F.R.I. PROJECT REPORT

NO. 2013

INITIAL REPORT ON THE GROWTH PERFORMANCE OF THE GENETICALLY IMPROVED PINUS RADIATA BREEDS

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FRI/INDUSTRY RESEARCH COOPERATIVES

EXECUTIVE SUMMARY

Preliminary results have been obtained from a nationwide series of experiments aimed at determining the nature and extent of genetic improvement of *Pinus radiata* (D. Don). These results show substantial increases in growth rate and yield over unimproved stock, particularly for the Growth and Form breed: the 'first orchard', or '850' clonal series showed volume gains ranging from 4 to 37% for clearwood and a pulpwood regimes; while the second orchard, or '268' clonal series exhibited gains in volume ranging between 14 and 36% for a clearwood type regime.

Performance of the long internode breed, represented by the '870' clonal series, was more varied, ranging from reduced volume production of some 16% to improved growth performance of 26% (on a less fertile site).

Volume gains in all cases were attributable to gains in both height and basal area.

Early results from a 'first orchard' silvicultural trial indicated genetically improved *P. radiata* responding to various thinning intensities in a similar manner to unimproved material of the same species, and expresses similar responses to differing inter-regional fertility levels.

It is recommended that measurements be continued for all trial series including, if possible, an increase the size of the database, particularly for the '268' clonal series.

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CONTENTS

1.0 INTRODUCTION

Over the past fifteen years, the forest area established with genetically improved *Pinus radiata* has substantially increased. Gains in volume ranging from 8% to 25% have been forecast for some of the improved breeds (King *et al.* 1987; Shelbourne *et al.* 1986; Ministry of Forestry 1987), but as yet very little data from this material has been included in the contemporary growth models currently used by forest managers. Such gains have substantial implications for management, viz, increased volumes at the end of the rotation, and/or shorter rotation lengths. Thus there is a necessity to quantify these gains as well as provide data suitable for validating existing models, or if required, updating models to accommodate the improved breeds.

Results presented in this report incorporate the early growth performance of genetically improved radiata pine from three trial series originally established by the Genetics and Tree Improvement Group (GTI). GTI's use of these trials has the primary objective of periodically assessing and ranking the various seed orchard alternatives, and establishing the approximate levels of genetic gains in growth rate and tree form expected from the orchard progeny. For purposes of improving current growth models, more controlled and frequent measurements are required, and these are being obtained in collaborative work by the Exotic Forest Management (EFM) and Forest Mensuration and Management Systems (FMMS) groups.

Results encompass the '850', '268' and '875' clonal series, which constitute the bulk of the 'Growth and Form' breed; and the '870' clonal series, which forms the bulk of the 'Long Internode' breed. The former breed, selected mainly for improved stem quality, growth rate and multinodality (Shelbourne *et al.*, 1986), has been developed over the past forty years in two main programmes, the first orchard ('850') and second orchard ('268', '875' and '880') clonal series. Development of the long internode breed commenced in 1969 with selection emphasis for the '870' clonal series placed on longer internodal length to obtain a higher proportion of clearcuttings at the end of the rotation.

2.0 TRIAL DESCRIPTIONS

2.1 '850' Final Crop Stocking Trial

This trial was established by GTI in 1975 as a 'polycross' trial using control pollinated '850' tree stock. The original purpose was to rank the female clones used in the '850' seed orchards. The original polycross trial contained square plots of 144 trees each, with individual progeny randomly located within the plot. The mixture of polycross progenies approximated a first orchard seed mixture thus allowing the final crop stocking trial to be imposed at age 11 following achievement of GTI's objectives.

The objective of the final crop stocking trial is to provide performance data over a range of final stockings. As most planting of the 850 series has occurred since 1975, this trial series will provide information regarding responses of genetically improved *P. radiata* to varying silviculture. Table 1 provides a description of silvicultural operations applied to the final crop stocking trial.

TABLE 1 - Silvicultural treatments used for the final crop stocking trial

Year planted	1975	
Initial stocking	625 sph	
Silviculture	Pruned to 6 m in 3 lifts*	
	Thinned <u>once</u> to	- 100 sph
		- 200 sph
		- 400 sph
	at <u>either</u>	- age 11, or
		- age 14
	and	- 600 sph (unthinned)

* On some sites a portion of plot trees were medium and high pruned only.

The delayed thinning treatment was included to provide growth and yield information on late thinning and/or simulated production thinning. A randomised complete block design was used with three blocks per site. Total number of treatments was eight (four final stockings by two thinning treatments) thus providing a total of 24 plots.

The final stocking trial was established at four locations in 1986 by staff of the Mensuration and Exotic Forest Management Groups (Table 2).

TABLE 2 - Final crop stocking trial locations

Site	Sample plot number	Region*
Golden Downs	NN 529	Golden Downs
Eyrewell	CT 597	Canterbury
Kaingaroa	RO 2098	Central NI Pumice Plateau
Woodhill	AK 1056	Auckland Sands

* Region is defined by the applicable growth model.

2.2 First Orchard Genetic Gain Trial Series

Most data in this series were obtained from the 'large plot' genetic gain trials established by the Genetics and Tree Improvement group in 1978. These trials were established to quantify any genetic gain resultant from the first orchard or '850' breeding programme. Actual 'climbing-select' and first orchard seedlots (Appendix 1) were compared with other seedlots for a direct sawlog regime using a randomised complete block experiment design with six replicates per seedlot.

Silvicultural treatments are outlined in Table 3.

TABLE 3 - Silvicultural treatments for the first orchard genetic gains series

Planted	1978	
Initial stocking	1111 sph	
Silviculture	Thinned twice	- to 600 sph at MCH 6 m
300 sph		
		- to 300 sph at MCH 12 m
	Final crop pruned to 6 m in three lifts	

A further (pulpwood) regime trial was established on one site adjacent to the Kaingaroa direct sawlog trial. This was an untended regime planted at 711 sph. Date of planting and experimental design remain the same.

In 1986, circular permanent sample plots (PSP's) were established in all seedlot/replication plots of the first orchard and climbing select treatments only, by EFM staff.

The trial was established on four locations listed in Table 4.

TABLE 4 - Trial sites for first orchard genetic gain series

Location	Sample plot number	Region
Aupouri	AK 1058	Auckland Sands
Kaingaroa - clearwood	RO 2103/1	Central North Island Pumice Plateau
- pulpwood	RO 2103/2	
Mohaka	WN 377	Hawkes Bay
Golden Downs	NN 530/2	Golden Downs

A further set of data originates from an initial crop stocking trial established in Rotoehu Forest during 1970 to investigate appropriate initial stockings for the first orchard clonal series (James, 1979). This trial was planted at stockings ranging from 250 to 1500 sph for the '850' material, and thinned to a final crop of 250 sph (hence selection intensity ranged from 1:1 to 6:1 initial to final stocking ratio). A control seedlot incorporating climbing select seedlings planted at 1500 sph was used. Each treatment was replicated twice.

Thinning was carried out to 750 sph at a mean top height (MTH) of 10 metres, in plots where stocking exceeded 750 sph, with a second thinning at a MTH of 17 m to 250 sph. All final crop trees were pruned to six metres in three lifts. Plots were randomly arranged within a single block with two replicates per seedlot/initial stocking treatment.

2.3 **Second Orchard/Long Internode Genetic Gain Series**

This trial series was established by the Genetics and Tree Improvement Group during 1979/80 on three sites - Kaingaroa (RO 2103/3), Golden Downs (NN 530/1) and Dean Forest in central Southland (SD 682). Seedlots compared included '268', '875' (both second orchard clonal series), '870' (long internode) and climbing select (Appendix 1). The '268', '875' and '870' seedlots were all simulated seed orchard seedlots, made up of mixed control-pollinated seed from crosses among parent clones of seed orchard standard. Recent evaluations of the seedlot compositions indicate the simulated '875' seedlot may express below average performance for growth compared to current second orchard seedlots, while growth rate of the simulated '870' and '268' seedlots should more closely reflect the actual performance of the seed orchard seedlots they represent (G. Johnson, J. King, pers. comm.). A randomised complete block trial design was used, with either five or six replicates per seedlot. Table 5 provides a summary of silvicultural treatments. As for the first orchard series in 1986 circular PSP's were superimposed on the '268', '875', '870' and climbing-select seedlots by EFM staff. On the Dean trial, climbing select PSP's were placed in the forest surround planting, as the original GTI trial did not contain an equivalent seedlot.

TABLE 5 - Silvicultural treatments used in the second orchard genetic gains trial

Year planted	1979 - Kaingaroa (5 reps), Golden Downs (6 reps)
	1980 - Dean (5 reps)
Initial stocking	1111 sph
Silviculture	Thinned at MCH 6 m to 600 sph
	Thinned at MCH 12 m to 300 sph
	Final crop of 300 sph pruned to 6 m in three lifts

3.0 DATA COLLECTION METHODOLOGY AND ANALYSIS

3.1 '850' Final Crop Stocking Trial

In the 200, 400 and 600 sph treatments circular permanent sample plots were placed within the square treatment plots (which also corresponded with square GTI plots). Each PSP contained a minimum of 20 final crop trees, therefore plot size varied according to final stocking (Table 6). The 100 sph PSP's were too large to fit within the square treatment plots therefore a rectangular plot shape was adopted using two adjoining square treatment plots and placing the PSP within them.

In all cases the sample plots were adequately buffered.

Measurement consisted of a 100% DBH sample as well as 15 trees per plot measured for height. Where possible, both pre- and post-thinning DBH measurements were recorded.

TABLE 6 - PSP dimensions for the final crop stocking trial

Treatment	Size* (ha)	Shape
100 sph	0.2	Rectangular
200 sph	0.1	Circular
400 sph	0.05	Circular
600 sph	0.04	Circular

Plot basal areas, mean crop heights and volumes were calculated. An earlier data point, usually at age 8, was estimated from GTI assessment data. Treatment means were subsequently calculated and graphed to facilitate visual comparisons.

3.2 First and Second Orchard/Long Internode Genetic Gain Series

For both trial series, data collection methodology was virtually identical. Circular permanent sample plots of 0.05 hectares in size were established within the square 'treatment' (i.e., climbing select, '850', '268', '875', or '870' seedlot) plots. Measurement encompassed a 100% DBH sample, along with 15 height trees per plot (100% in thinned plots and 50% in plots yet to receive a final thinning). Measurements were recorded at ages eight and nine years. An earlier data point was estimated from GTI measurements at age five or six.

Data from the Rotoehu trial originated from square 0.2 ha experimental plots with a 100% DBH sample taken.

Basal areas, mean top heights and volumes were calculated on a plot basis and treatment means subsequently calculated. Regional volume functions were used for volume calculation. Growth trajectories for the above variables were graphed and percentage gains calculated for both 1986 and 1987.

4.0 RESULTS AND DISCUSSION

4.1 Final Crop Stocking Trial

4.1.1 Results

On all sites, thinning has reduced stand volumes in proportion to thinning intensity (Figure 1). A selection effect associated with differential thinning has occurred: mean diameter of the residual crop has increased with the application of a greater selection intensity (e.g., Figure 2). A similar (but less marked) trend occurs with height (Appendix 2).

Examination of volume per tree increments (Table 7) indicate the lack of a significant 'thinning shock' effect: volume increments are already greater on a per tree basis for the low stocking treatments.

TABLE 7 - Mean volume/tree increments, Kaingaroa

Stocking (SPH)	Volume/tree increment (m^3) at age 12
100	0.12
200	0.10
400	0.10
600	0.07

Fertility levels vary among the four sites to a large degree - growth comparisons of volume response (Appendix 3) indicate regional growth differences: the two North Island sites are more fertile than the Golden Downs and Eyrewell sites.

4.1.2 Discussion

Results from this trial should be considered as preliminary, since it is still at an early stage; with the late thinning treatment yet to be imposed on all sites.

The effects of thinning, viz, volume reductions and subsequent variation in growth responses of the first orchard seedlot relative to residual stocking and inherent site fertility, are evident, and similar to those observed for unimproved material (although the absence of comparative treatments of unimproved material in this trial prevents evaluation of the magnitude of any differences).

The selection effect in the thinned plots is a result of selective thinning to differing final stockings from fixed initial stockings. For the subsequent analysis, the selection effect will be partially offset with a covariate adjustment using post-thinning measurements, thus providing an indication of the effect of varying final stockings independent of the individual tree size dimensions following thinning.

The appearance of inter-regional growth differences is to be expected due to differences in site fertility. However, it is too early to predict whether patterns of growth for improved breeds will be markedly different between regions (as is the case for unimproved *P. radiata*), and similarly, whether intra-regional growth patterns will differ depending upon genotypic characteristics.

