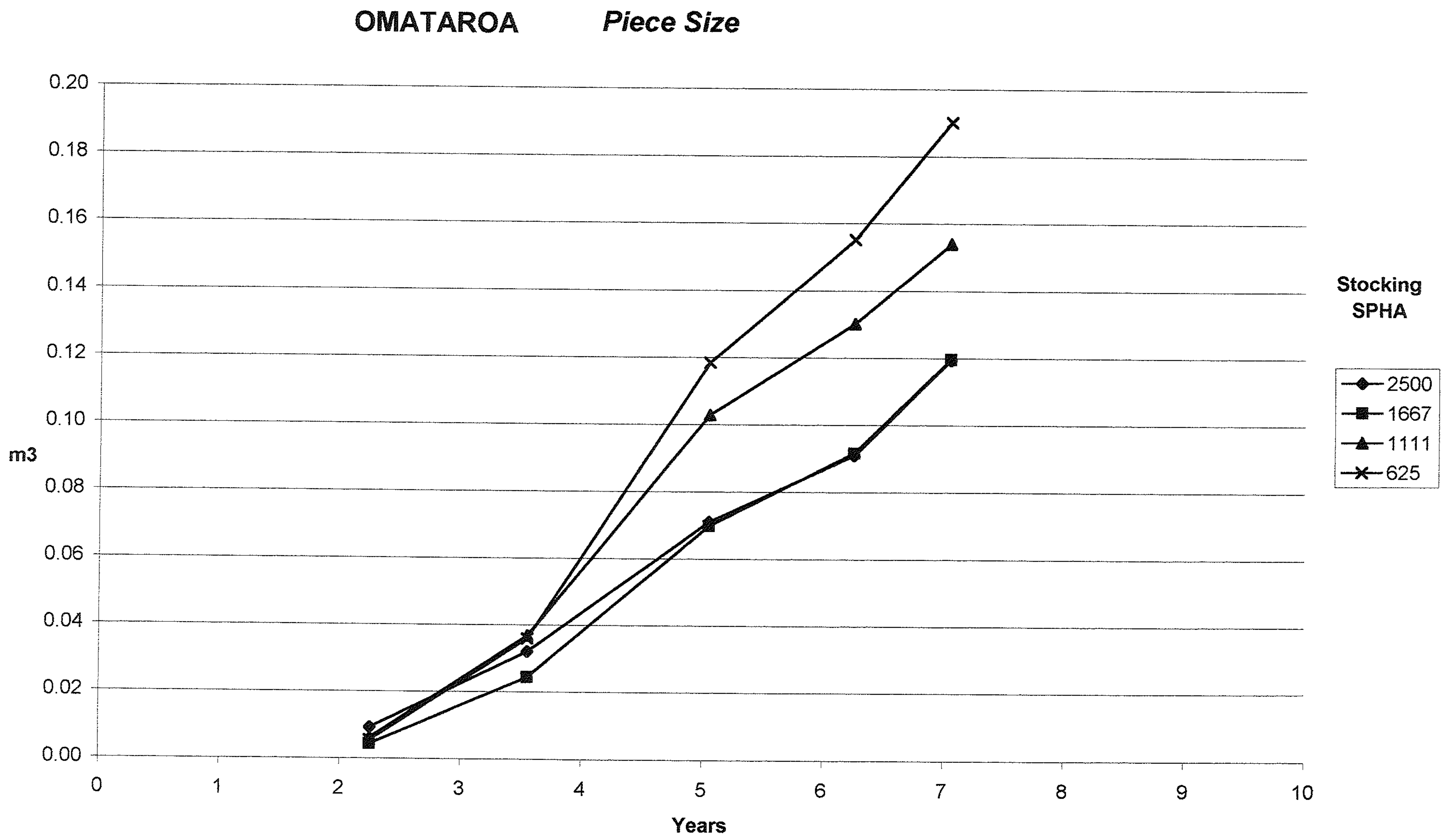

OMATAROA
Average of Height
20
18
16
14
12
10
8
6
4
2
0
m
0
1
2
3
4
5
6
7
8
9
10
Years
Stocking
SPHA
2500
1667
1111
625

