PO Box 1127
Rotorua 3040
Ph: + 64 7 921 1883
Fax: + 64 7 921 1020
Email: info@ffr.co.nz
Web: www.ffr.co.nz

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Comparison of Stocking and Thinning Regimes for Cypresses in New Zealand

Authors:
C Low, C Andersen

Research Provider:
Scion

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EXECUTIVE SUMMARY

The cypress regime trials were designed to provide clear direction on the timing and severity of pruning and thinning treatments. They are mostly still a long way from a harvest age of around thirty years, but are showing clear trends.

Cypress timber has mainly “appearance grade” uses, where its attractive heartwood and lustre make it much in demand. The highest prices are paid for clear heartwood, followed by good prices for timber with inter-grown knots. The only use for timber with dead, loose knots is firewood. Pruning and thinning regimes are very important for maximising profits for cypress growers.

The New Zealand cypress regime trials were designed to test the effects of different spacing and pruning treatments on the growth of cypress stands. Most of the regime trials of *C. lusitanica* and *C. macrocarpa* were in young stands on sites well suited to the species. There was also one replicated spacing trial planted for each of the two species in 1984. Thinning and pruning trials were installed into existing stands of around six years of age during the 1990s. We plotted growth over time from permanent sample plot summaries, and identified significant differences in tree diameter due to silvicultural regime.

Cupressus lusitanica

Cupressus lusitanica regime trials are located in the North Island at Rotoehu, Waihou, Gwavas, Tapuwae, Meads and Okiwa and two trials at Kaingaroa, and were of varying quality. The Kaingaroa trials had just been thinned and pruned in 2011, so were not reviewed here. The Gwavas trial had poor growth and form so may have been sourced from an inferior seedlot and it was not analysed.

Rotoehu Spacing Trial

The 1984 Rotoehu spacing trial was planted at stockings ranging from 100 to 1000 sph. The trees grew well at about one metre of height growth per year. Overall volume growth was best for the highest stocking, but stockings higher than 800 stems per hectare (sph) suffered mortality after age 20. The best diameter growth was at low stockings (100 & 200 sph) but came with unacceptable losses in volume growth. Stocking of around 400 sph appeared to be a reasonable compromise between volume growth and diameter growth. However, volume growth at 400 sph had not gained on that at 800 sph through to age 20.

Pruning and Thinning Trial at Tapuwae, Northland

The best replicated pruning and thinning trial was at Tapuwae in Northland where growth was slightly better than growth at Rotoehu. Growth trends for different spacings were similar to those at Rotoehu, although the higher stockings were suffering from annual mortality presumably caused by toppling. Early thinning resulted in less loss of growth than later thinning, but no production thin was scheduled. The trees were only 16 at the time of the last measurement.

Aggressive pruning resulted in a reduction in diameter growth the following year, but trees appeared to bounce back and long term effects were negligible. Late pruning even appeared beneficial for tree growth, where such treatments had better growth than unpruned treatments at the same stocking. The smaller regime trials gave similar results to the Tapuwae trial, although microsite differences were confounded with treatment effects.

Highest volumes were achieved by high stockings with small diameters. However, there is a premium paid for clear heartwood, so the regime must compromise between volume and diameter growth maximised by low stockings. The regime trials are too young to evaluate regimes based around production thinning. Barring a potential production thin, the best regime would be to:

- plant at 1100 sph,
- prune 400 sph fairly hard to a four-metre green crown, then
- thin to leave pruned trees at age 8.

C. lusitanica can be prone to toppling on some sites and to possum damage of dominants, so a higher stocking (500 sph) would be recommended at first thinning on such sites.

Cupressus macrocarpa

Cupressus macrocarpa regime trials are located at Rotoehu and Kinleith in the North Island and Hanmer, Otago Coast, Frasers and Fergusons in the South Island. The 1984 spacing trial started well at Rotoehu, but cypress canker moved in aggressively and wiped out the trial by age 12. Canker appeared in the replicated pruning and thinning trial at Kinleith, but the thinning treatments have minimised the effects. The Hanmer trial had received no silviculture for sixty years and had stagnated, so was not analysed.

The other South Island trials appeared healthy, but growth rates were generally less than one metre of height growth per year. The replicated trial at Otago coast revealed significant differences between treatments, but there were no hard pruning treatments. The smaller South Island trials showed the same trends identified at Kinleith and Otago coast.

Stocking followed similar patterns to *C. lusitanica*, but with little mortality at the high stockings except at Kinleith. The pruning schedules were less aggressive and there were signs at Kinleith that harder pruning resulted in growth losses, which might reflect canker attacking trees that were stressed. More time is needed to verify this.

The best silvicultural regime would be very similar to the regime recommended above for *C. lusitanica*. On sites with some canker problems it would be best to leave some extra stems until age twelve as mortality from canker would still be ongoing.

Although cypress hybrids such as Leylands and Ovensii have been popular for shelterbelts, there have been few stands planted. There is only one PSP of the Leighton Green Leyland clone that can be compared to *C. lusitanica* on similar sites and stocking. The Leyland trees were slightly less vigorous out to age 20, but with much longer green crowns.

INTRODUCTION

Background to the Issues

Permanent sample plots have been installed into stands of cypresses for many years. However, many older stands were not well sited and have not been thinned or pruned. Interest in cypresses was stimulated by the Alternative Species Symposium in the early 1980s, and the first cypress spacing trial was planted by Bruce Glass in 1984. John Miller set up progeny trials in *C. lusitanica* and *C. macrocarpa* in 1984-85 and also planted comparison trials of Leyland clones and other cypress species.

Farm foresters had used *C. macrocarpa* timber from old shelterbelts and were the main cypress enthusiasts until the mid 1990s, by when forestry companies had noted the emergence of very good cypress stands. Increasing interest prompted pruning and thinning trials in the mid 1990s, but the results of various treatments require years of subsequent growth. Steven Brailsford[1] advanced radical theories of growing cypresses on short rotations and high stockings with aggressive pruning.

Pascall Berrill[2, 3] looked closely at the coverage of potential sites provided by the sample plots in 2000 and concluded that there were enough to set up a reasonably robust growth model, but ideal silvicultural regimes were not well understood. Michael Watt[4] combined the sample plot data with site and climate information and generated a siting map for *C. lusitanica* throughout New Zealand in 2008. Ian Nicholas wrote a cypress grower's handbook, available from the New Zealand Farm Forestry Association Website[5]. Lars Hansen used the data to set up a web-based cypress growth "calculator" in 2008 (available to FFR). The calculator can provide very good profitability comparisons between growing cypresses and a variety of other land uses. Unfortunately, few plots have been measured since 2007, so few new data were available for this report.