FIGURE 1 – KAINGAROA FCS : BASAL AREA ON AGE

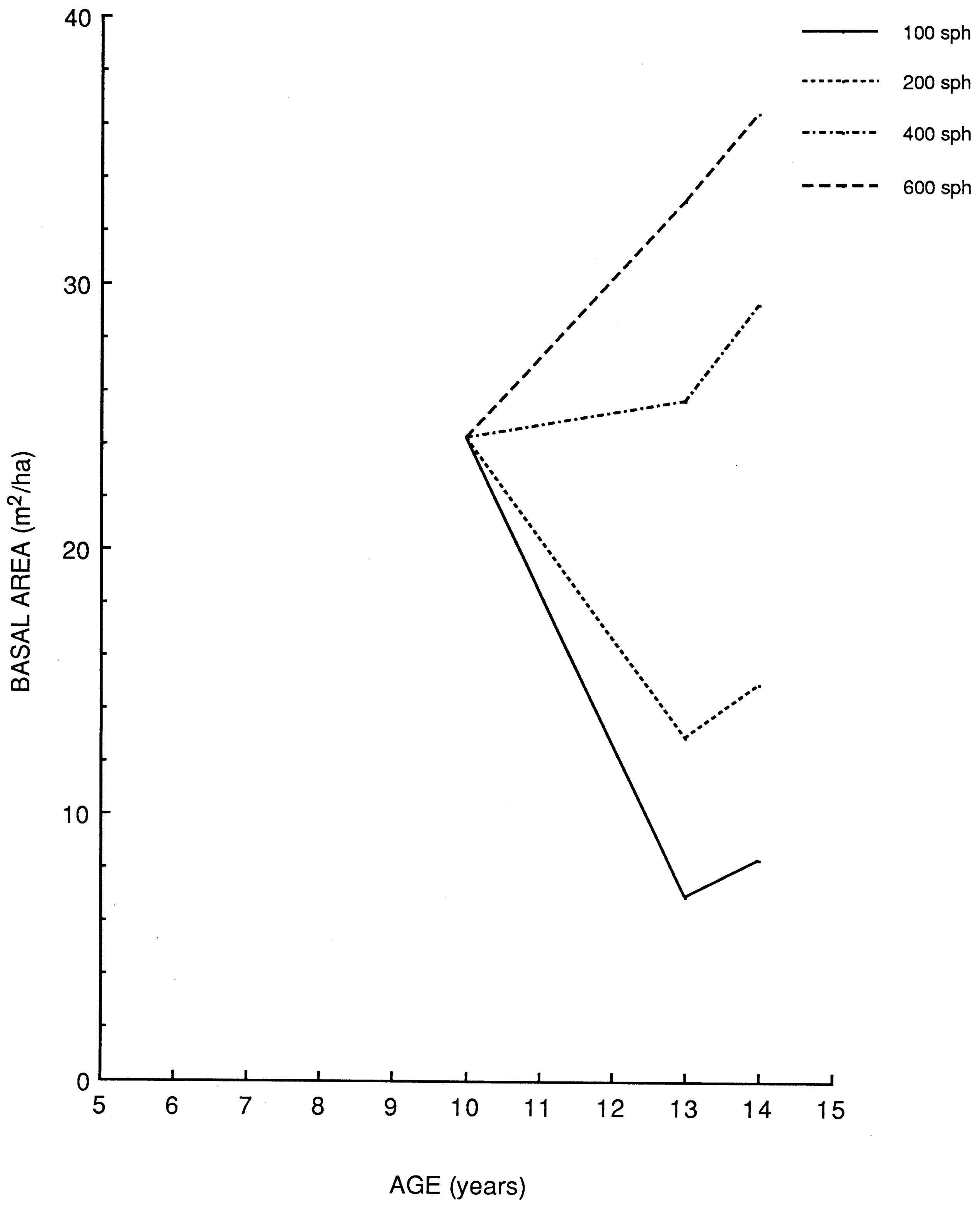
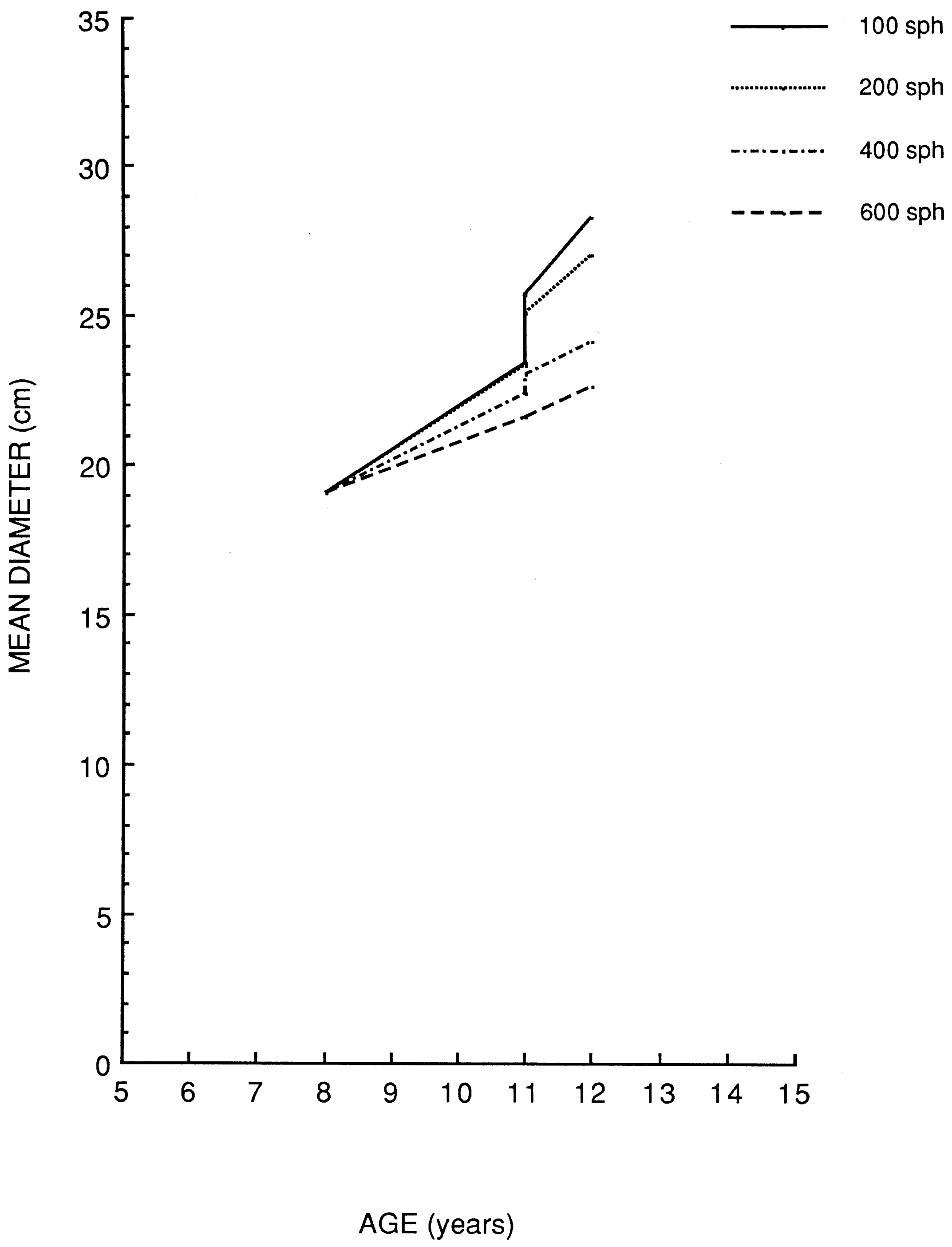


FIGURE 2 – WOODHILL FCS : DIAMETER ON AGE



4.2 **First Orchard Genetic Gains Trial Series**

4.2.1 Results

On all sites, with the exception of Golden Downs, the first orchard material exhibited superior growth performance to that of the climbing select seedlot. Improved performance in terms of volume (Table 8) of up to 36% was resultant from gains in both basal area and height (Appendix 4).

TABLE 8 - Genetic gains trial - percentage volume gains

Site	Volume gain (%)	
	Age 8	Age 9
Nelson	-23.5	-19.0
Kaingaroa (clearwood)	12.5	13.8
Kaingaroa (pulpwood)	1.6	4.1
Mohaka	26.8	36.7
Aupouri	14.1	9.35

Figures 3 and 4 and Appendix 5 show an indication of levels of improvement for each site. The Rotoehu result (Figure 4) shows basal area development over the age 8 to 15 period for the two seedlots, and indicates the difference between them is increasing in absolute terms over time (although the percentage gain over time remains constant at 10%).

4.2.2 Discussion

Results from this trial series confirm earlier published estimates of genetic gain (Carson, 1987; Shelbourne *et al.*, 1986). However, they also indicate that the extent of gain can vary according to both region and silvicultural regime: volume gains ranged from 9% to 37% for a standard clearwood regime established in three regions, and for one example of differing silviculture, volume gain differed by almost 10% (4% gain for a pulpwood regime compared with 13.8% for the clearwood regime).

The longevity of genetic gain is unknown: do the increased rates of growth shown in these 9-year-old trials occur throughout the entire length of the rotation, or are they simply an artefact of early growth performance only? Examination of the growth curves, particularly for basal area and volume, generally show divergent trajectories even at this early stage. Furthermore, results from the Rotoehu initial stocking trial indicate that growth trajectories will continue to diverge with age. This suggests growth patterns of the first orchard material will mirror those currently exhibited throughout the range of regions within New Zealand (although the amount of gain will vary, as earlier stated). However, this is supposition only: more growth information will be obtained as time progresses and will be used to confirm this trend for different sites and silvicultural regimes.

Volume calculations were performed using the appropriate regional volume functions. These functions have yet to be validated for the improved breeds, thus some error in estimating volume gain may have occurred. This error is however, unlikely to significantly reduce calculated gain, as both height and basal area development (which are independent of three dimensional tree shape) are markedly improved for the first orchard material.

The Golden Downs result is an anomaly: 20% less volume growth for the improved breed has been shown for this site. Three explanations have been offered:

(i) A nursery effect due to the seedlots being raised in separate nurseries before planting.

FIGURE 3 – MOHAKA : BASAL AREA ON AGE

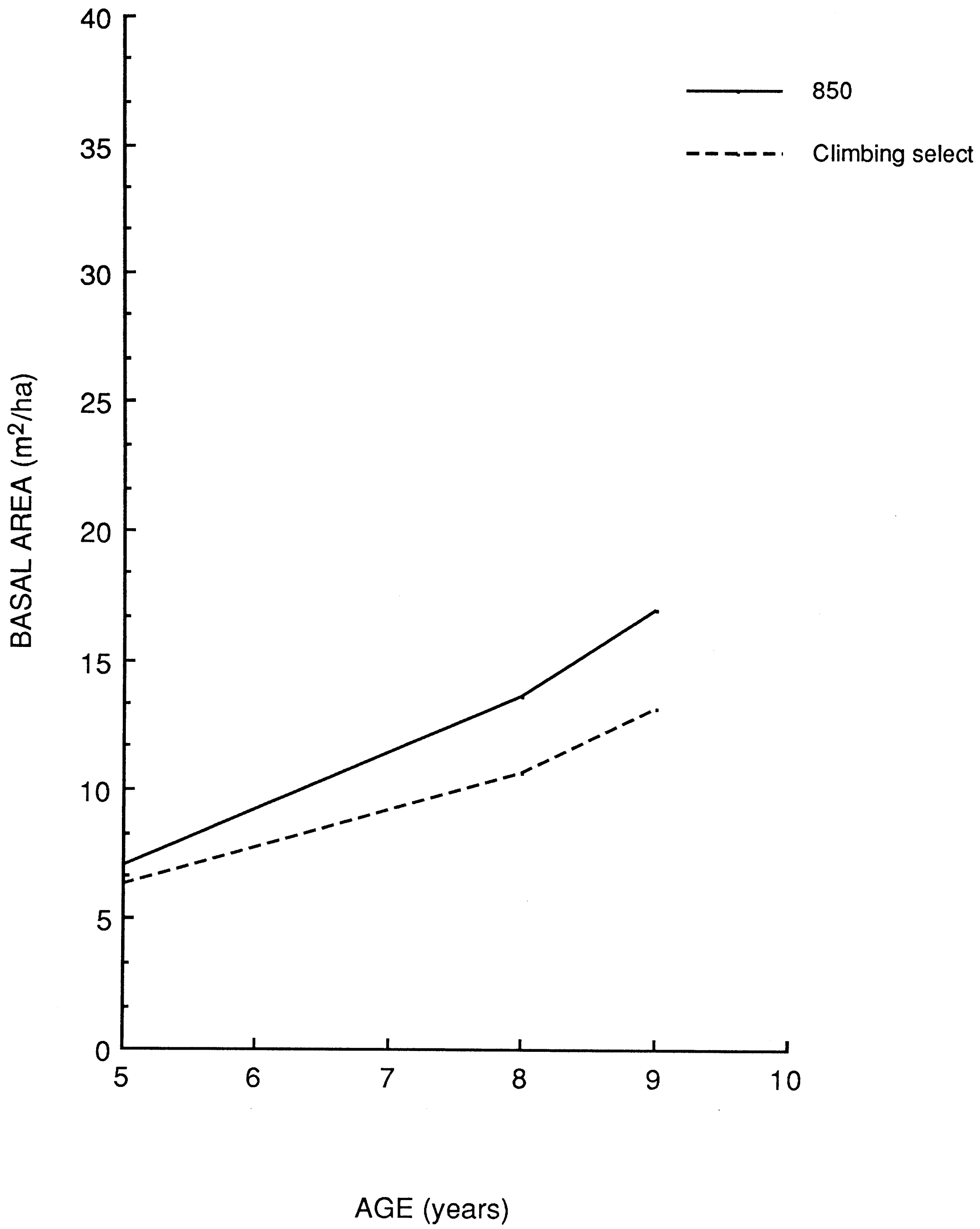
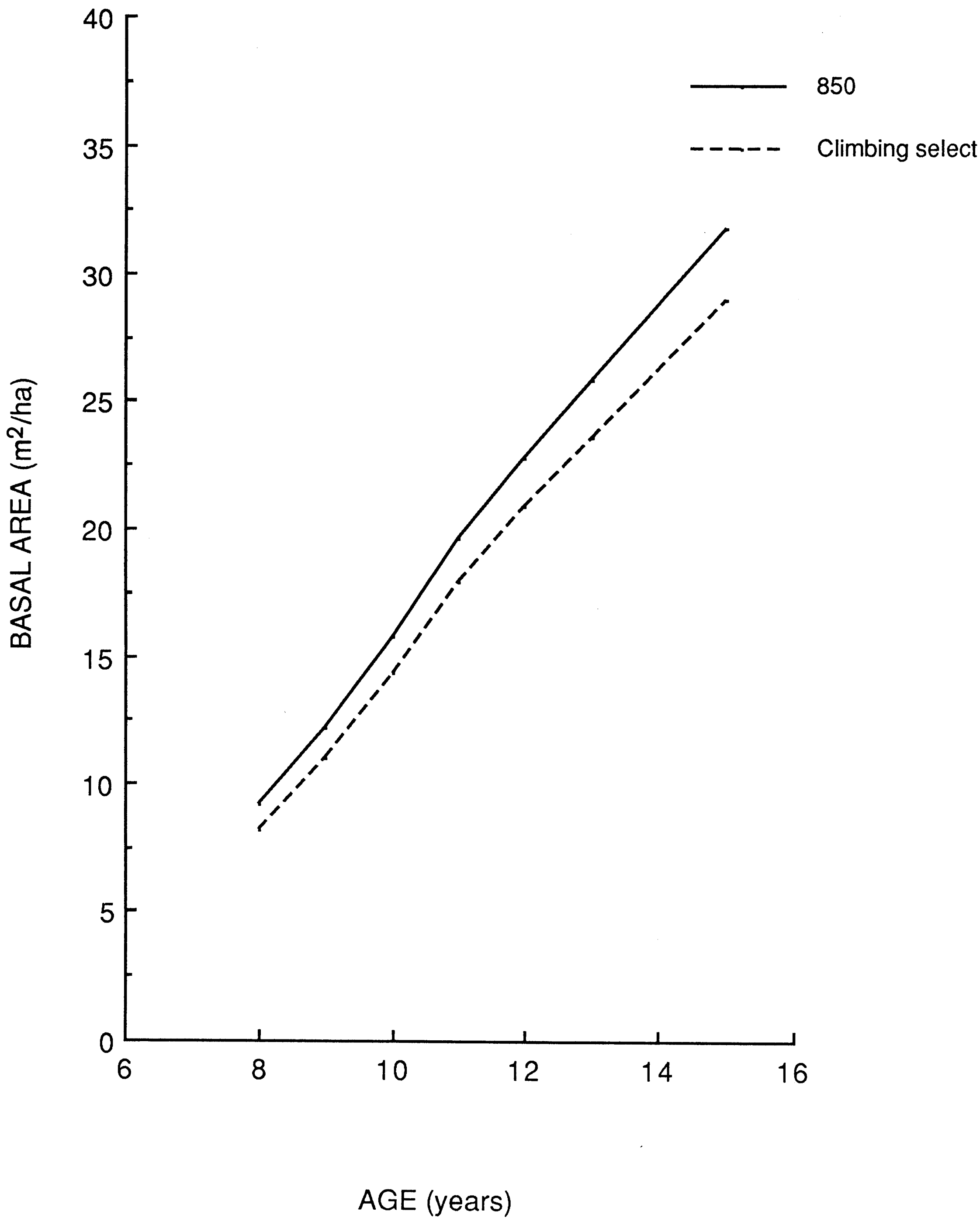