Graph 17

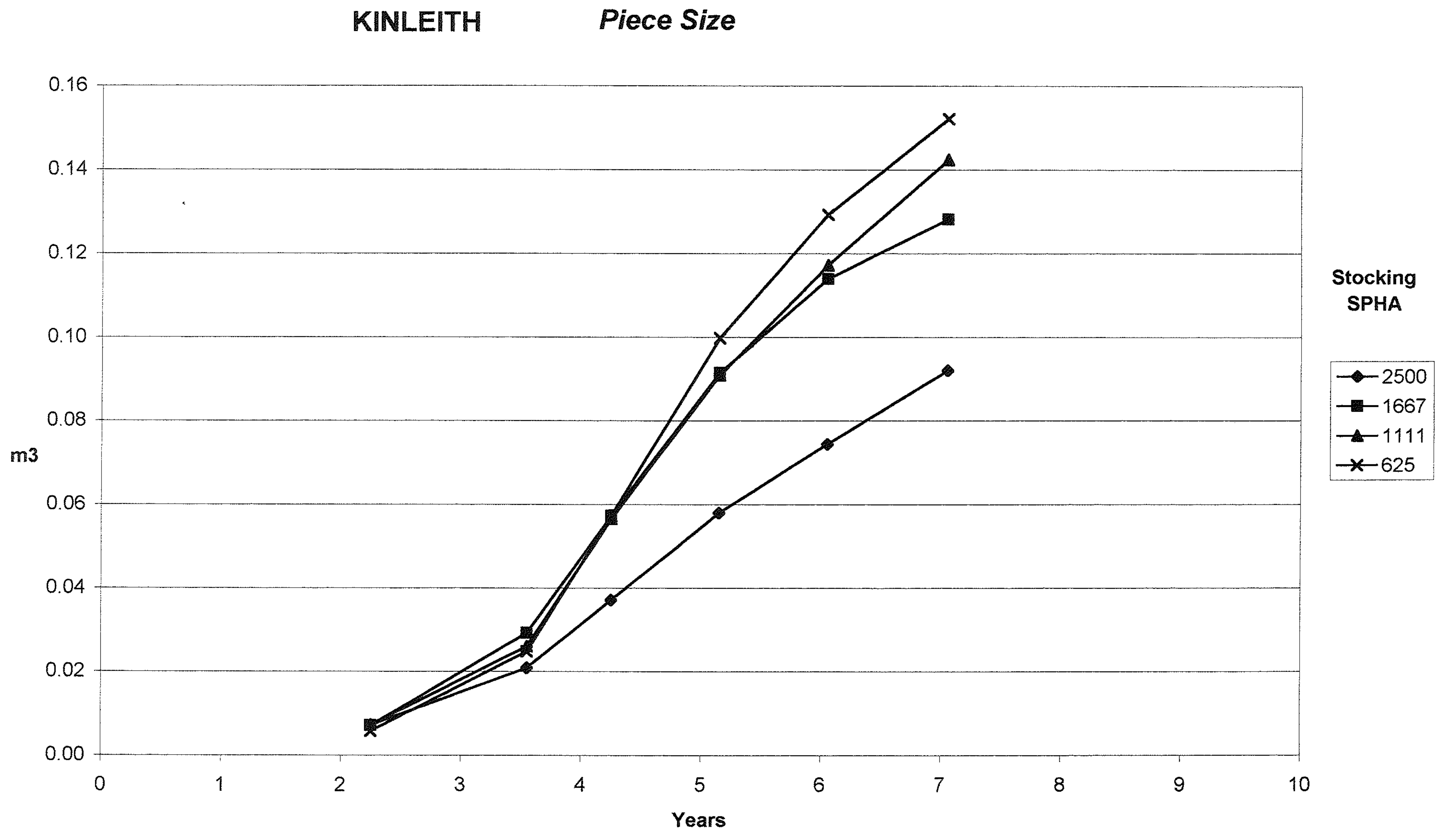


KINLEITH
Average of Height
m
Years
Stocking
SPHA
2500
1667
1111
625
0
2
4
6
8
10
12
14
16
18
0
1
2
3
4
5
6
7
8
9
10