We analysed data collected from all cypress sample plots (except shelterbelts) and some genetics trials to get a feel for the potential growth of *C. lusitanica* and *C. macrocarpa* on the full range of New Zealand sites. There are not enough plots in any of the other cypress species to provide fair appraisal of their growth. Fortunately the *C. lusitanica* and *C. macrocarpa* regime plots were in reasonably well sited stands so their results are quite relevant. This report was based on results from these regime trials.

The expected benefits and relevance to forest management are:

- Clear indications of volume growth and log size from different stockings on good sites for growing cypresses
- The loss of growth caused by pruning at different intensities.

METHODS

Variation between forest trees in even-aged stands dictates a minimum sample size of around 20 trees. Permanent sample plots are usually 0.04 hectares (0.1 acres), which provides for many more than 20 trees in the early life of a stand, but somewhere around that number at harvest. The size of these plots varies from 0.01 hectares (heavily stocked plots) to 0.2 hectares for plots at very low stockings in designed spacing trials.

There are 193 *C. lusitanica* plots and 342 *C. macrocarpa* plots, but quite a number are poorly sited and are languishing.

Actual regime trials established by Scion are relatively few and are listed in Tables 1 & 2. Their approximate location in New Zealand is shown in Figure 1. The latest assessments for the regime trials are at ages of between 15 and 24 years, which are well short of harvest age.

Table 1.Location and characteristics of *C. lusitanica* regime trials planted in New Zealand between 1984 and 1996.

Plot	Forest	cpt	Planted	reps	treat	remarks
RO2022/2	Rotoehu	8	1984	2	10	Spacing only, Good trial
FR134/7	Waihou	13	1985	1	6	Good growth
FR134/41	Gwavas	60	1984	1	6	Slow growth, inferior source?
FR292/1	Tapuwae	0	1992	3	8	V good growth, but mortality
FR292/2	Okiwa	9	1992	1	8	Good growth
FR292/3	Meads		1995	1	8	Good growth
FR495	Kaingaroa	1204	1996	3	7	Treated 2011
FR496	Kaingaroa	51	1996	2	5	Treated 2011

Table 2. Location and characteristics of *C. macrocarpa* regime trials planted in New Zealand between 1984 and 1996.

Plot	Forest	compartment	Planted	reps	Treat-ments	Remarks
CY569	Hanmer		1929	1	4	Stagnated stand
RO2022/1	Rotoehu	8	1984	2	8	Spacing only, killed by canker
FR196	Otago Coast	13	1986	3	6	3 stockings, pruning only
FR378/1	M. Fraser	0	1993	2	4	
FR378/2	A. Ferguson	0	1991	1	4	
FR292/4	Kinleith	0	1993	3	6	Canker problems

This analysis will consist of two parts.

1. One part will use the data from plot summaries to plot growth increment for different silvicultural treatments over time.
2. The second part will be to analyse the individual tree data to see whether differences between silvicultural treatments are statistically significant.

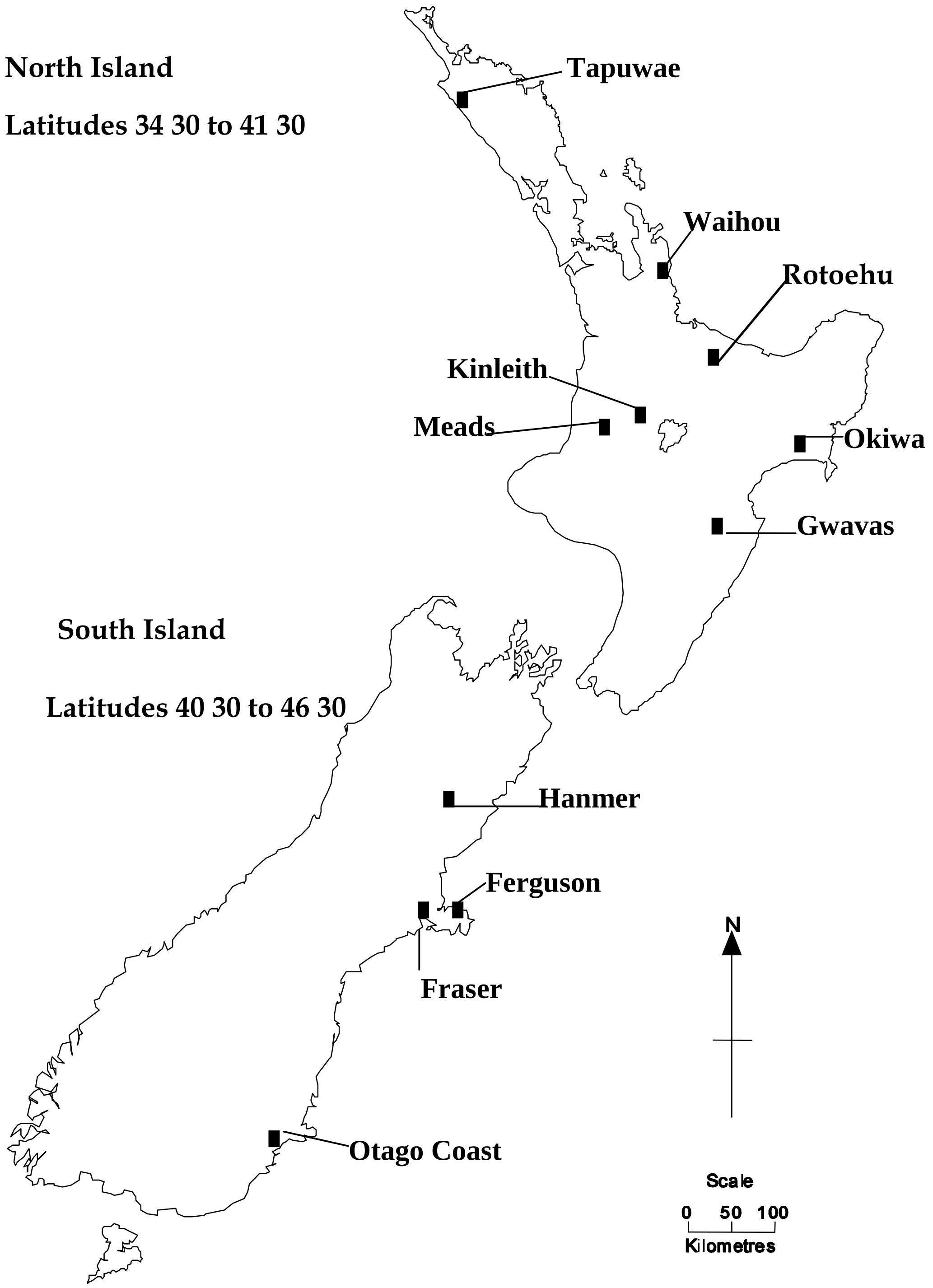


Figure 1. Approximate location of cypress regime trials.