FIGURE 4 – ROTOEHU : BASAL AREA ON AGE



(ii) Volume per hectare differences are inflated by uneven numbers of trees per plot: climbing select plots have 33 trees/plot on average compared with 29 trees/plot for 850; and

(iii) The exceptional quality of this particular climbing select seedlot following two earlier selections from previous rotations (A. Firth, pers. comm.).

The nursery effect is likely to be a contributing factor in the reported growth differences, as similar results have been reported in a smaller trial in the Nelson region, but is unlikely to wholly account for the 20% volume difference nine years after planting. The origin of the climbing select seedlot may be another factor - the Nelson material was collected from local stands which had already undergone 'mild' selections from previous rotations. Performance results over the next few years should reveal whether the present disadvantage of the first orchard material is maintained.

This result is indicative of variability of climbing/felling select material, which therefore should not be regarded as a 'fixed' baseline for quantifying genetic gain but rather as an approximate level from which relative improvement can be gauged. It should also be noted that data used to construct existing models comes mostly from seed of unimproved or climbing/felling select origin, suggesting some variation in growth performance within regions is attributable to a larger genetic variation in growth rate of these seedlots compared to the improved breeds.

4.3 **Second Orchard/Long Internode Genetic Gain Trial Series**

4.3.1 Results

Results presented in Table 9 show the '268' seedlot to be clearly superior on all three sites to all other seedlots, with volume gains ranging from 15% to 36% over the climbing select seedlot. Improved growth performance is also evident for the '875' seedlot, but is consistently less than that of the '268' seedlot.

Performance of the '870' long internode seedlot however, varied depending upon site: volume gains of 23% occurred on the lower fertility Southland site, whereas on the Kaingaroa site, volume yields were 16% less than for climbing select.

TABLE 9 - Percentage volume gains for the second orchard/long internode genetic gain series

Site		Percentage volume gains					
	Breed:	Long internode		Growth and form			
	Clonal series:	870		875		268	
	Year:	1986	1987	1986	1987	1986	1987
Golden Downs		2.21	1.8	3.2	1.8	24.7	25.6
Dean		26.7	23.0	33.7	27.4	39.4	36.3
Kaingaroa		-13.9	-16.0	8.3	5.7	16.0	14.8

Figure 5 and Appendix 6 show actual levels and rates of height, basal area and volume growth for each of the seedlots over the range of sites examined.

4.3.2 Discussion

Results from this trial series clearly demonstrate the superiority of the '268' clonal series. Growth performance, in terms of both height and basal area (and hence volume) is superior to all other breeds on all sites. The material in the trials described here is representative of seed currently available from open-pollinated '268' seed orchards, but is not expected to perform as well as 'best' control-pollinated material of the same series.

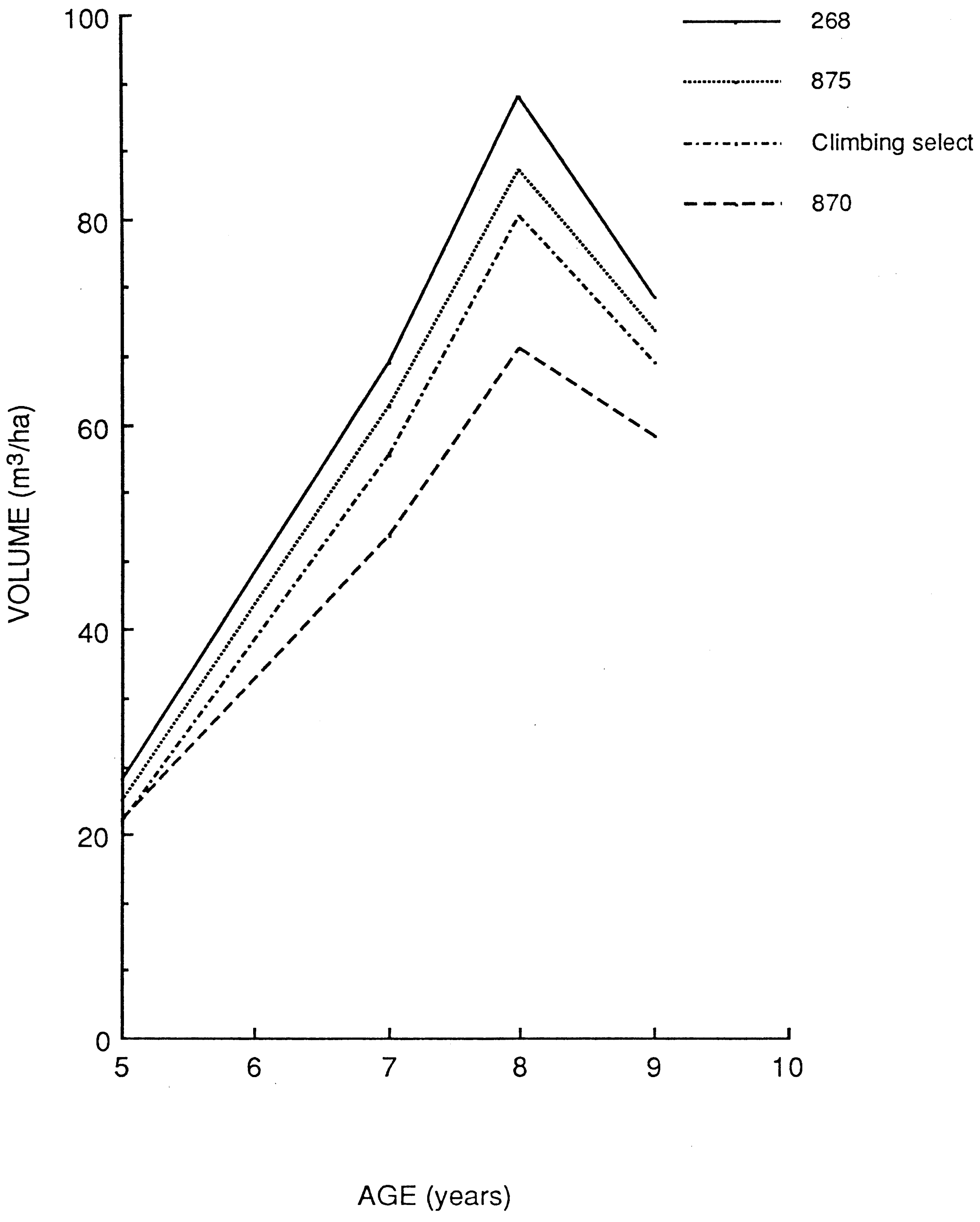
The '875' series select did not perform as well as the '268' series seedlot, despite being a 'second orchard' derivative. This series was selected with major emphasis on multi-nodality and high wood density from families within the '268' clonal series but without subsequent progeny testing. It is therefore representative of the lower end of the second orchard performance spectrum. Some improvement over climbing select was found, but on the two South Island sites the magnitude of gain was limited (1.8 to 8.3% volume gains) compared to the more superior '268' seedlot.

The '870' seedlot, selected with major emphasis on the long internode branch habit, performed in a variable manner. Growth performance at the more fertile Kaingaroa site was poor with up to 16% less volume than the climbing select series. On the lower fertility South Island sites, performance was somewhat improved with growth rates equivalent, or in the case of Dean, superior to the climbing select seedlot. In all cases however, long internode performance was inferior to that of seedlots representing the second orchard breed. The long internode breed is therefore more suited to lower fertility site which favour the long internode expression (e.g., Southland), and less suited to higher fertility and sandy sites.

Since the trial series is currently 8-9 years old and planted on three sites, only preliminary conclusions can be reached on growth trends. Growth trajectories appear to be divergent with respect to the '268' seedlot, with the remaining seedlot trajectories almost parallel. More information will be gained as these trials age. Information from these trials and younger stands composed of '268' seedlots as well as trials currently being planted will provide future growth modelling data.

An accurate comparison of the '268' and '850' performance is difficult to make. Kaingaroa and Golden Downs Forests had both trial series planted, with a similar climbing select seedlot as an experimental control. However, these trials were established on different sites, with differing planting dates and dissimilar nursery treatment. Given these differences, volume gain for the '268' series was greater on both sites compared to the '850' material. Data from smaller row-plot genetic gains trials over a larger number of sites confirm this trend (King *et al.*, 1987) the second orchard material is superior in growth to the '850' orchard material.

FIGURE 5 – KAINGAROA : VOLUME ON AGE



NB : THIS TRIAL WAS THINNED AT AGE 9

5.0 CONCLUSIONS

Results presented in this report generally show increased growth performance for the improved breeds on most sites investigated. The extent of gain depended upon:

(i) Breed.
(ii) Site.
(iii) Silvicultural regime.
(iv) Nature of the 'control' seedlot (i.e., climbing select).

Improved growth rates were most marked for the '268' seedlot, with substantial gains also exhibited by the '850' series. Variation in performance depending upon site was also found, with all seedlots tested exhibiting a range of gain (or losses) compared to the climbing select controls (although the performance of the control seedlots may also have varied). A limited amount of information regarding the influence of silvicultural treatments was obtained also, with increased gains apparent in the more intensive clearwood type regime.

Large differences in growth patterns between climbing select seedlot and the genetically improved material do not appear to be occurring, but since most trials are still relatively young and with only limited quantities of data to date, any statement regarding differences in the shape of growth trajectories would be premature. As a result, the measurement program should be continued until sufficient data is obtained.

The spread of current data for improved breeds both:

(i) within regions, and
(ii) across a range of silvicultural regimes;
is limited.

While the '850' series final crop stocking trial does provide some intra-regional overlap with the '850' genetic gains series (with additional information regarding final stocking), most trials have been limited to a clearwood-type regime and are represented by only one site per region. To accurately model and predict performance of the genetically improved *P. radiata* over a range of sites and silvicultural regimes within a given region may require a considerably larger database than currently exists, particularly for the '268' series. Current plans are to increase the PSP coverage for the '268' series on existing trials (mainly in the Central North Island region) including modifying some of these trials in order to gain comparative information on silvicultural regimes.

Future work should:

(i) Aim to establish whether the functions used in current growth modelling are appropriate for the improved breeds,

(ii) In the short-term, develop adjustment methods to approximate genetic gain using existing models, and

(iii) In the longer term, provide a methodology for predicting growth and yield of further improved breeds (and clones) of *P. radiata*.