Graph 18

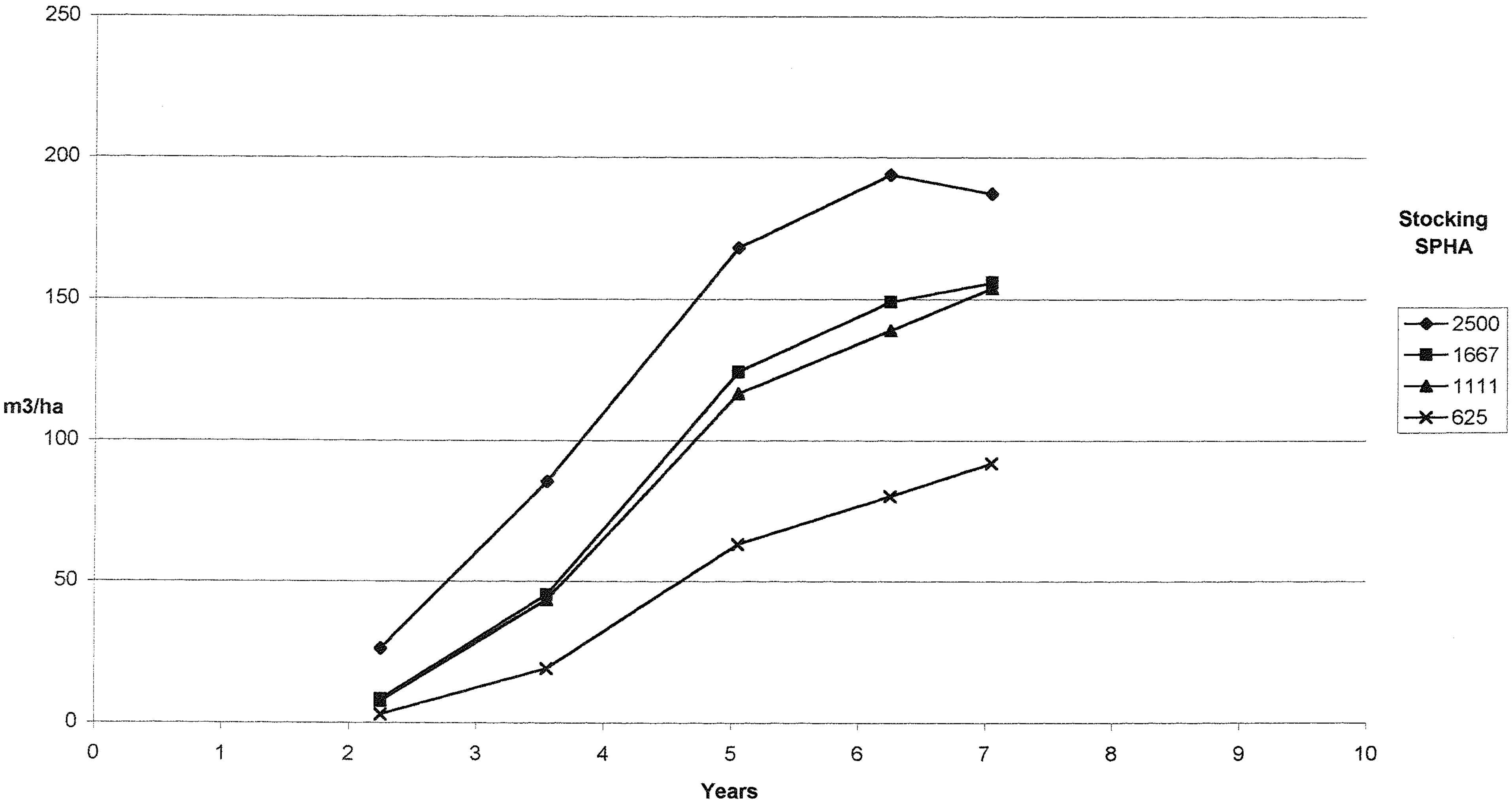

OMATAROA Piece Size
m3
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
0
1
2
3
4
5
6
7
8
9
10
Years
Stocking SPHA
2500
1667
1111
625

Graph 19

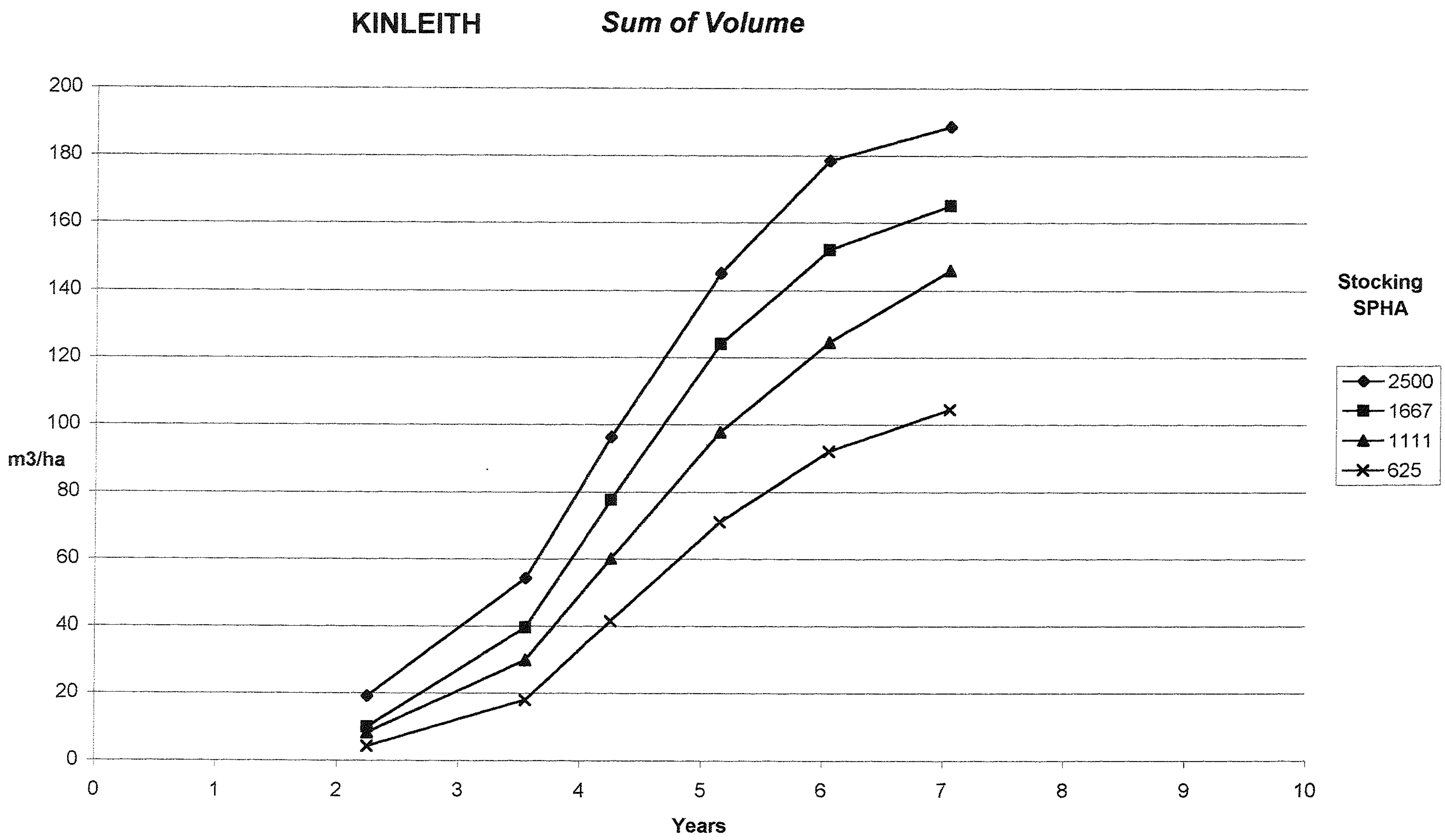

KINLEITH
Piece Size
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
m3
0
1
2
3
4
5
6
7
8
9
10
Years
Stocking
SPHA
2500
1667
1111
625