RESULTS

Cupressus lusitanica (North Island only)

Rotoehu *C. lusitanica* Stocking Rate Regime Trial

The Rotoehu trial was planted on a forest site, so although the climate is ideal for this species, the fertility is lower than the farm sites that are commonly planted with *C. lusitanica*. This trial is very useful for looking at growth trends for different stockings without confounding effects from other treatments. However, the lower stockings would be at some disadvantage to more conventional stands at low stockings where only the best and healthiest trees are retained. A high standard of releasing from weeds and a lack of damaging agencies helped to establish this trial very well. Treatments at this site are given in Table 3. These treatment numbers are used in the following figures.

Table 3. Treatments in the Rotoehu spacing trial. This trial was planted with two replicates at 10 different spacings, with larger plot areas to accommodate more trees for low stockings. No thinning or pruning.

Treatment	Stems per hectare (sph)
1	100
2	200
3	200
4	400
5	500
6	600
7	700
8	800
9	900
10	1100

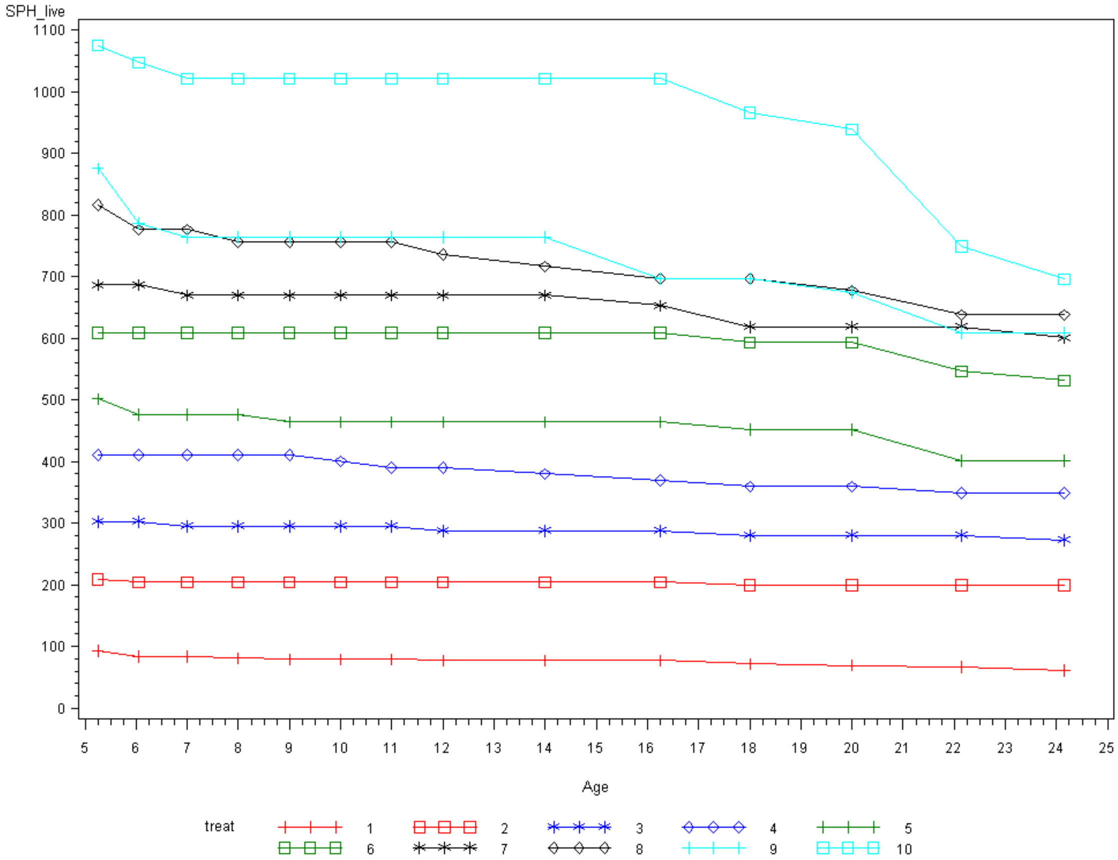
Some trees become suppressed in the higher stockings and these die off from around age 16 (Figure 2). This is a signal that lowering the stocking by thinning would improve the health of the stand, and it also shows that the stand would start to thin itself. Allowing the stand to self-thin is not a good idea as the intense competition results in short green crowns on all trees and reduces diameter growth.

The higher stocked plots had the greatest total volume (Figure 3), in spite of losses through mortality. The lowest stockings of 100 and 200 sph was not fully utilising the site as the rate of growth was still falling behind higher stockings at age 24 sph, while the 300 sph stocking was just starting to catch up.

The lowest stockings had the highest diameter growth (Figure 4) although they were carrying less than half of the volume of most of the higher stockings. This rapid diameter growth could make low stockings very profitable if the trees had been pruned and large logs with clear heartwood commanded high prices. At age 5 there were significant differences for diameter growth between the highest and lowest stockings. However, by age 24 the higher stockings were clumped together, while the lower stockings were significantly different from each other. Annual diameter growth was greatest for years six and seven at three centimetres per year (Figure 5), falling to two centimetres per year for the lowest stocking of 100 sph. The diameter increment of most other stockings fell to one centimetre per year by age 16, and high stockings affected by canopy closure reduced this to 0.8 cm per year.