ACKNOWLEDGEMENTS

The author would like to acknowledge the work of the Genetics and Tree Improvement research field, in particular Mr A. Firth and Dr C.J.A. Shelbourne who established the majority of these trials and kindly allowed the establishment of PSP's within them. The authors would also like to acknowledge the assistance of the Forest Mensuration and Management Systems and Improved Breeds groups in collecting and preparing the data.

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LIST OF APPENDICES

APPENDIX 1 - List of seedlot numbers

1.1 850/climbing select comparison

Site	850	C/S
Kaingaroa/1	R/76//01/3[1]	WN/76/A2/3
/2	R/76//01/3[1]	WN/76/A2/3
Golden Downs	NN/C/75/02[2]	WN/76/A2/3
Mohaka	WN/C/75/15/4[3]	WN/76/A2/3
Aupouri	R/76//01/3[1]	WN/76/A2/3
Rotoehu	WN/68/A1	R/67/795

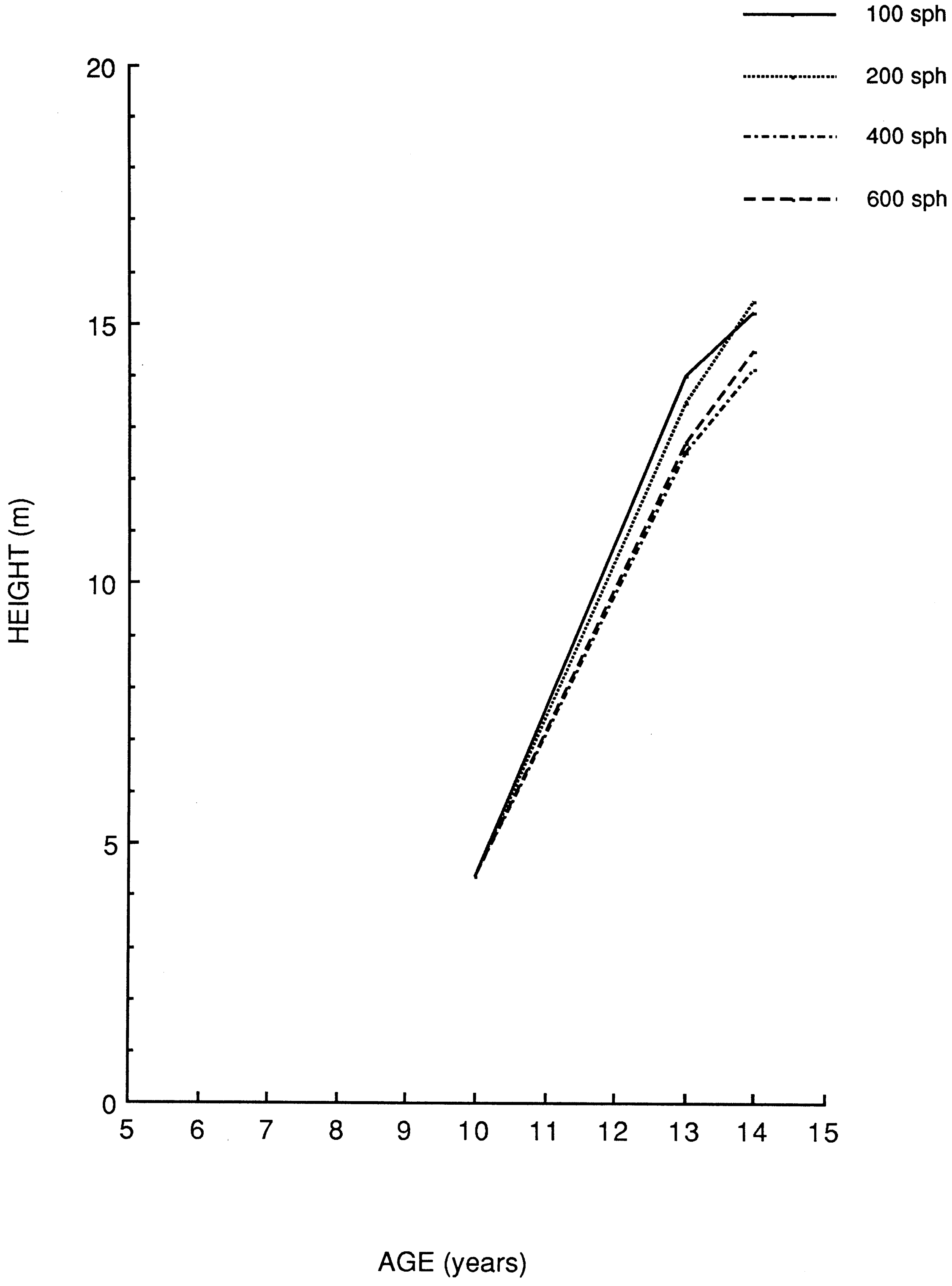
1.2 268/875/long internode comparison

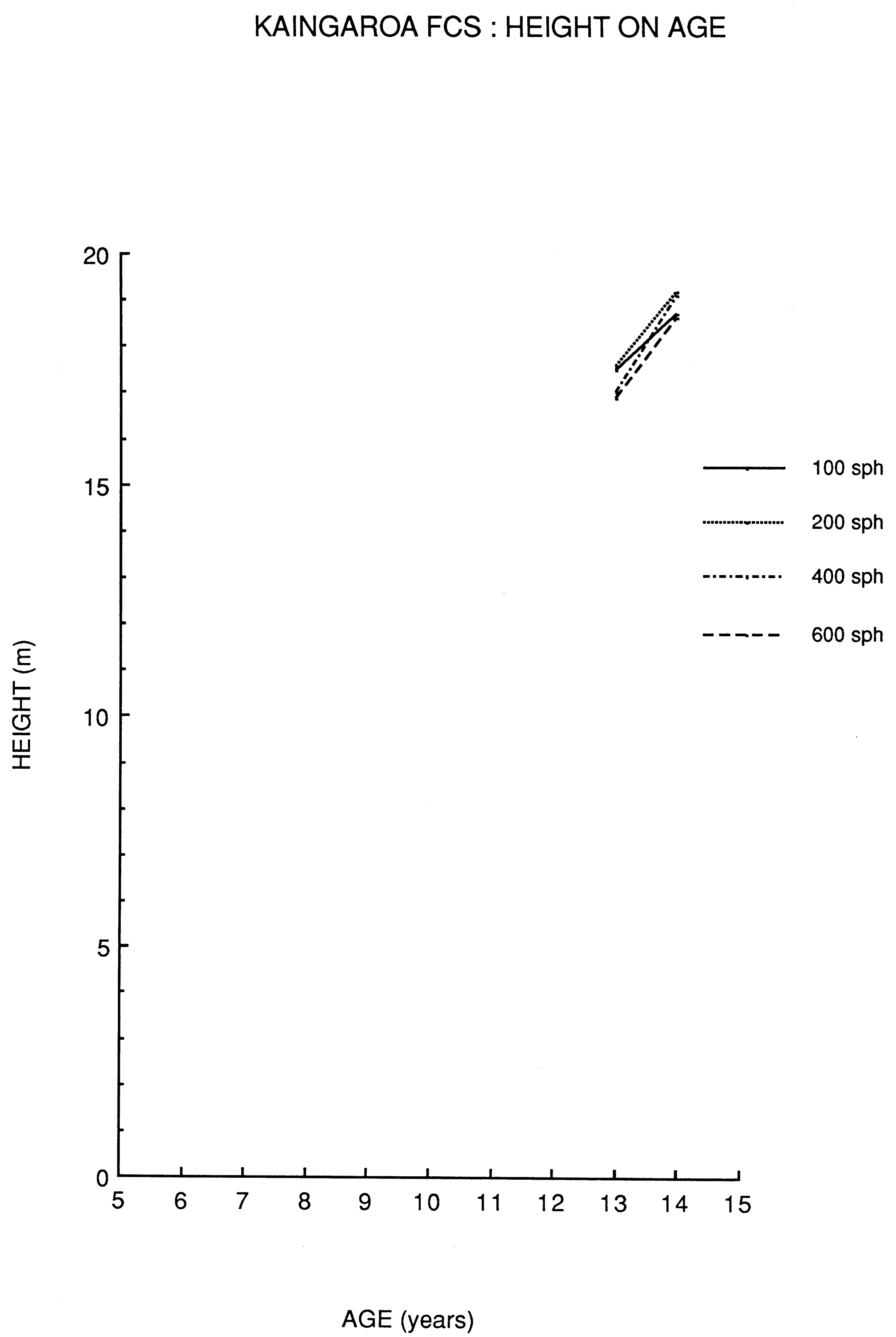
Site	268	875	870	C/S
Kaingaroa	FRI 2300	FRI 2299	FRI 2301	R/76/01/3[1]
Dean	FRI 2300	FRI 2299	FRI 2301	7/1/76/002[4]
Golden Downs	FRI 2300	FRI 2299	FRI 2301	R/76/01/3[1]

1 Kaingaroa climbing select.
2 Nelson climbing select.
3 Mohaka climbing select.
4 Rankleburn climbing select.

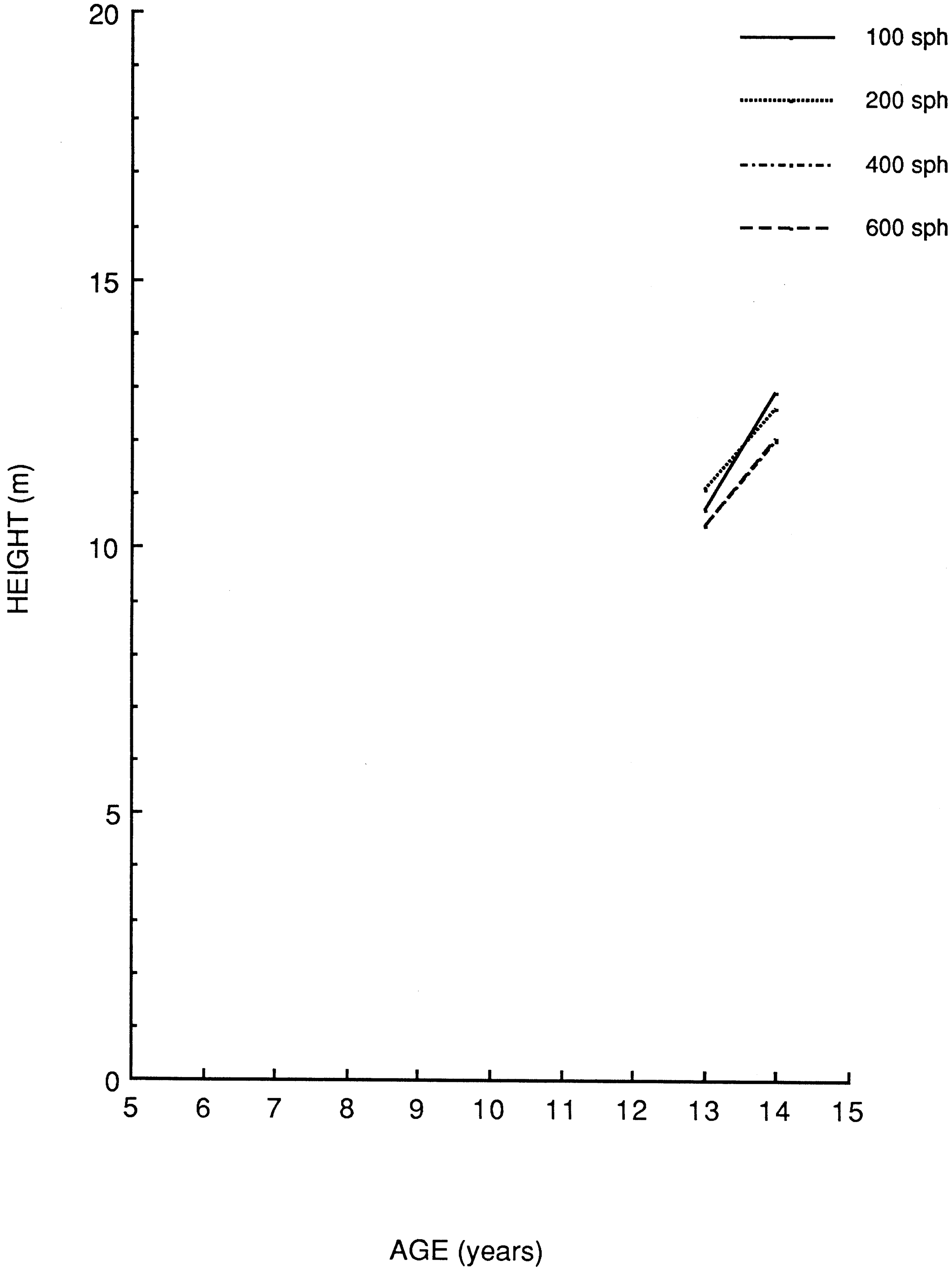
APPENDIX 2 - 850 FCS trial: height/age performance