Graph 20

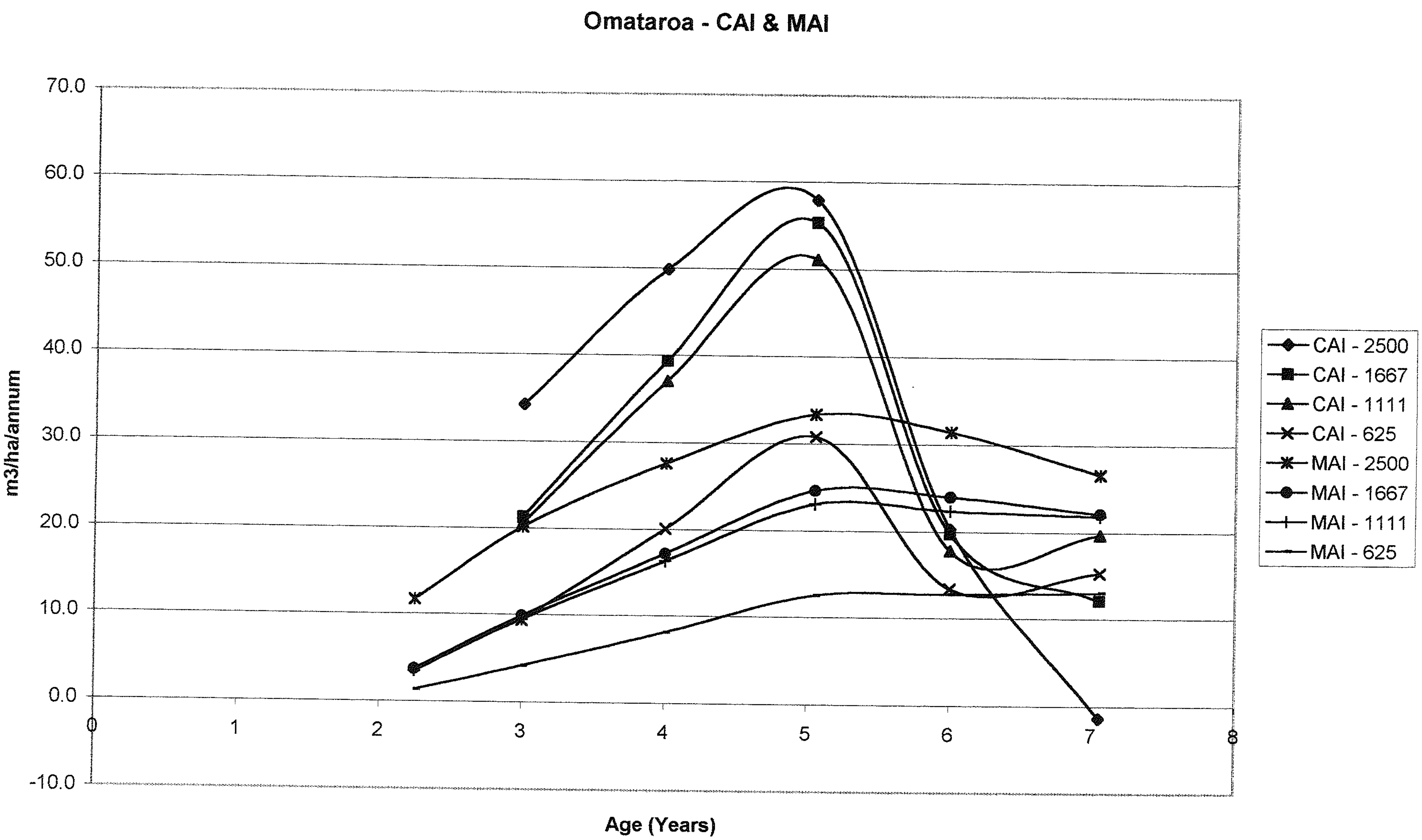
OMATAROA *Sum of Volume*



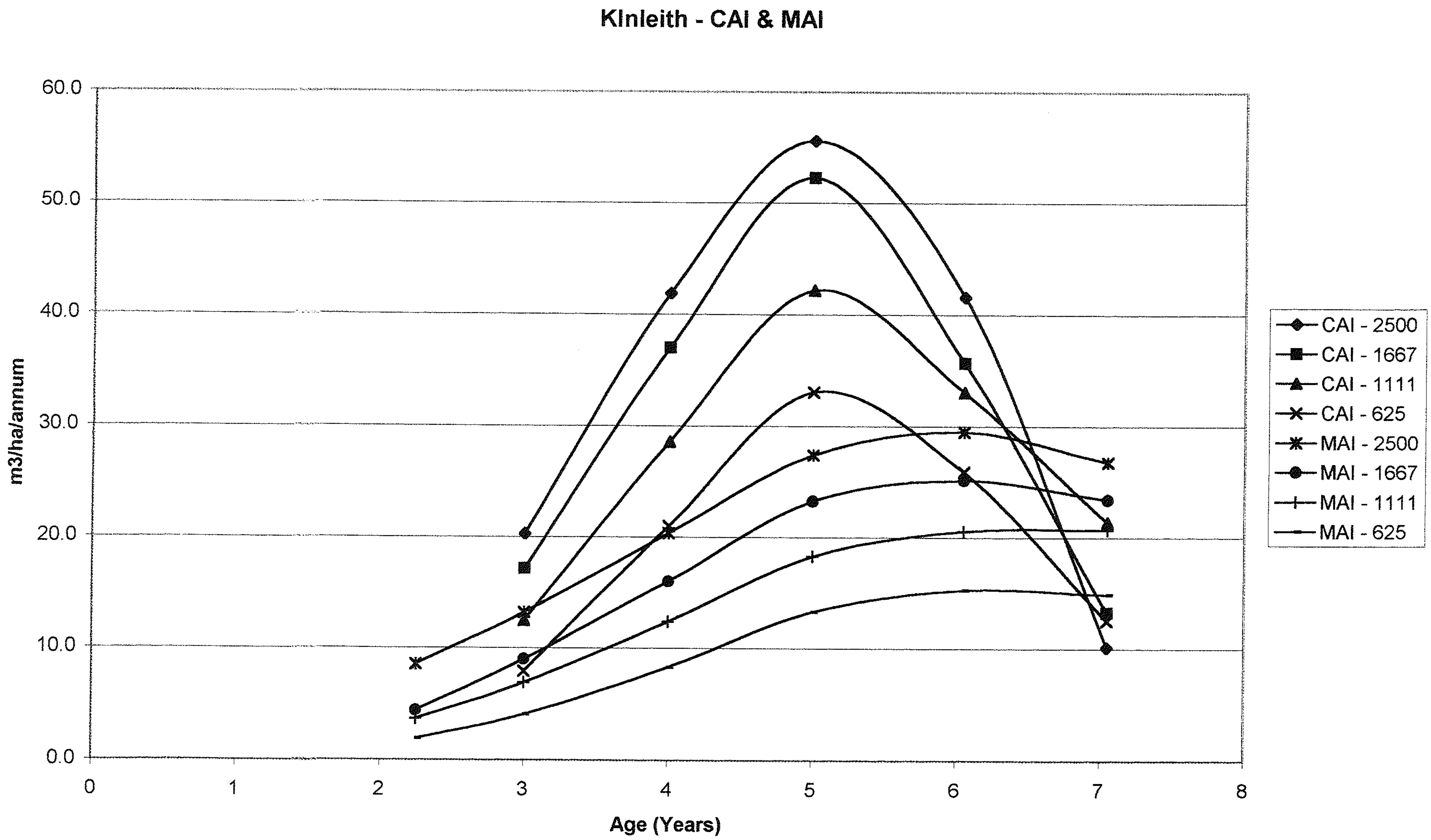
Graph 21


KINLEITH
Sum of Volume
200
180
160
140
120
100
80
60
40
20
0
m3/ha
0
1
2
3
4
5
6
7
8
9
10
Years
Stocking SPHA
2500
1667
1111
625