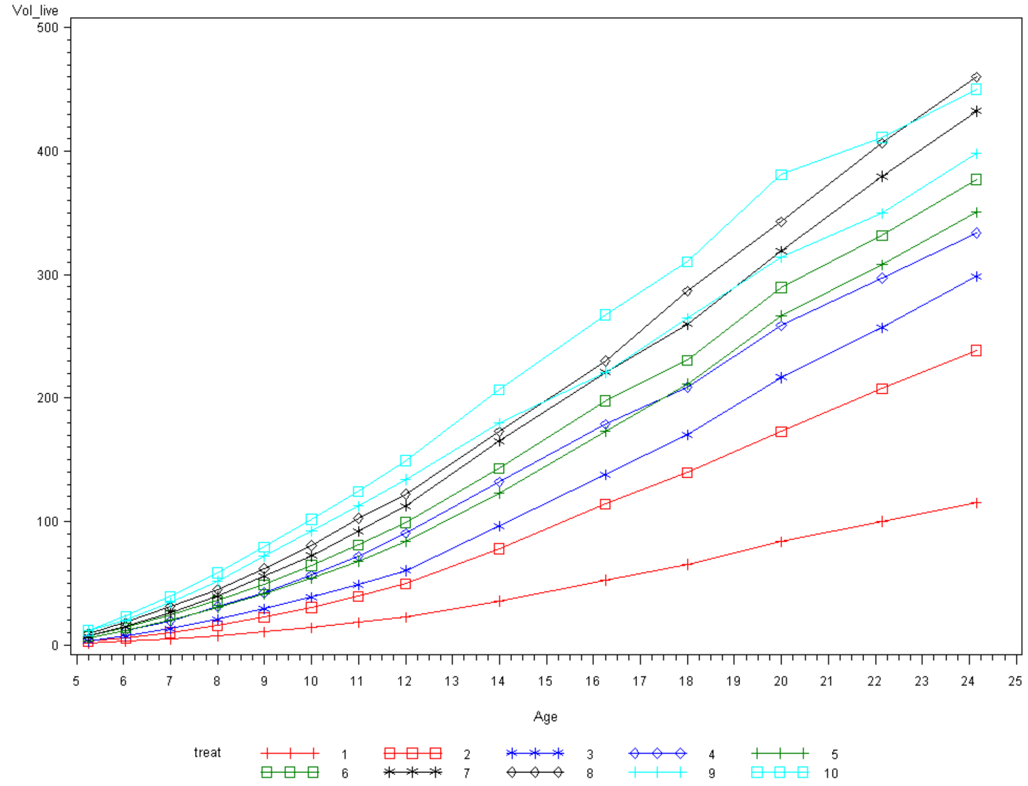
Stocking will account for the amount of living foliage as measured by the length of the green crown. Trees at the lowest stocking have had few branches die and retain 17 metres of green crown (Figure 6). The low to intermediate stockings of 300 to 500 sph all reached a plateau where they stayed at about 11 metres. For the higher stockings the plateau began at nine metres from the age of nine years for the highest stocking, so this might mark a suitable time for thinning.

Mean height over time was also graphed (Figure 7). The lack of tree-to-tree competition in the lower stockings has resulted in reduced height growth, but height differences between treatments are smaller than diameter differences on this site.



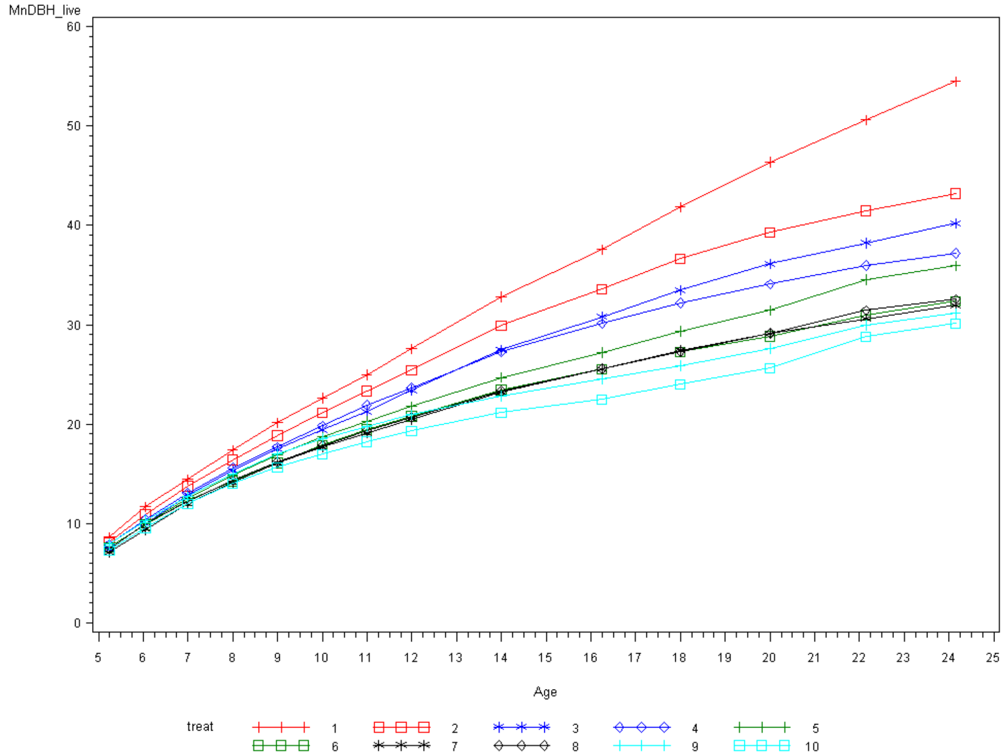
Treatment	1	2	3	4	5	6	7	8	9	10
Stems per hectare (sph)	100	200	200	400	500	600	700	800	900	1100

Figure 2. Stocking (sph) by age for the *C. lusitanica* regime trial at Rotoehu



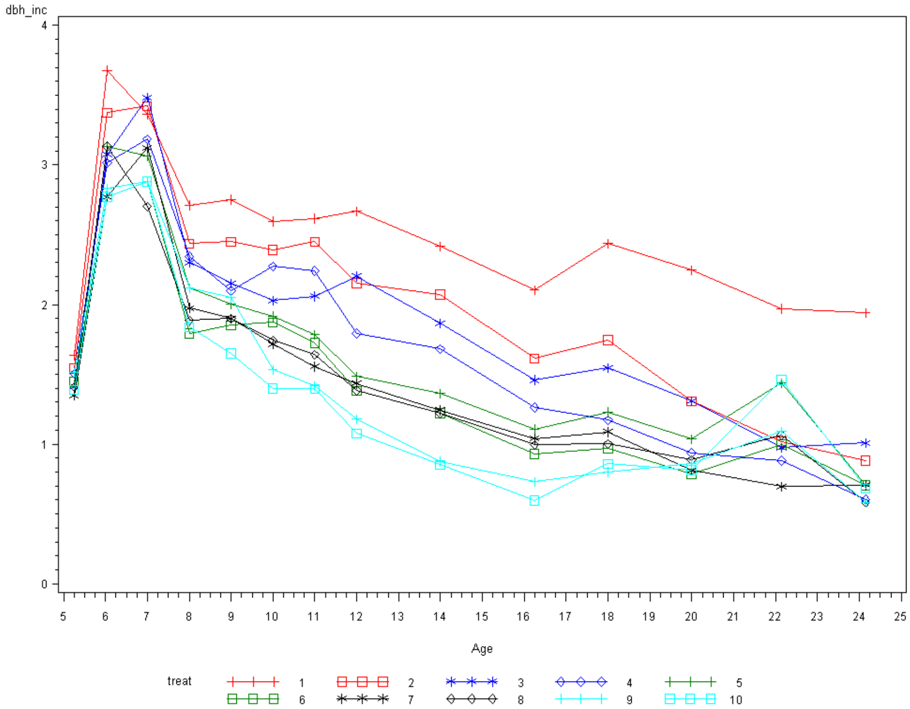
Treatment	1	2	3	4	5	6	7	8	9	10
Stems per hectare (sph)	100	200	200	400	500	600	700	800	900	1100