GOLDEN DOWNS FCS : HEIGHT ON AGE



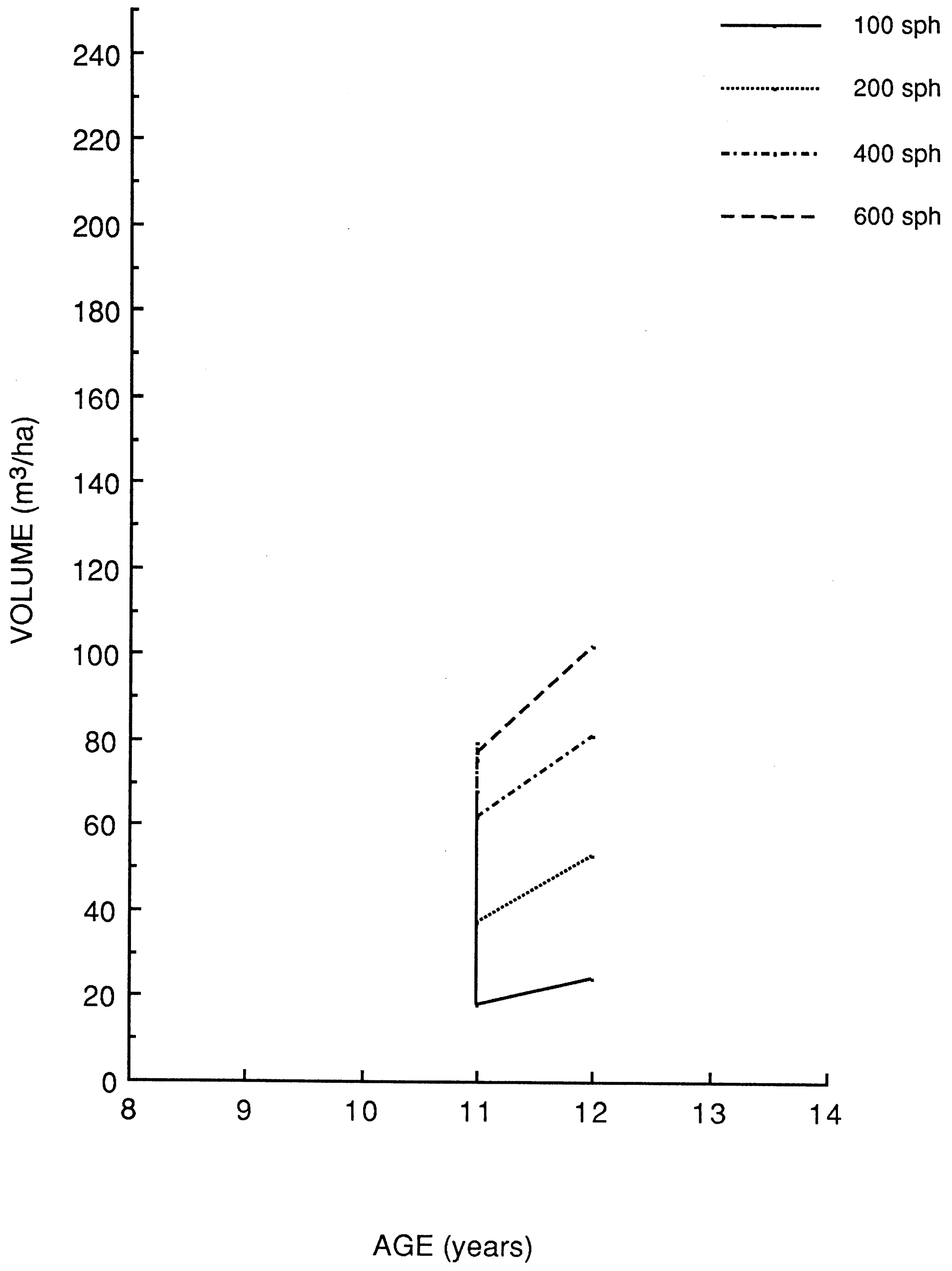

KAINGAROA FCS : HEIGHT ON AGE
HEIGHT (m)
0
5
10
15
20
AGE (years)
5
6
7
8
9
10
11
12
13
14
15
100 sph
200 sph
400 sph
600 sph

EYREWELL FCS : HEIGHT ON AGE

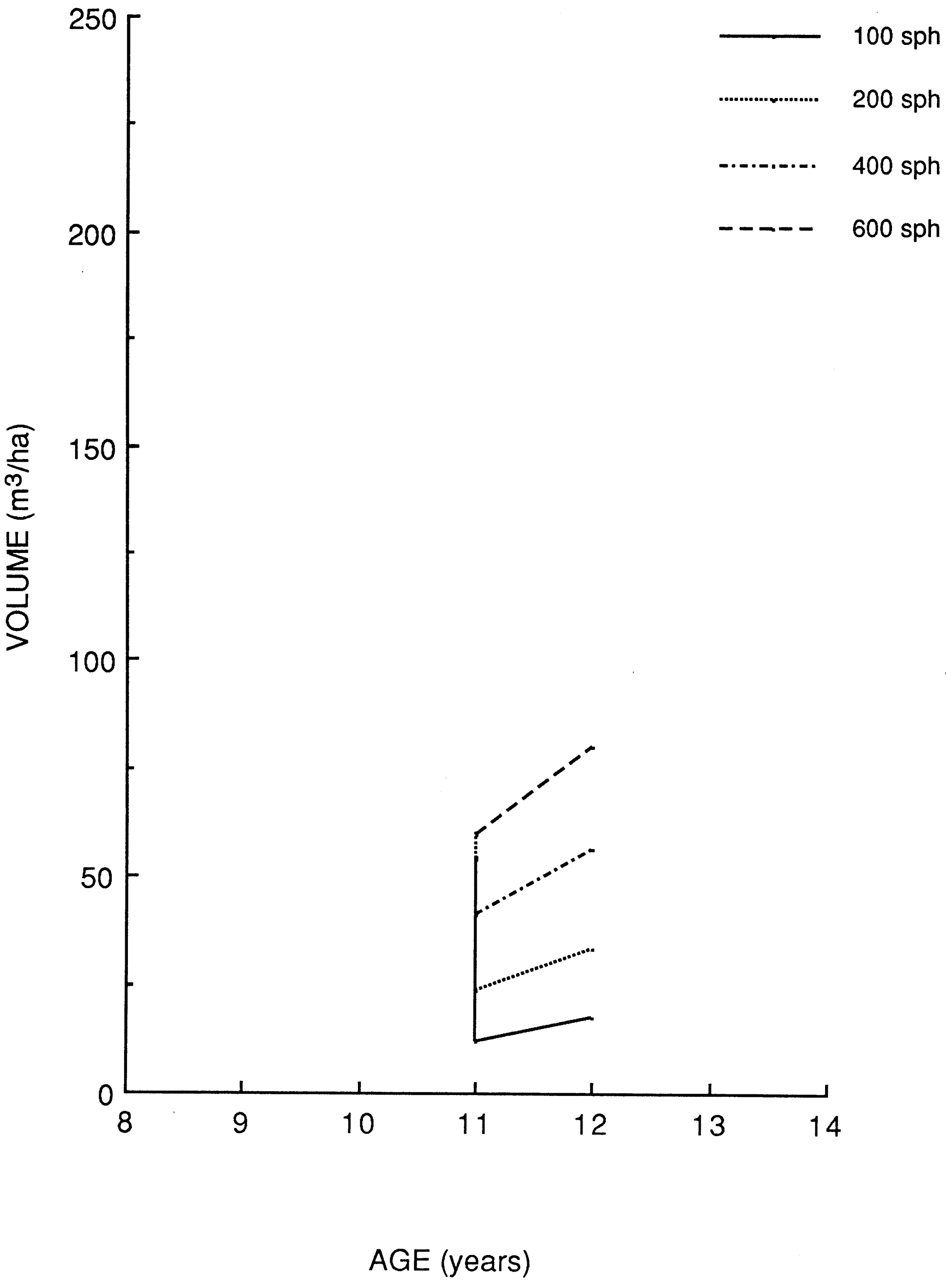


APPENDIX 3 - 850 FCS trial: volume/age performance

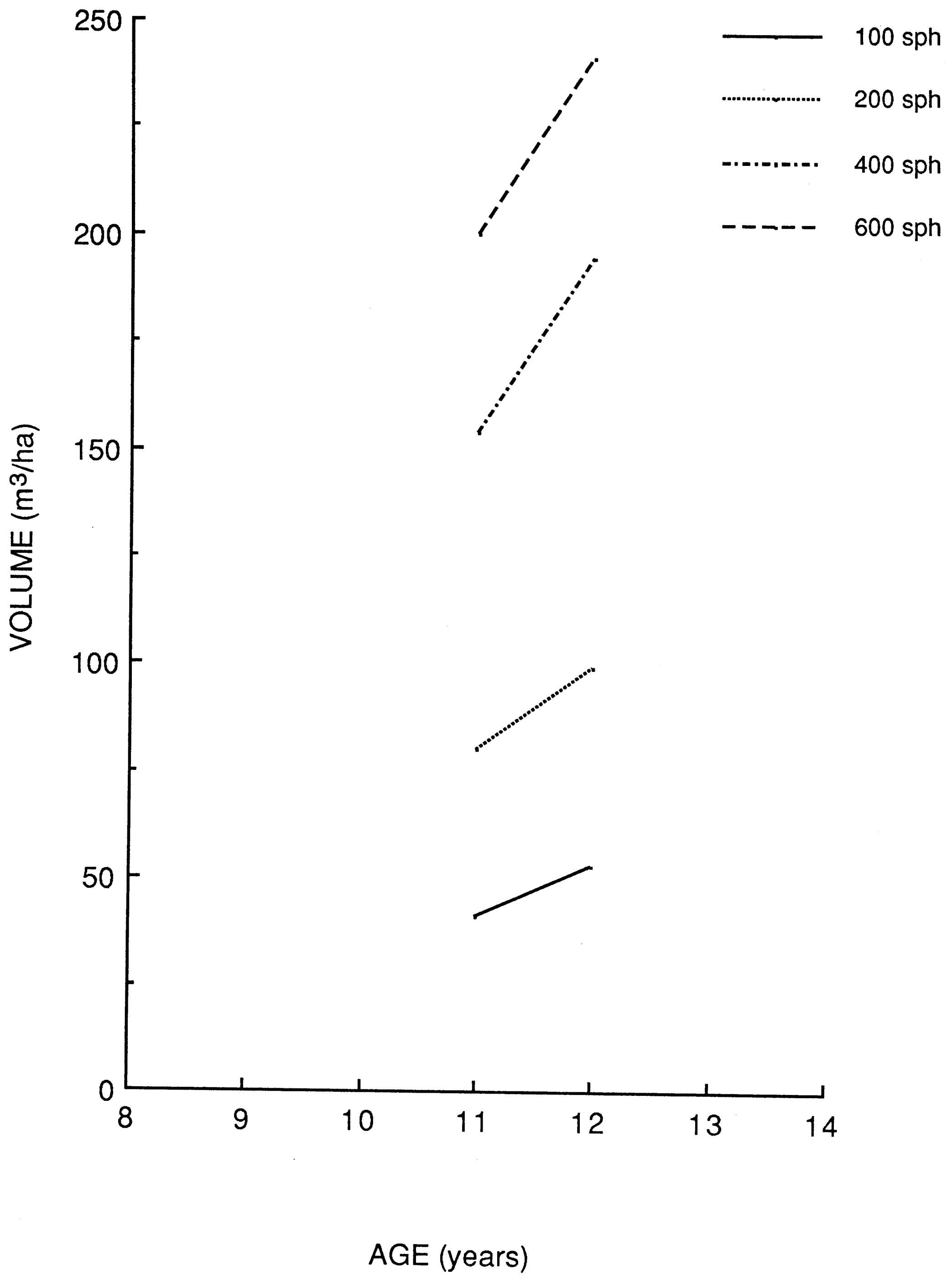
GOLDEN DOWNS FCS : VOLUME ON AGE



EYREWELL FCS : VOLUME ON AGE



KAINGAROA FCS : VOLUME ON AGE



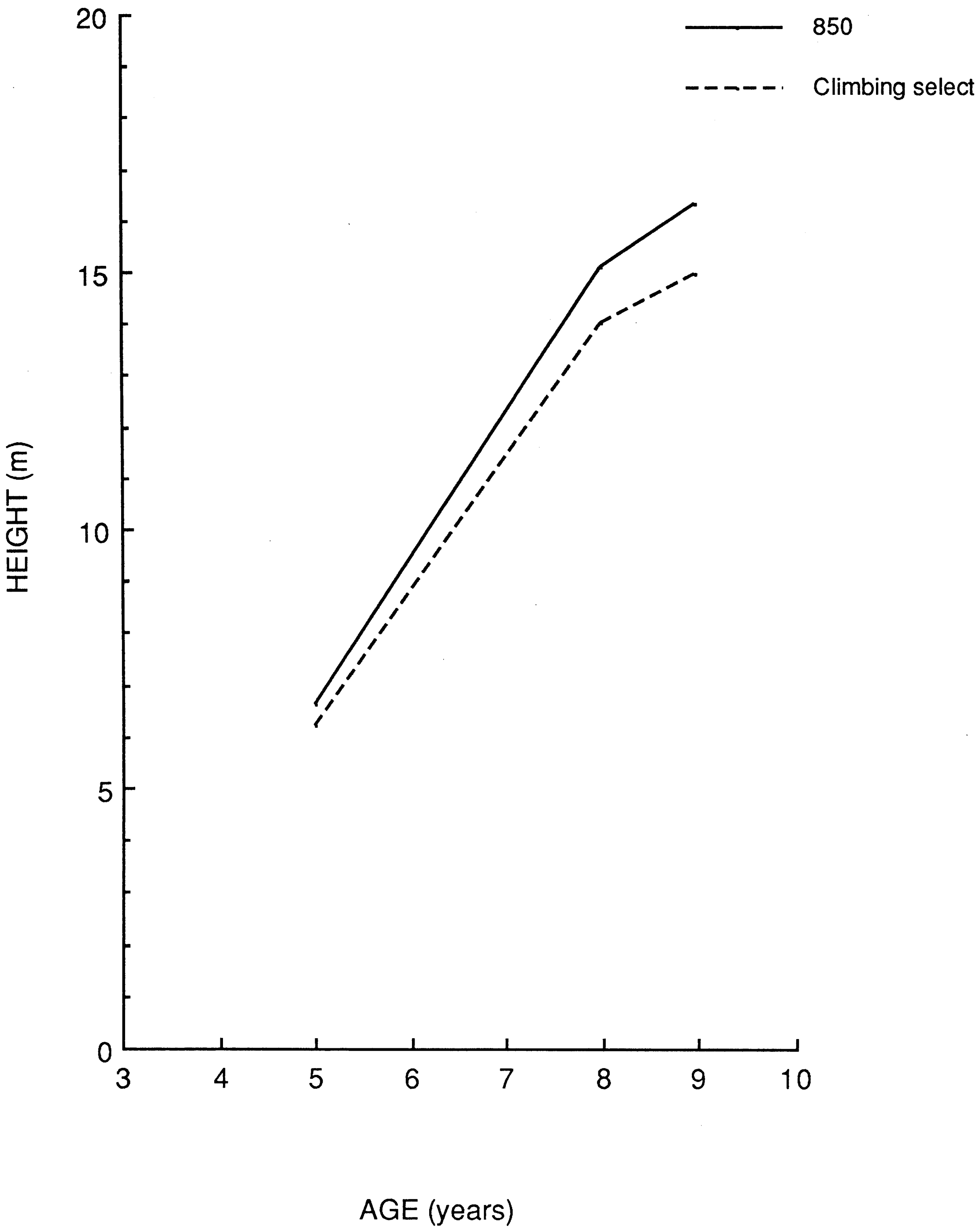
APPENDIX 4 - First orchard genetic gains: percentage basal area and height gains