Graph 22

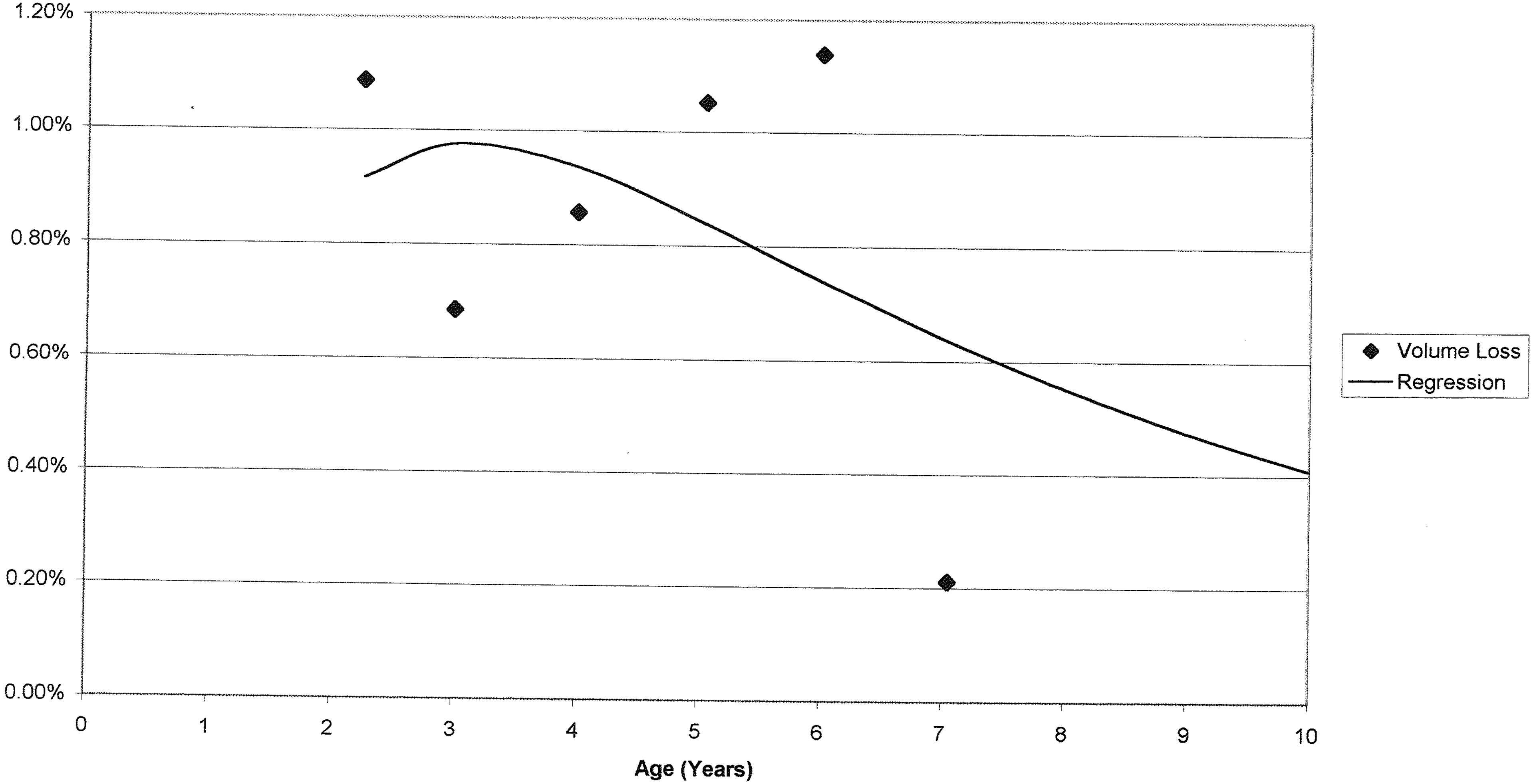

Omataroa - CAI & MAI
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
-10.0
0
1
2
3
4
5
6
7
8
m3/ha/annum
Age (Years)
CAI - 2500
CAI - 1667
CAI - 1111
CAI - 625
MAI - 2500
MAI - 1667
MAI - 1111
MAI - 625