Figure 3. Cumulative volume (m^3 / hectare) by age for *C. lusitanica* regime trial at Rotoehu



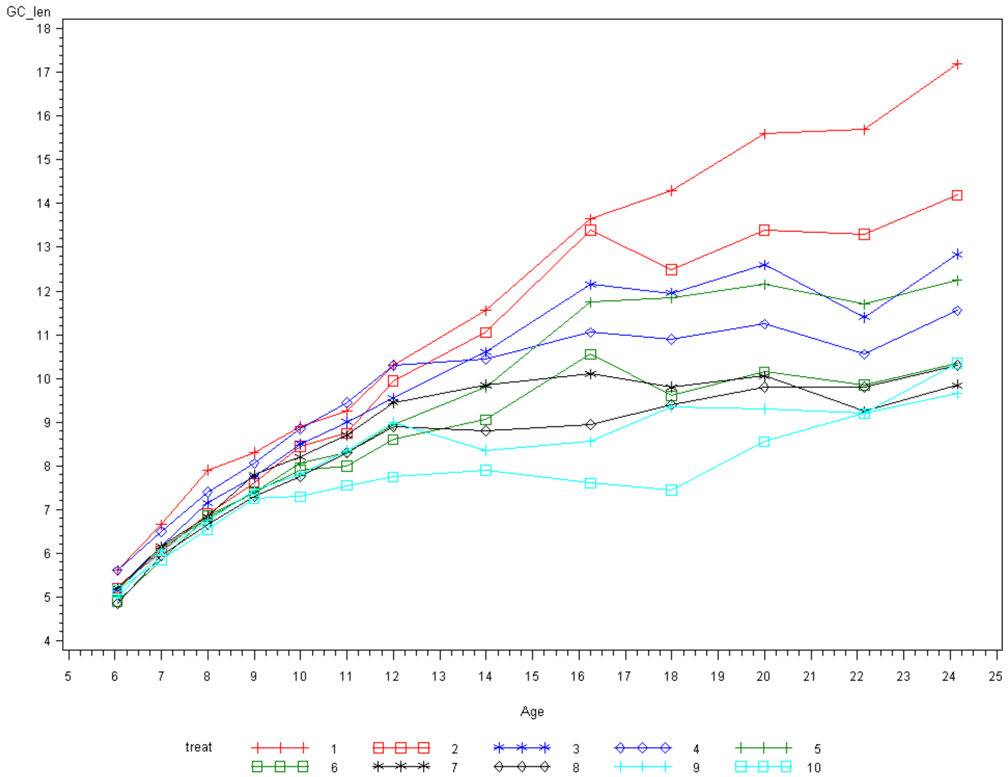
Treatment	1	2	3	4	5	6	7	8	9	10
Stems per hectare (sph)	100	200	200	400	500	600	700	800	900	1100

Figure 4. Cumulative diameter (mm) by age for *C. lusitanica* regime trial at Rotoehu



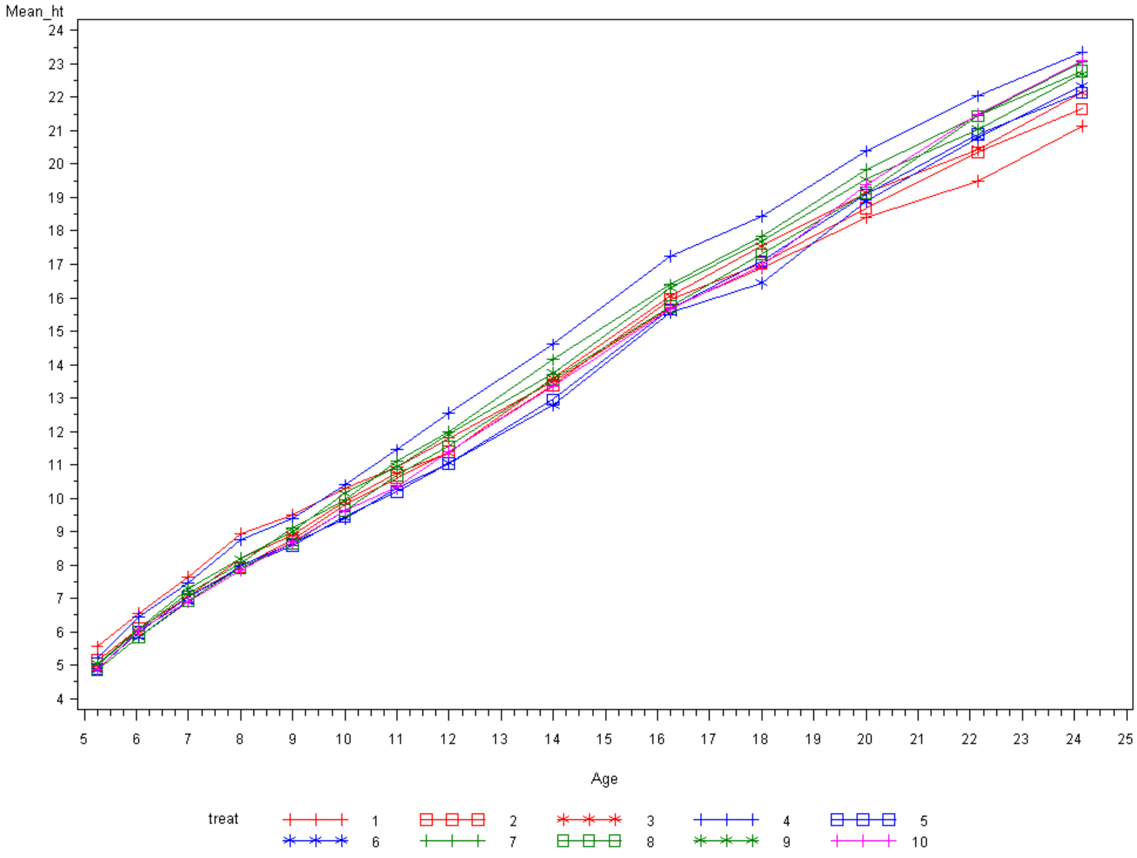
Treatment	1	2	3	4	5	6	7	8	9	10
Stems per hectare (sph)	100	200	200	400	500	600	700	800	900	1100

Figure 5. Annual diameter (mm) by age for *C. lusitanica* regime trial at Rotoehu.