Location	% gain			
	Height		Basal area	
	1986	1987	1986	1987
Aupouri	5.7	1.9	8.8	7.4
Golden Downs	-7.1	-4.9	-20.0	-16.6
Kaingaroa[1]	6.1	6.5	7.5	8.1
Kaingaroa[2]	0.9	1.6	1.6	3.7
Mohaka	6.9	9.2	21.6	28.7

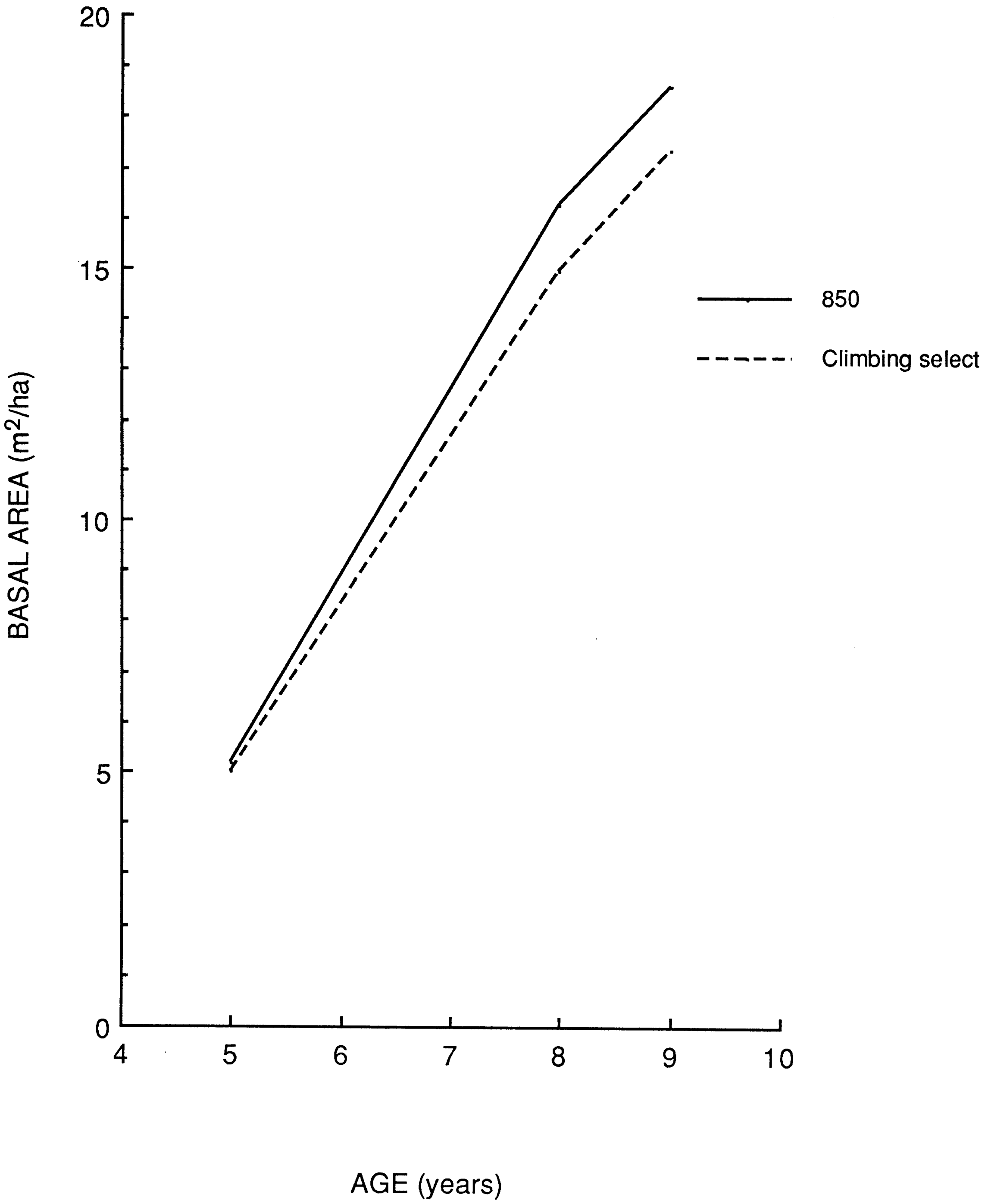
NB: [1] Clearwood regime.
[2] Pulpwood regime.

APPENDIX 5 - First orchard genetic gains: height, volume and basal area performance