Graph 23

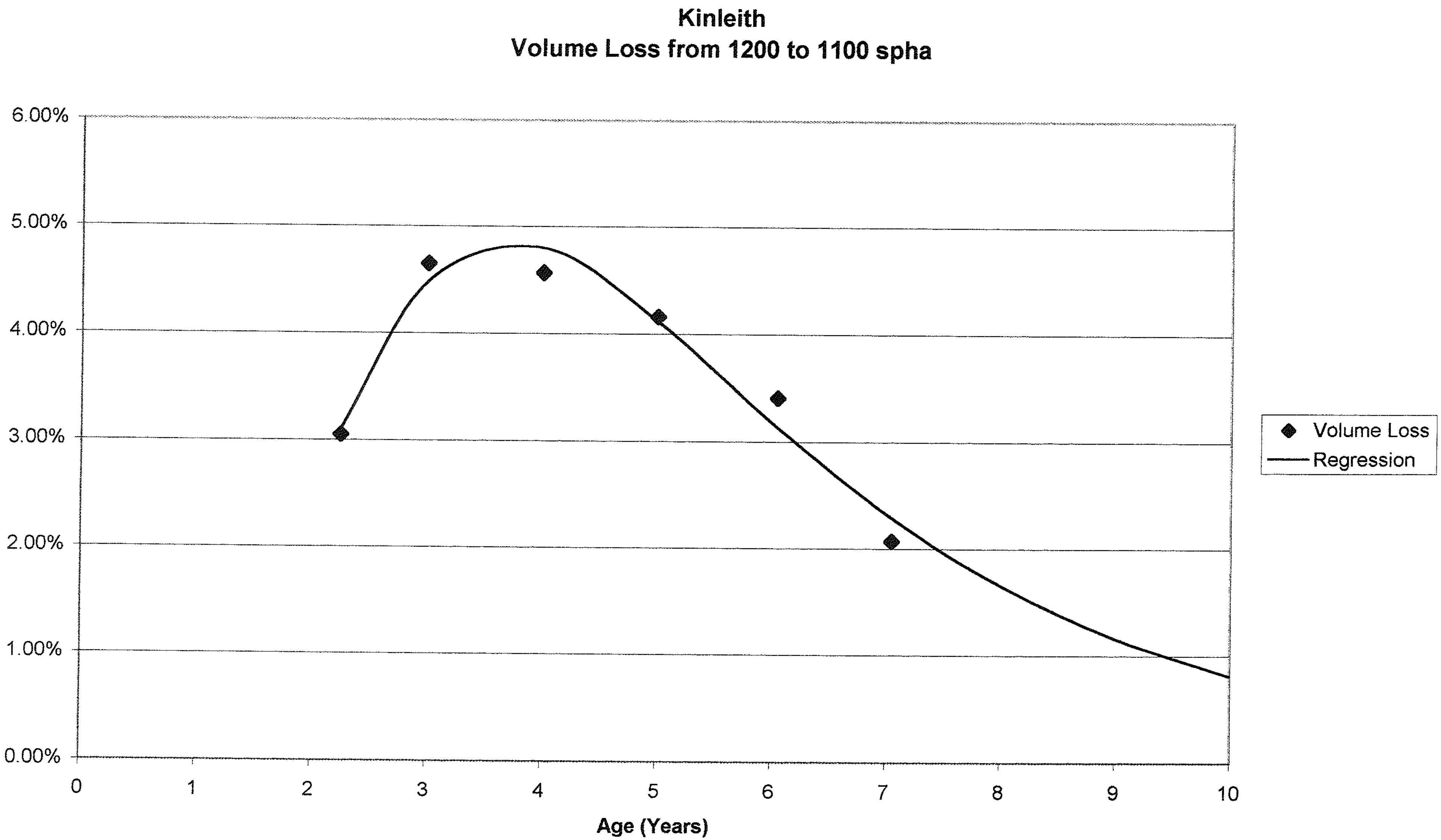

Kinleith - CAI & MAI
60.0
50.0
40.0
30.0
20.0
10.0
0.0
m3/ha/annum
0
1
2
3
4
5
6
7
8
Age (Years)
CAI - 2500
CAI - 1667
CAI - 1111
CAI - 625
MAI - 2500
MAI - 1667
MAI - 1111
MAI - 625