Treatment	1	2	3	4	5	6	7	8	9	10
Stems per hectare (sph)	100	200	200	400	500	600	700	800	900	1100

Figure 6. Green crown length (metres) by age for *C. lusitanica* regime trial at Rotoehu



Treatment	1	2	3	4	5	6	7	8	9	10
Stems per hectare (sph)	100	200	200	400	500	600	700	800	900	1100

Figure 7. **Height growth (metres) by age for *C. lusitanica* regime trial at Rotoehu**

Tupawae *C. lusitanica* Regime Trial

This trial was imposed in 1996 onto a stand that had been planted in 1991 at a nominal stocking of 1000 sph. The treatments (Table 4) consist of a broad division into four unpruned thinning treatments and four treatments that would be both thinned and pruned. The pruned treatments were further divided into mild pruning leaving a good length of green crown and hard pruning that would be likely to reduce diameter growth. The low elevation Northland site has an ideal climate for growing *C. lusitanica* and a history of farming, so represents the upper end of site quality.

Table 4. Treatments in Tapuwae trial

	Age of thinning and sph			Height of Pruning			Remarks
Treatment	5	9	13	5	7	9	
1	1000	850	700	0	0	0	No treatment
2	700	700	680	0	0	0	Thin once to 700
3	700	400	400	0	0	0	Early Thin twice to 400
4	700	700	400	0	0	0	Delayed thin twice to 400
5	700	400	400	1.6	4.8	6.1	Early thin, mild prune
6	1000	700	400	1.6	4.9	6.2	Delayed thin, mild prune
7	700	700	400	3.7	5.2	6.1	Mild thin, hard prune
8	700	700	400	3.9	5.8	6.2	Mild thin, hard prune

The three replicates per treatment were averaged to provide the data for the graphs of stocking, volume and diameter growth (Figures 8, 9, & 10). The change in stocking due to thinning (Figure 8) indicates when the thinning treatments were done. It also shows that the highest stockings were experiencing mortality from as young as six or seven years, and that the highest planned stocking lost one third of the trees. The most likely cause is toppling which is a problem on Northland clay sites where the high fertility causes the crowns to be quite dense and the soil can be softened up when wet.

Volume growth at Tapuwae (Figure 9) (similar to Rotoehu), is best at the higher stockings. It was unfortunate that the unthinned plots had a high mortality as the volume growth at Rotoehu suggested that a stocking near 1000 sph would have the greatest volume at age 16. Certainly the thinning to 400 sph cost volume and growth rates ran parallel with the 700 sph stockings through to age 16.

Diameter growth (Figure 10) was highest for unpruned treatment number 1. However, treatment 5 that was thinned to 400 sph at age 9 and had light pruning had similar diameter growth. Treatments 7 and 8 that were pruned hard lost some diameter growth, but bounced back after their second thinning at age 13. Some of the effects of pruning would have been masked by the presence of unpruned followers. It appeared that diameter growth of *C. lusitanica* recovered from hard pruning within a year.

There were significant differences between some of the treatments at all ages, with a LSD of 3 cm at age 16. That left the highly stocked treatments 1 & 2 at the smallest diameter of 29 cm and the treatments that were thinned to 400 sph at age 13 (4, 7 & 8) at 32-33 cm. The treatments that were thinned to 400 sph at age 9 and treatment 6 with the later thin but milder prune were diameter growth winners.

Mild pruning did not hurt growth rate but would confer genuine value gain at current log prices. Hard pruning could hurt diameter growth, but the trees would bounce back in a short time. The option of thinning to 400 sph at age 9 appeared to be better than waiting until age 13, as any possible returns from a thinning at that age would be negligible.

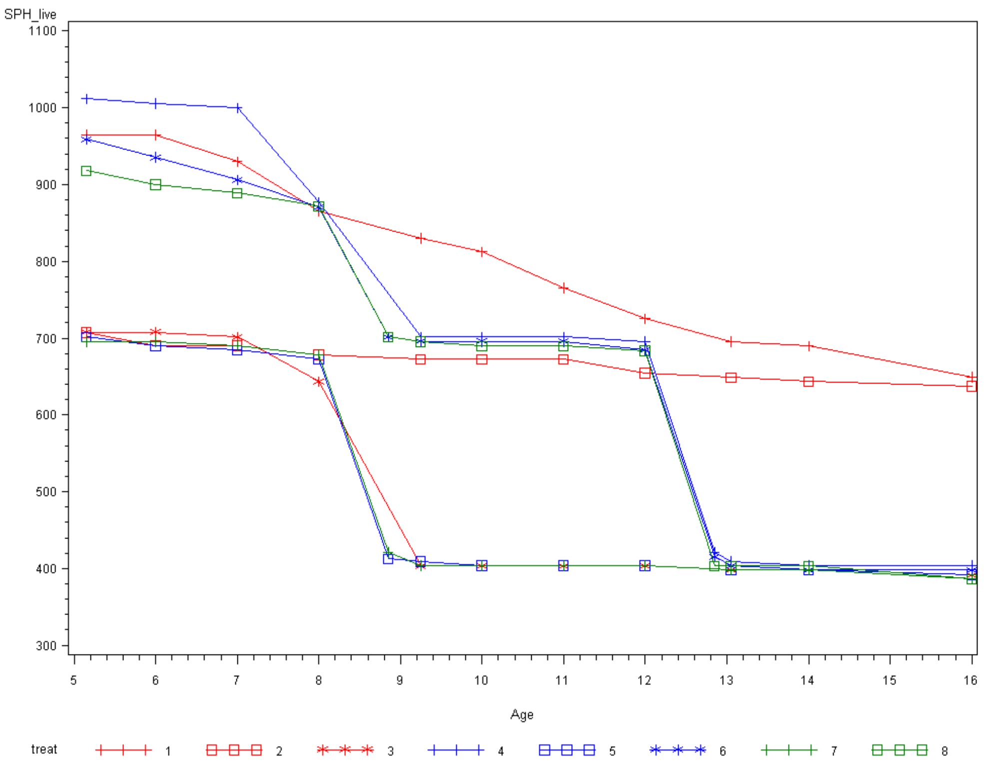


Figure 8. Stocking (SPH) by age for *C. lusitanica* regime trial at Tapuwae.