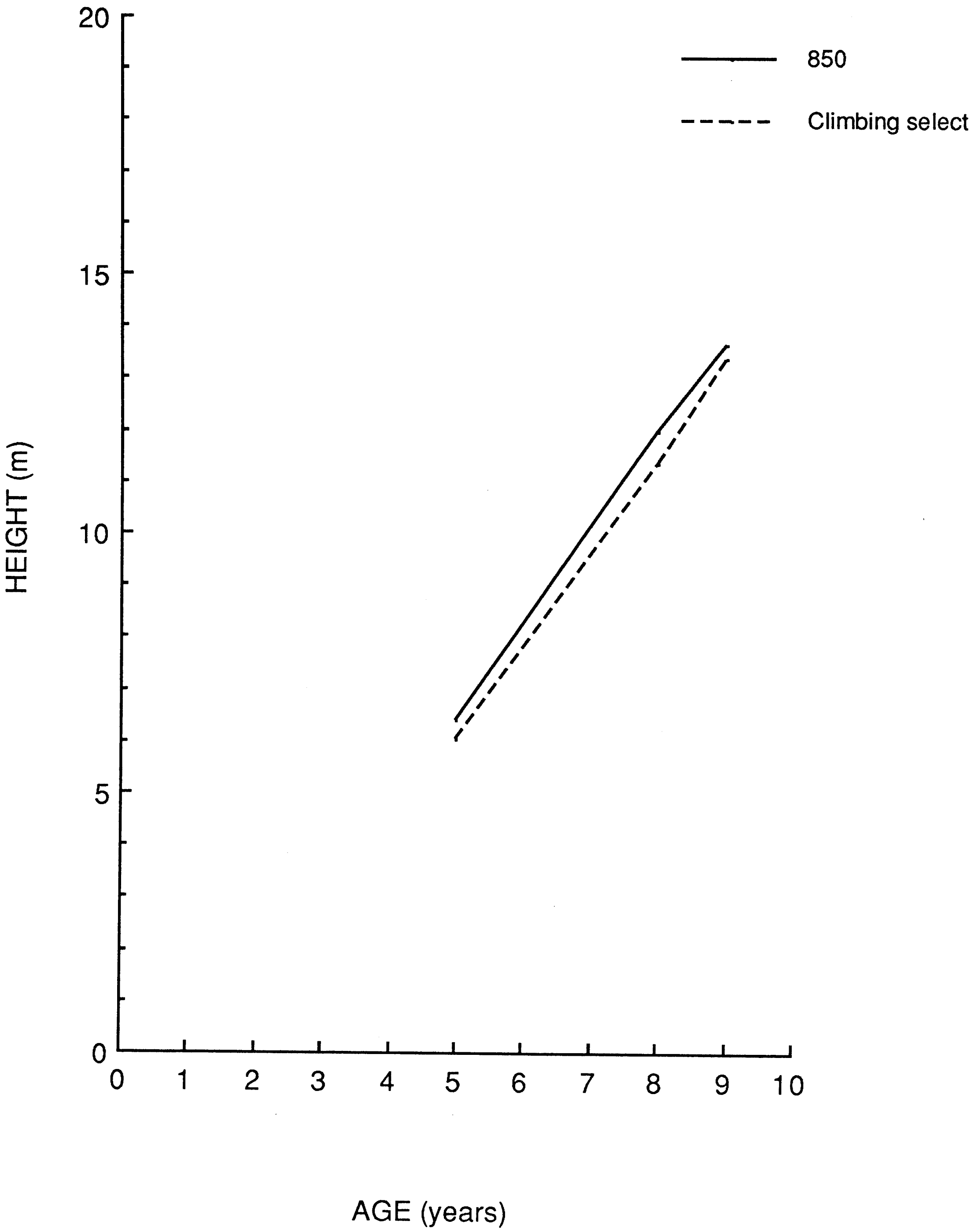
MOHAKA : HEIGHT ON AGE



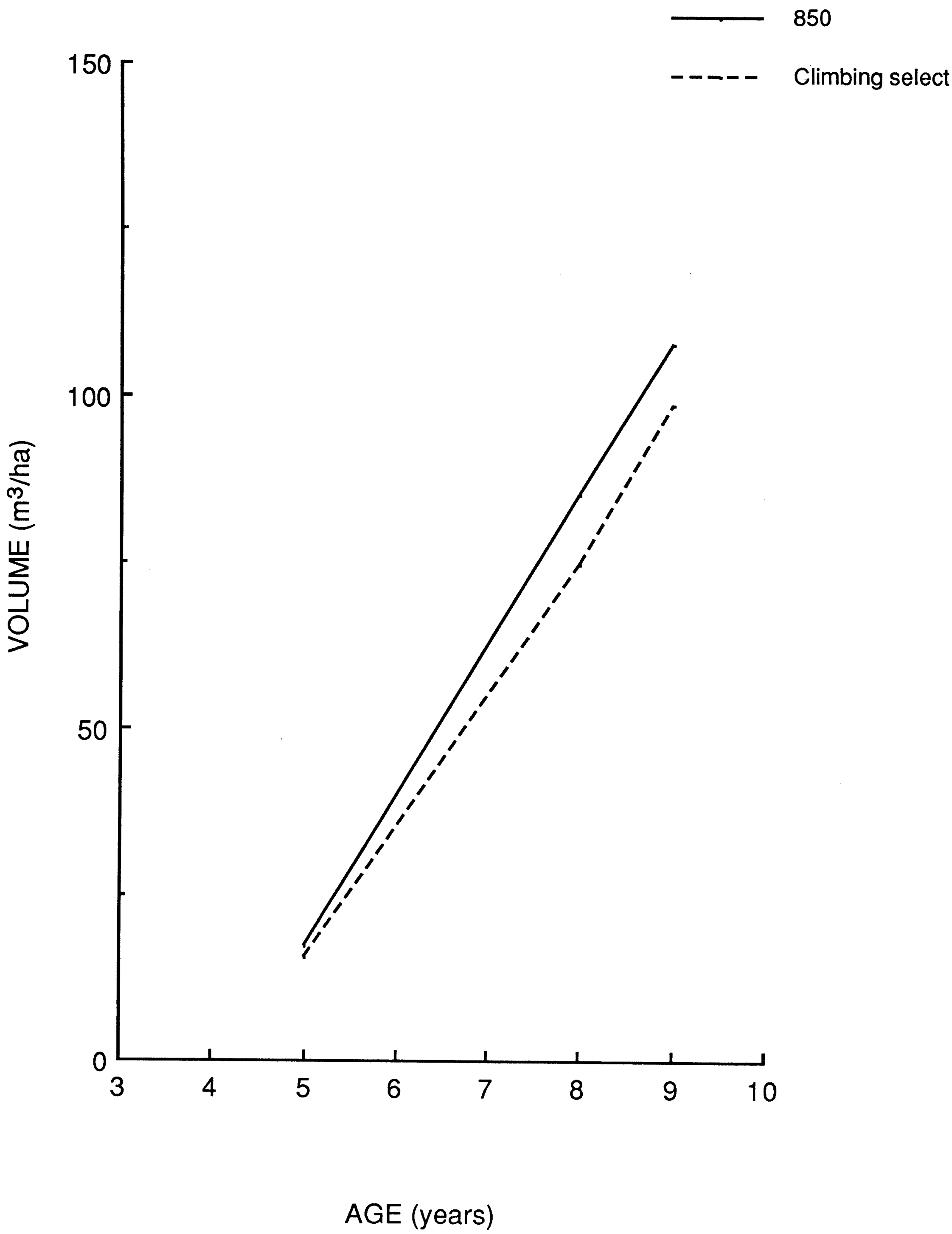
AUPOURI : BASAL AREA ON AGE



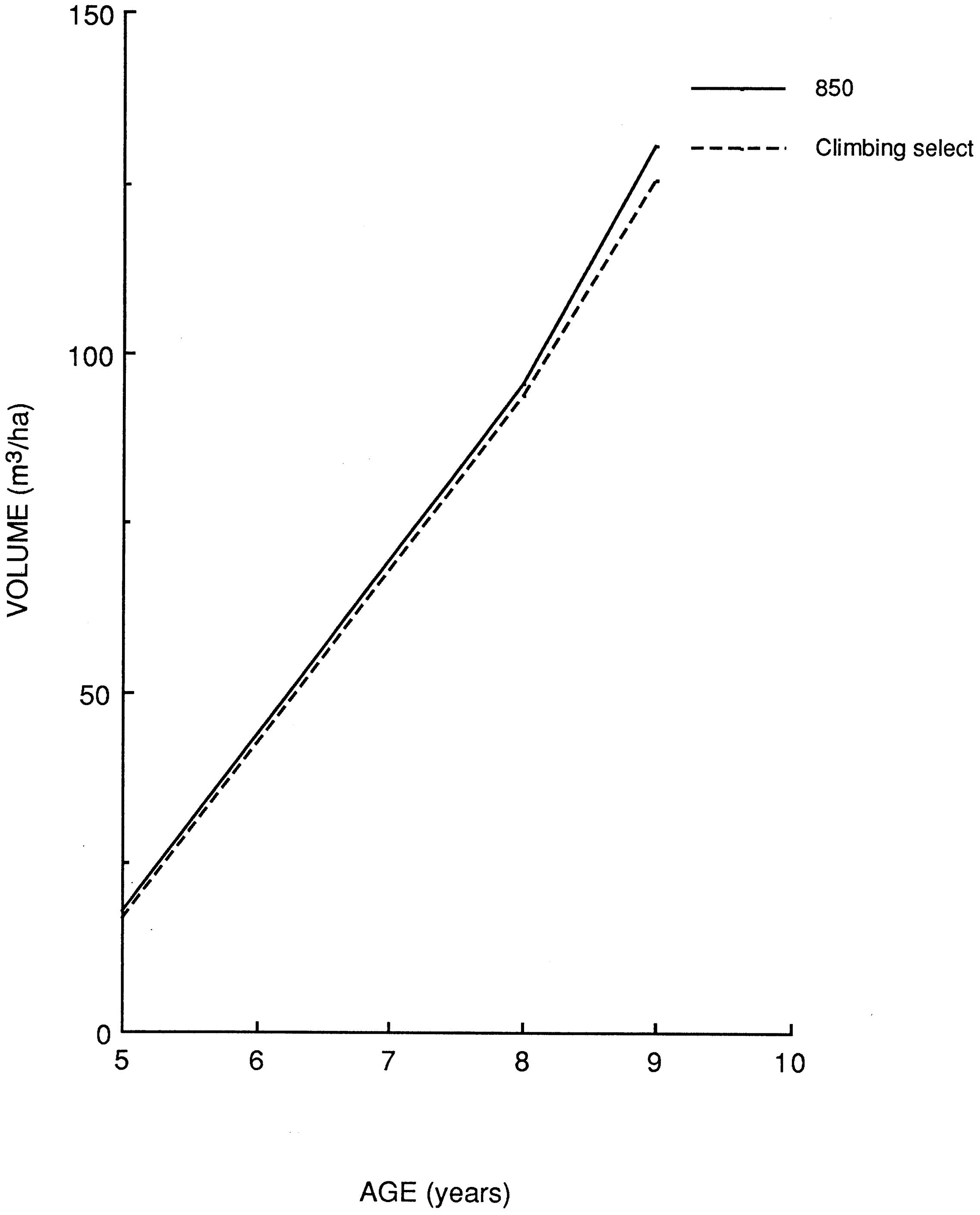
AUPOURI : HEIGHT ON AGE



AUPOURI : VOLUME ON AGE

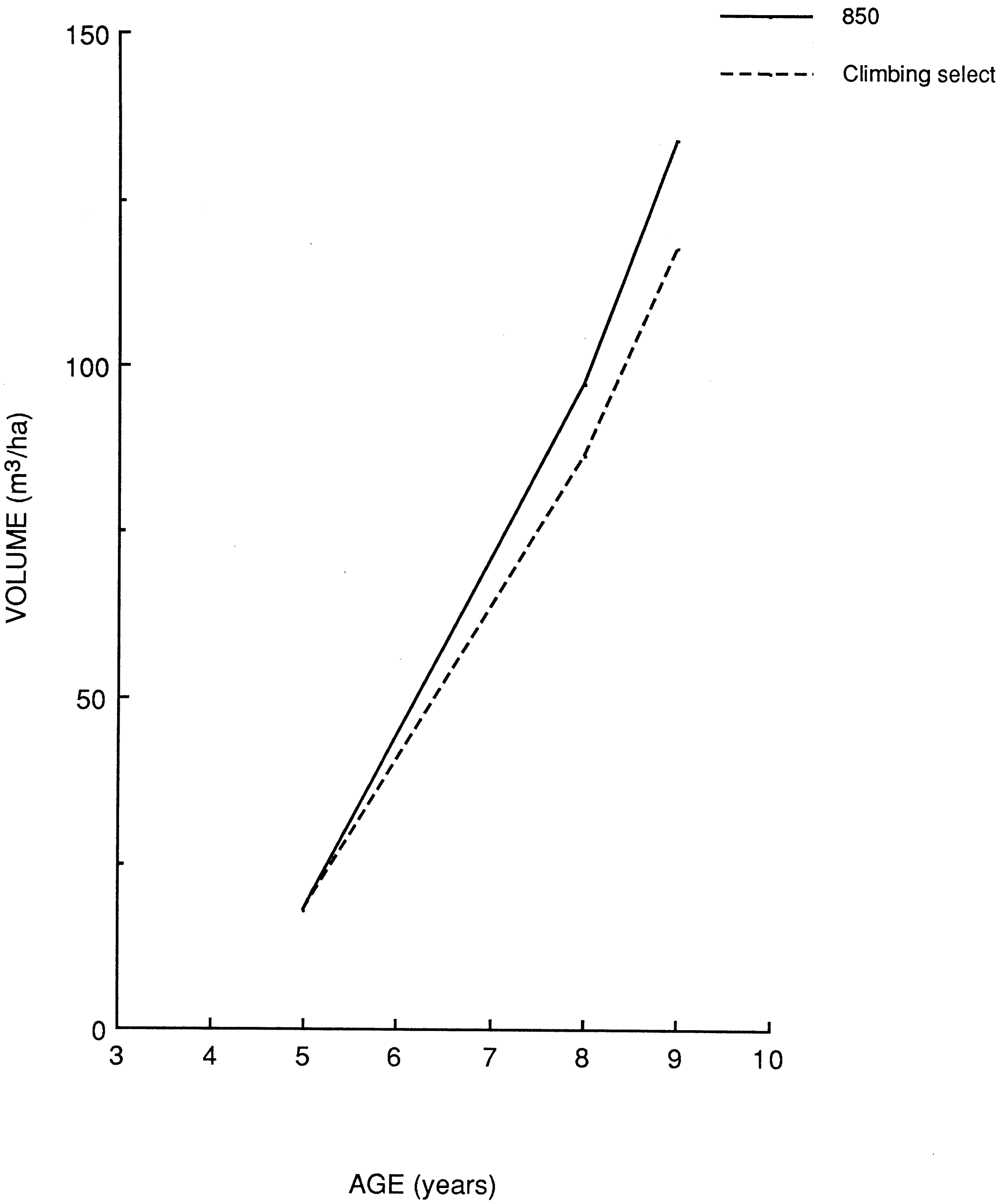


KAINGAROA : VOLUME ON AGE



NB : PULPWOOD REGIME

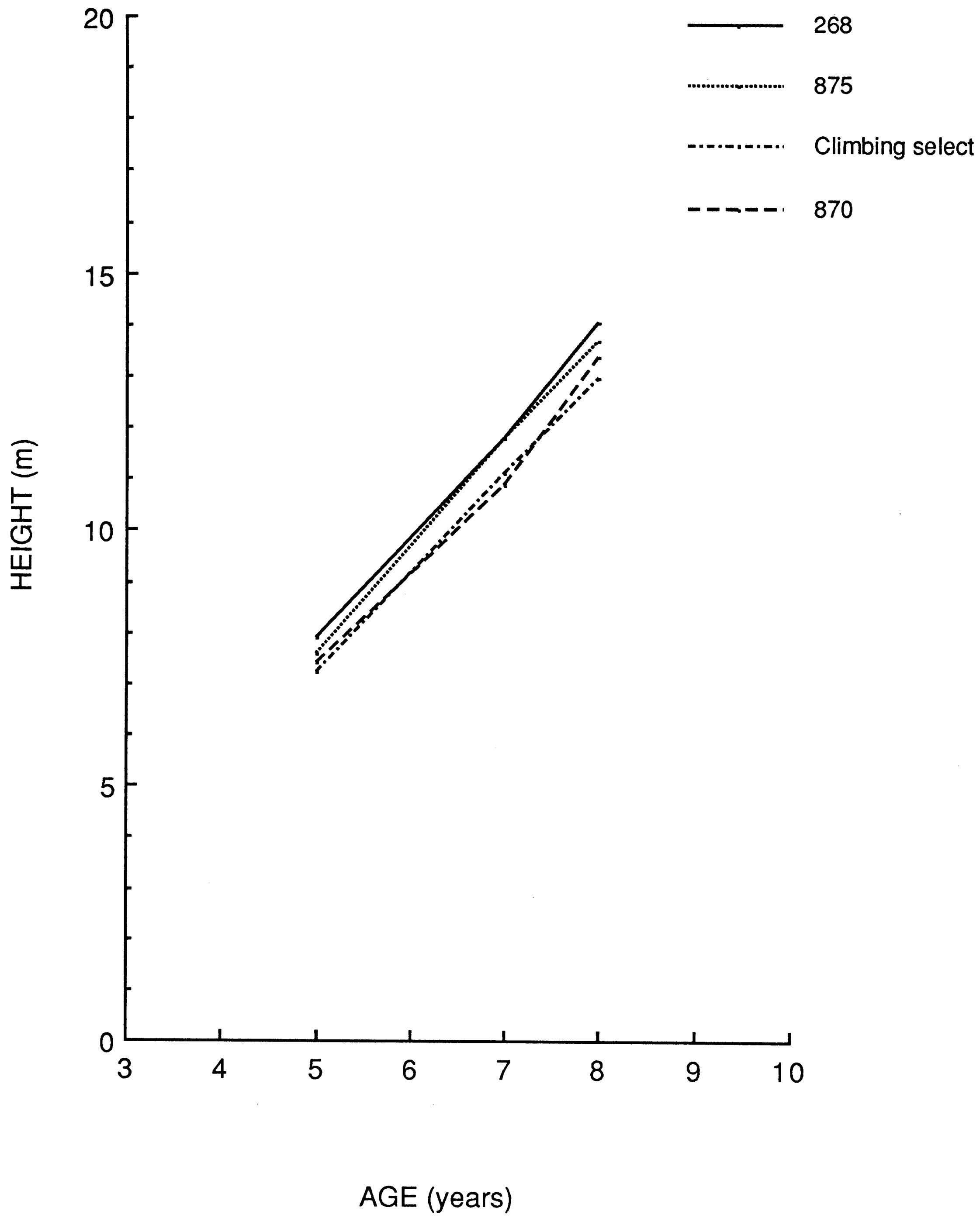
KAINGAROA : VOLUME ON AGE



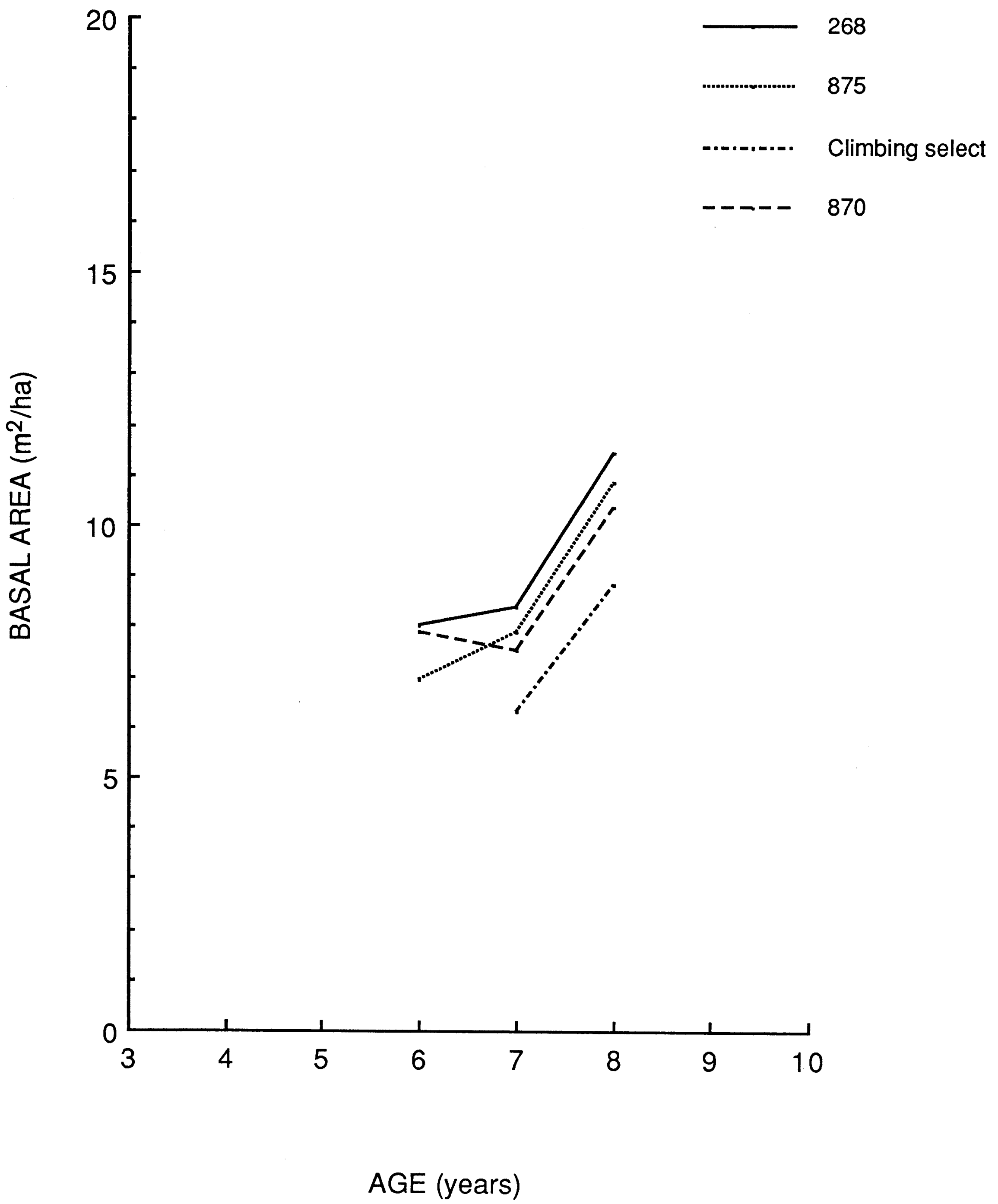
NB : CLEARWOOD REGIME

APPENDIX 6 - Long internode/second orchard genetic gains: height, volume and basal area performance