Graph 24

Omataroa
Volume Loss from 1200 to 1100 spha

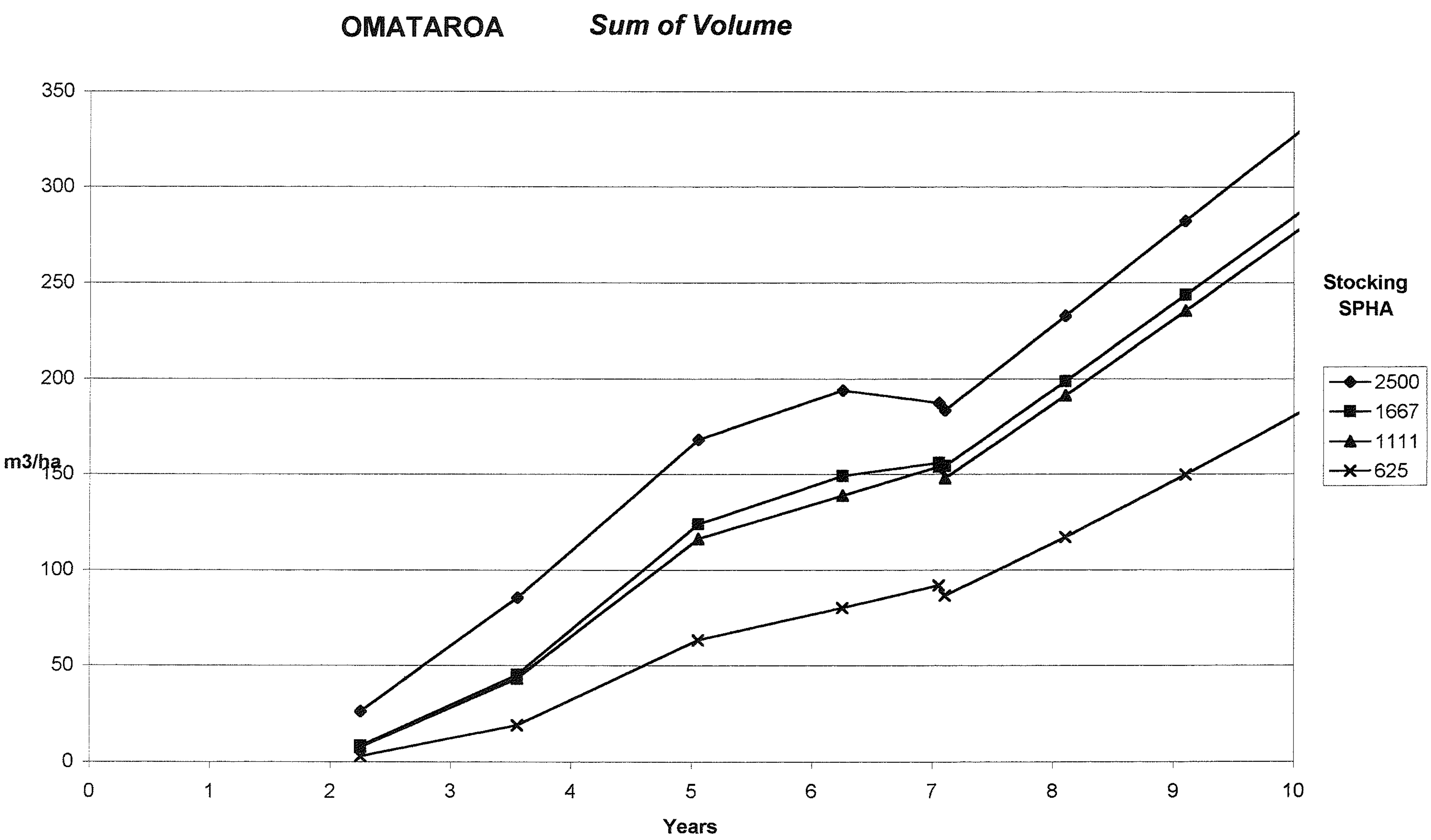


Graph 25

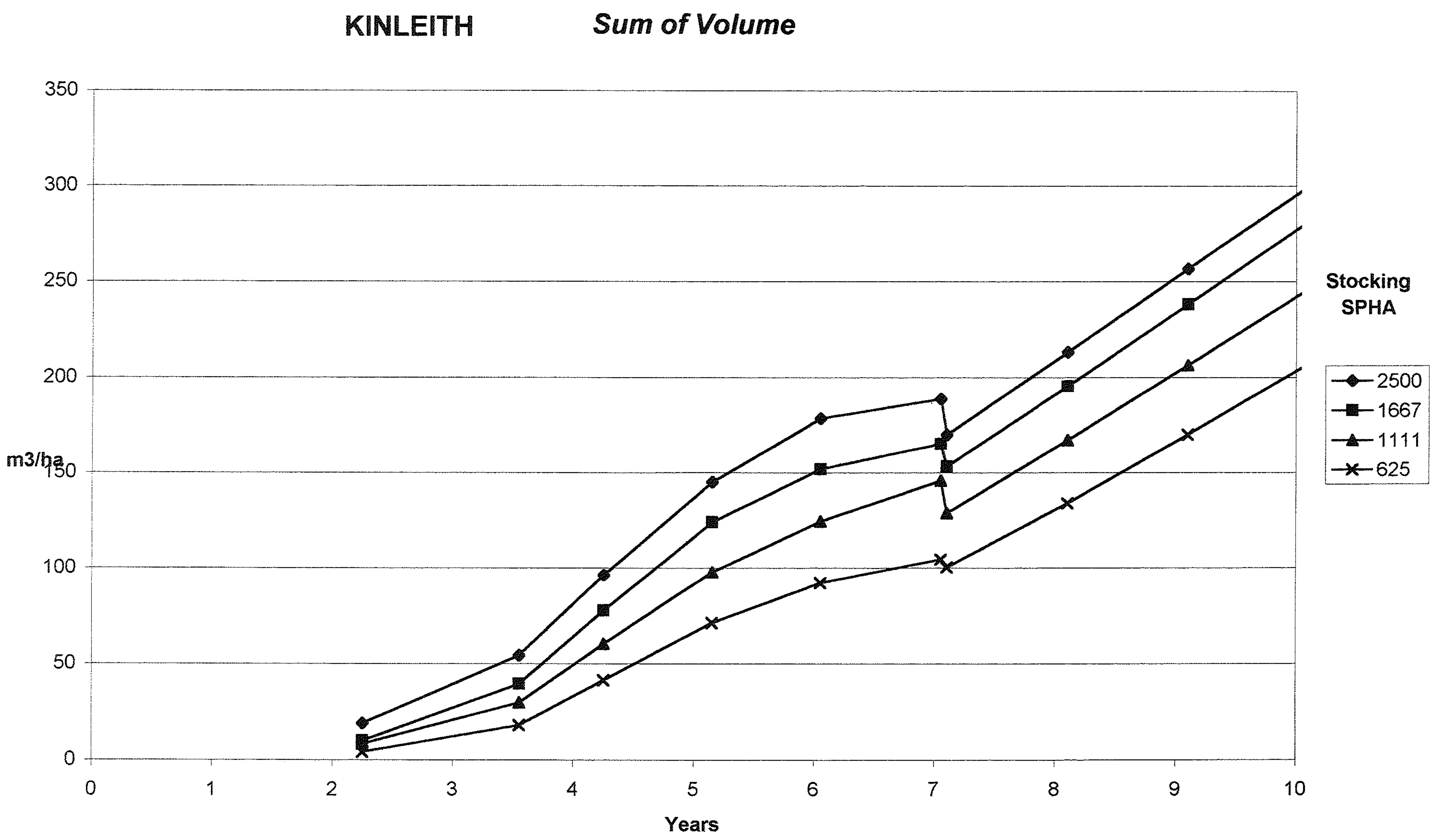


Kinleith
Volume Loss from 1200 to 1100 spha
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
0
1
2
3
4
5
6
7
8
9
10
Age (Years)
Volume Loss
Regression

Graph 26

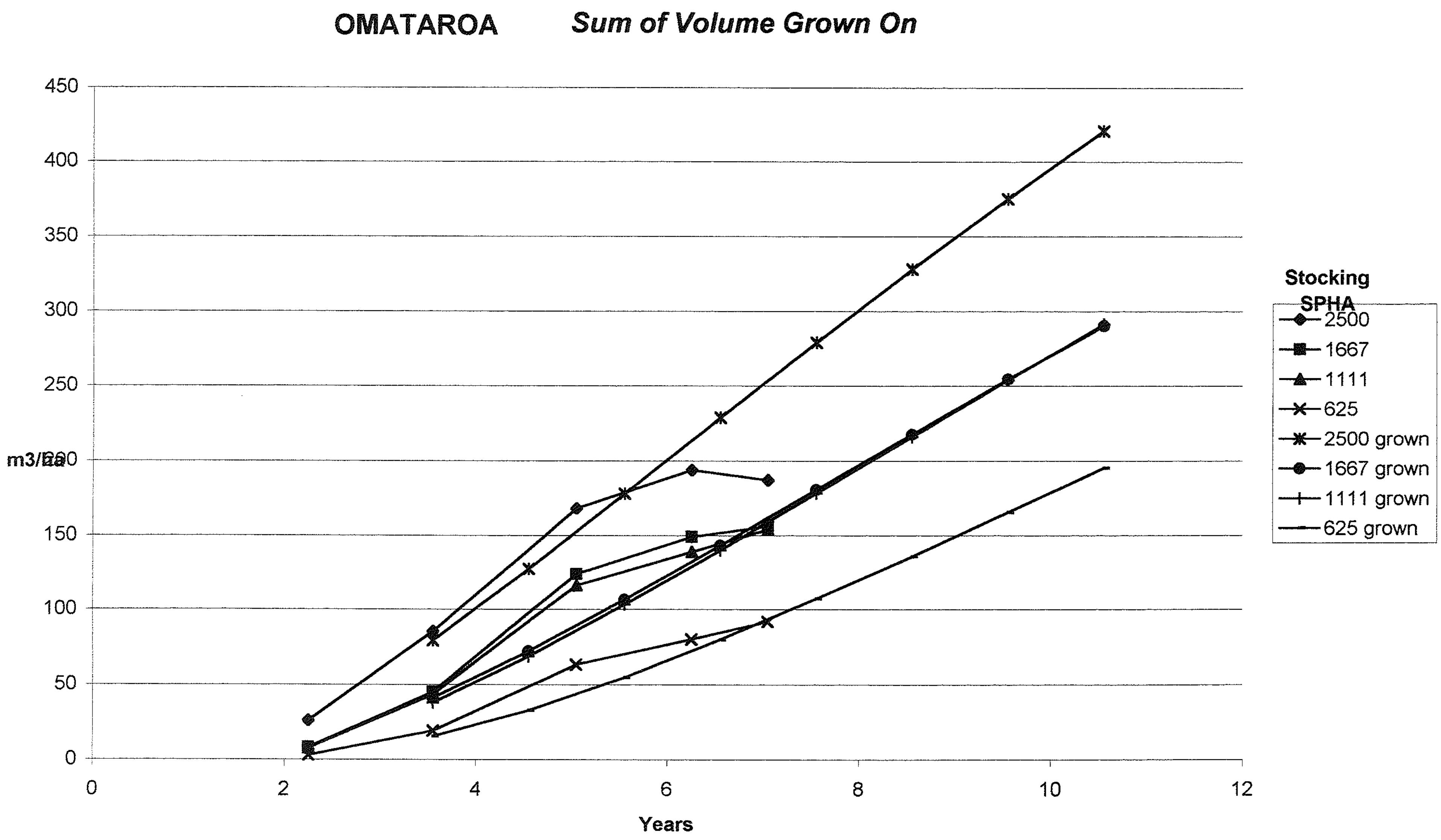

OMATAROA Sum of Volume
350
300
250
200
150
100
50
0
m3/ha
0
1
2
3
4
5
6
7
8
9
10
Years
Stocking
SPHA
2500
1667
1111
625

Graph 27



KINLEITH
Sum of Volume
350
300
250
200
150
100
50
0
m3/ha
0
1
2
3
4
5
6
7
8
9
10
Years
Stocking
SPHA
2500
1667
1111
625

Graph 28


OMATAROA
Sum of Volume Grown On
450
400
350
300
250
m3/ha
150
100
50
0
0
2
4
6
8
10
12
Years
Stocking SPHA
2500
1667
1111
625
2500 grown
1667 grown
1111 grown
625 grown

Graph 29