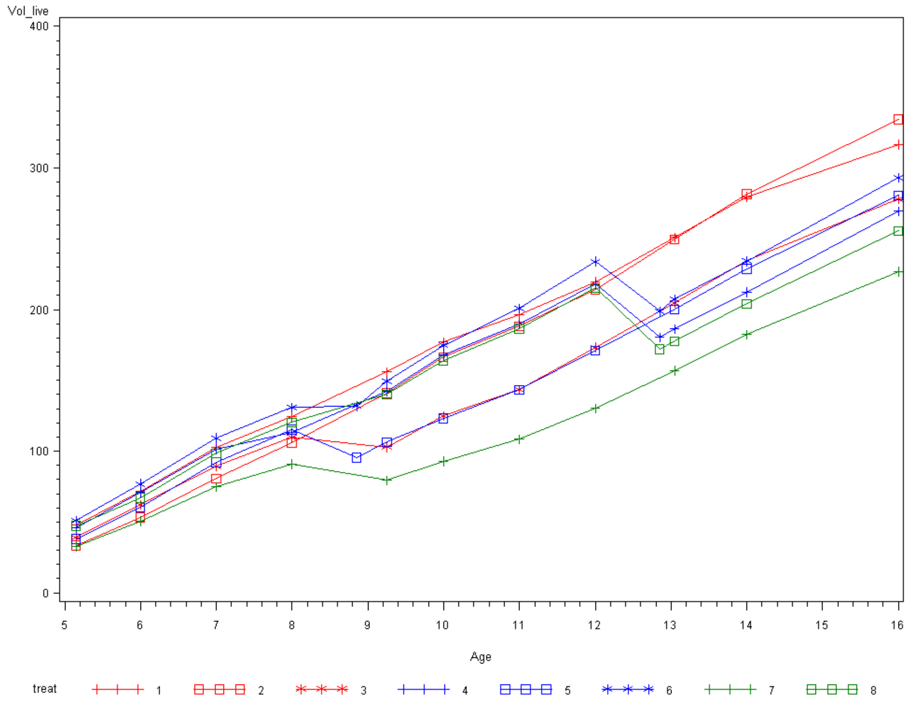
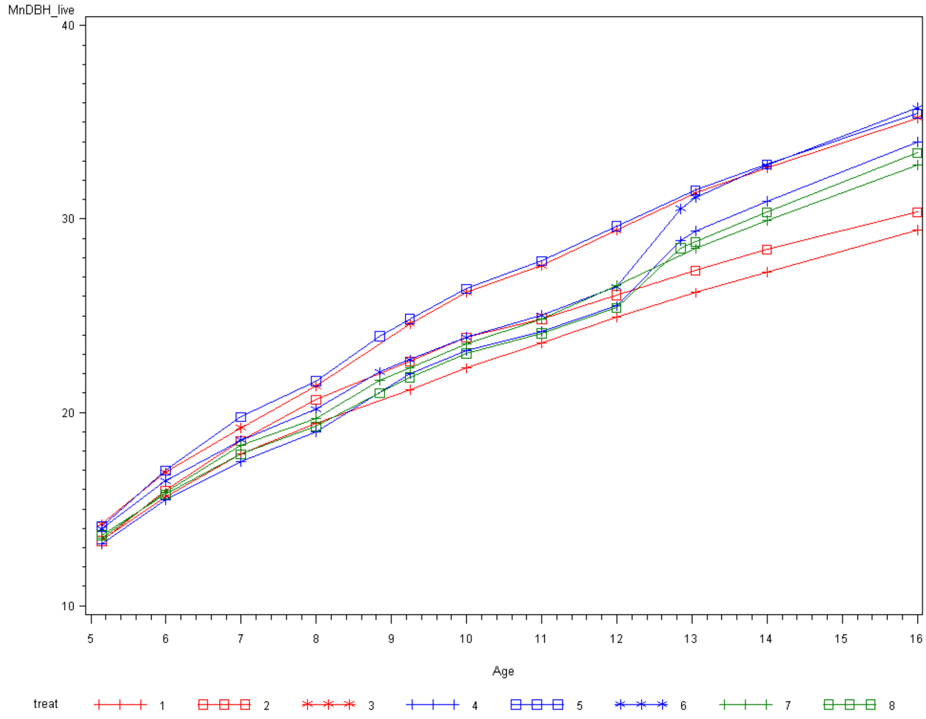


Figure 9. **Cumulative volume growth (m^3 / hectare) for *C. lusitanica* regime trial at Tapuwae**

Figure 10. **Cumulative diameter growth (mm) for *C. lusitanica* regime trial at Tapuwae**



Okiwa *C. lusitanica* Thinning and Pruning Regime Trial

The trial at Okiwa was set up as a smaller scale validation of growth at Tapuwae, with only one plot per treatment. The trial was imposed in 1997 onto a stand that had been planted in 1992 at a nominal stocking of 2400 sph. The treatments (Table 6) consist of a broad division into three unpruned thinning treatments and five treatments that would be both thinned and pruned. The pruned treatments were further divided into mild pruning leaving a good length of green crown and hard pruning that would be more likely to reduce diameter growth. *Cupressus lusitanica* growth on this site is good, quite similar to growth at Tapuwae.

Table 6. **Treatments in Okiwa trial**

	Age of thinning and sph				Height of Pruning				Remarks
Treat-ment	5	8	10	12	5	8	10	12	
11	2300	2300	2000	2000	0	0	0	0	No treatment
21	2100	2000	700	700	0	0	0	0	Age 10 thinning to 700
31	1800	700	400	400	0	0	0	0	2 stage thin, no pruning
41	2400	700	400	400	0	1.5	4.1	5.4	Age 10 thin, mild prune
51	1900	1000	700	400	0	2.4	5.3	6.2	Age 12 thin, mild prune
61	2300	700	400	400	0	3.8	5.6	6.1	2 stage thin, harder prune
71	1900	1000	700	400	0	4.6	5.9	6.1	3 stage thin, harder prune
81	2200	1000	700	400	2.3	2.8	5.7	6.3	3 stage thin, early prune

The actual stocking at Okiwa (Figure 11) leaves one plot at a very high stocking and unthinned, one thinned once to 700 sph and six plots thinned to 400 sph by several operations. The lack of replication means that microsite effects, which tend to be pronounced with *C. lusitanica*, are combined with treatment effects. Volume differences (Figure 12) are large, especially with the unthinned plot having 2000 sph, with the next highest stocking less than half of that.