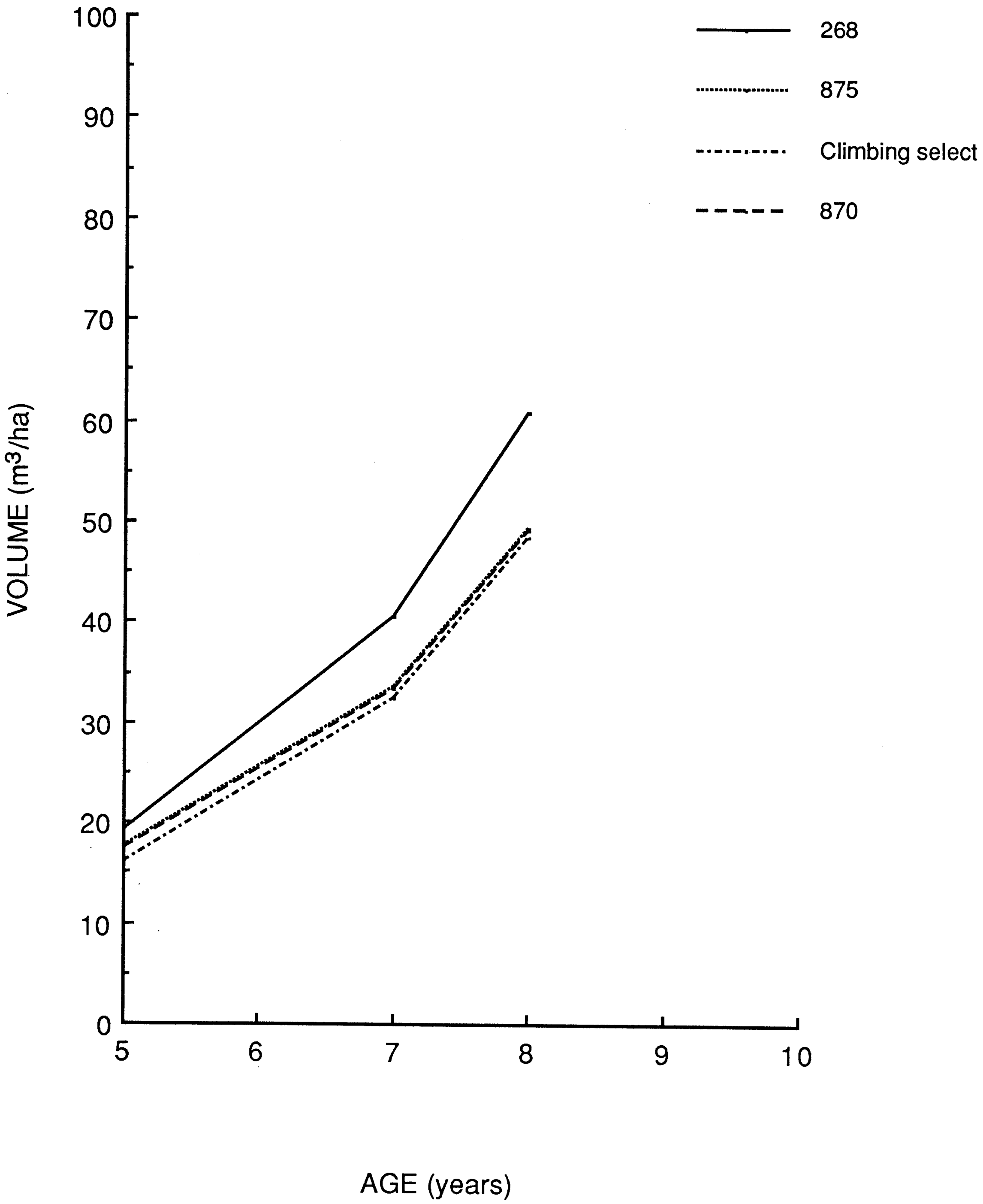
KAINGAROA : HEIGHT ON AGE



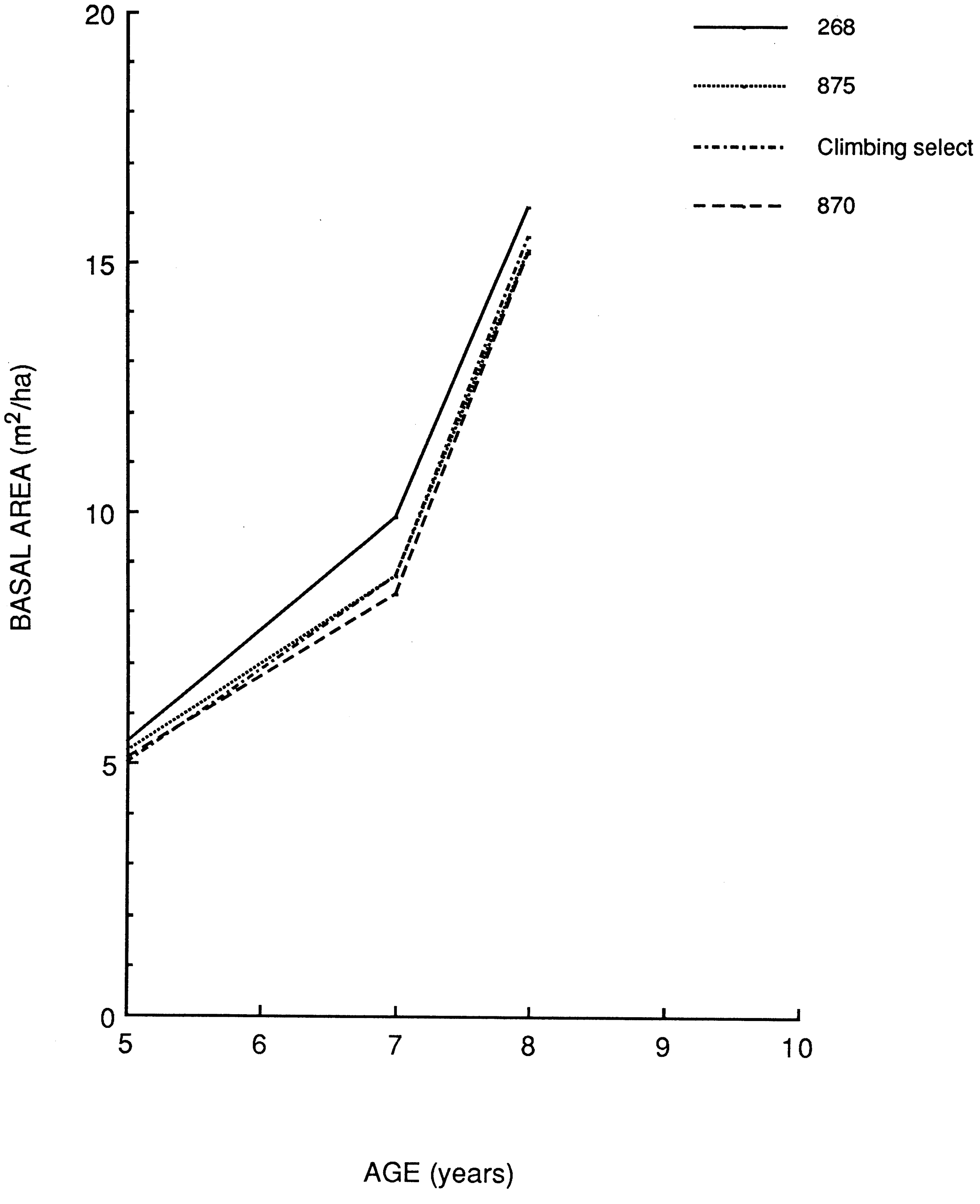
DEAN : BASAL AREA ON AGE



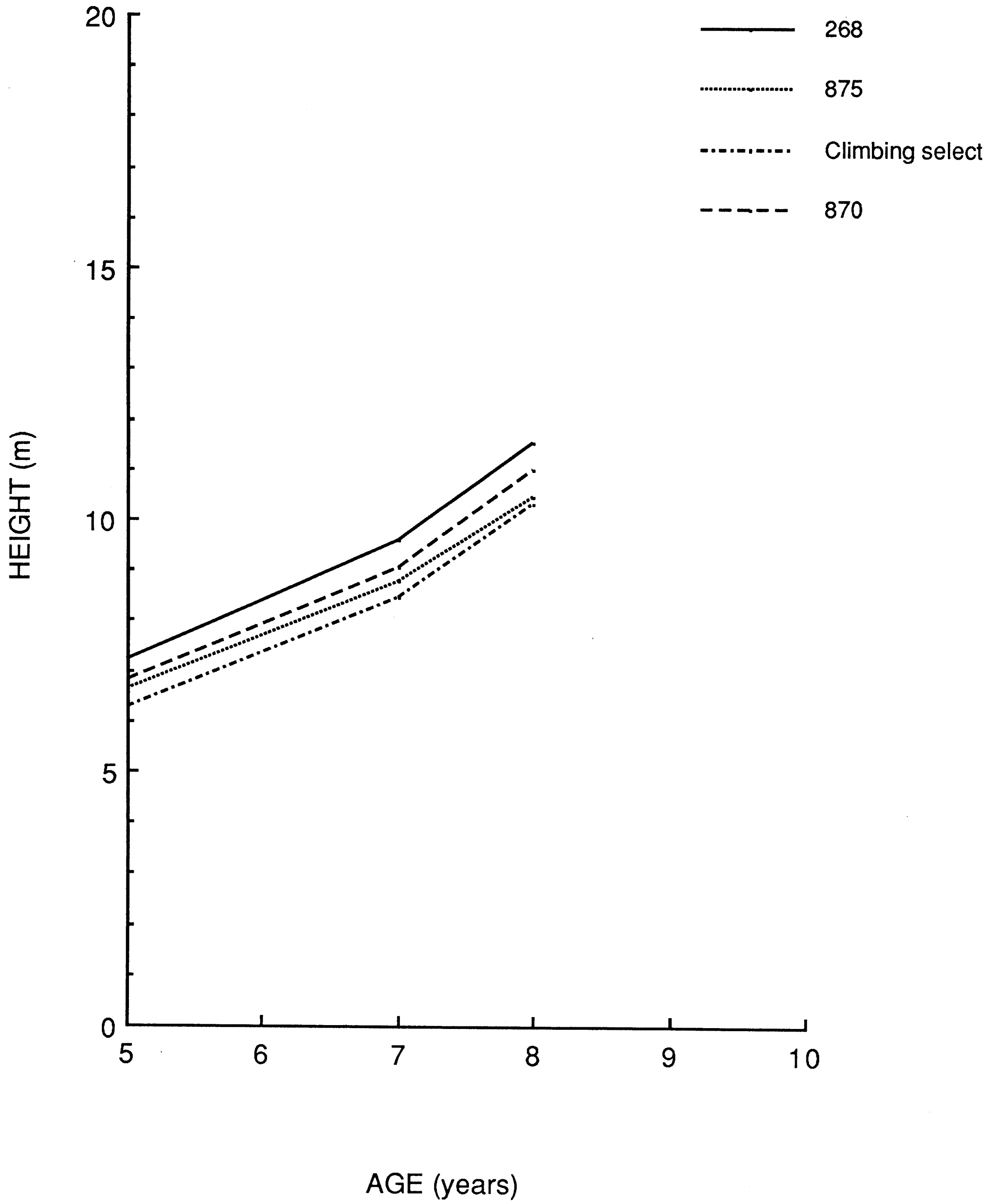
GOLDEN DOWNS : VOLUME ON AGE



GOLDEN DOWNS : BASAL AREA ON AGE



GOLDEN DOWNS : HEIGHT ON AGE



DEAN : VOLUME ON AGE