The unpruned treatment thinned to 400 sph had highest diameter growth (Figure 13), while the higher stocked unpruned treatments were lowest. All of the pruned treatments were tightly bunched, with the slightly harder treatments having lowest diameter growth.
Different treatments had little effect on height at Rotoehu and Tapuwae, but appear to have a significant effect at Okiwa. The unthinned plot is extremely tall for its age at 17.5 metres (Figure 14), but other highly stocked plots do not follow this trend.

Figure 11. **Stocking by age (sph) for *C. lusitanica* regime trial at Okiwa**.

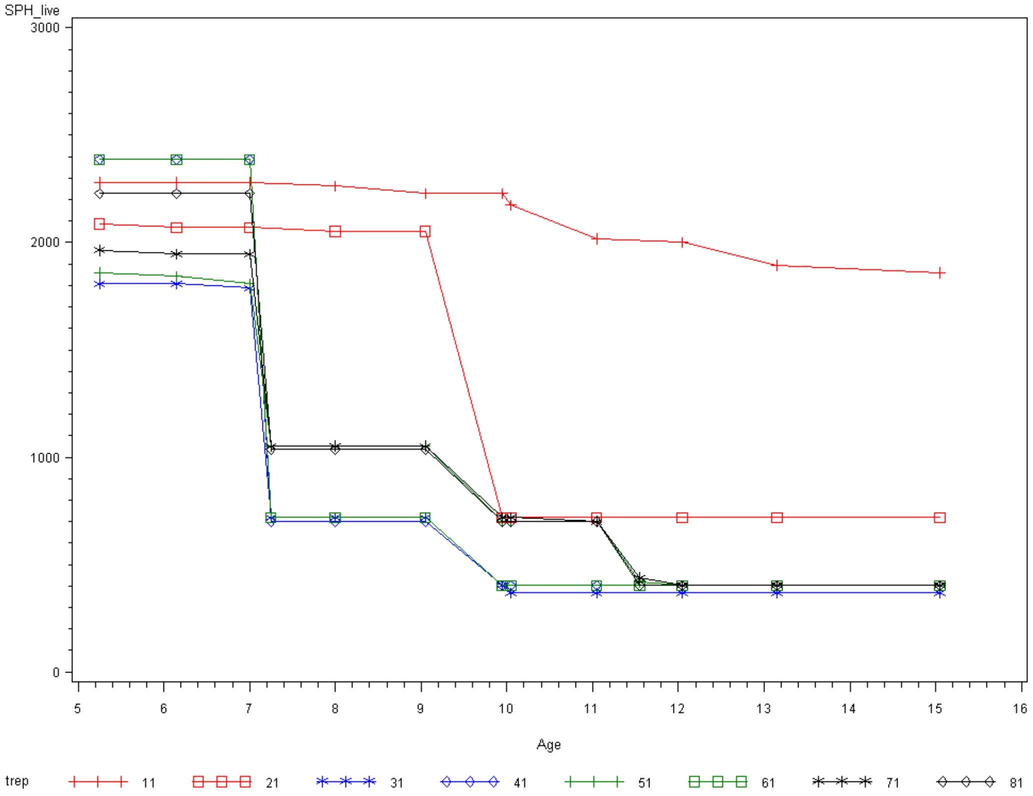


Figure 12. Cumulative volume growth (m^3 / hectare) by age for *C. lusitanica* regime trial at Okiwa.

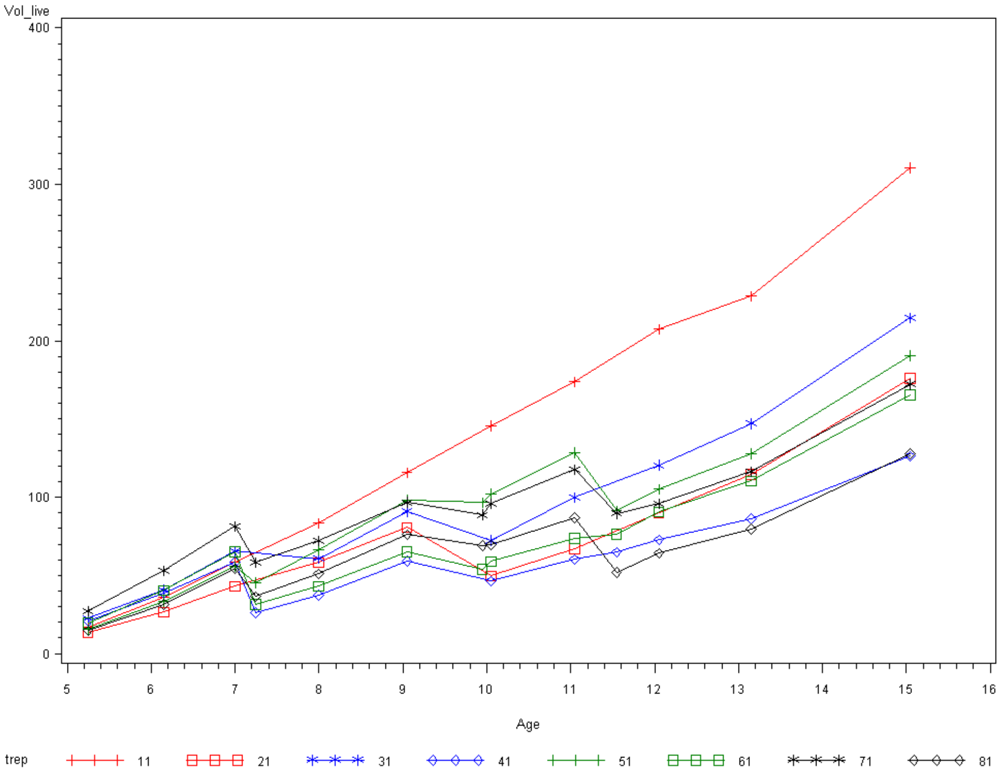


Figure 13. Cumulative diameter growth (mm) by age for *C. lusitanica* regime trial at Okiwa.

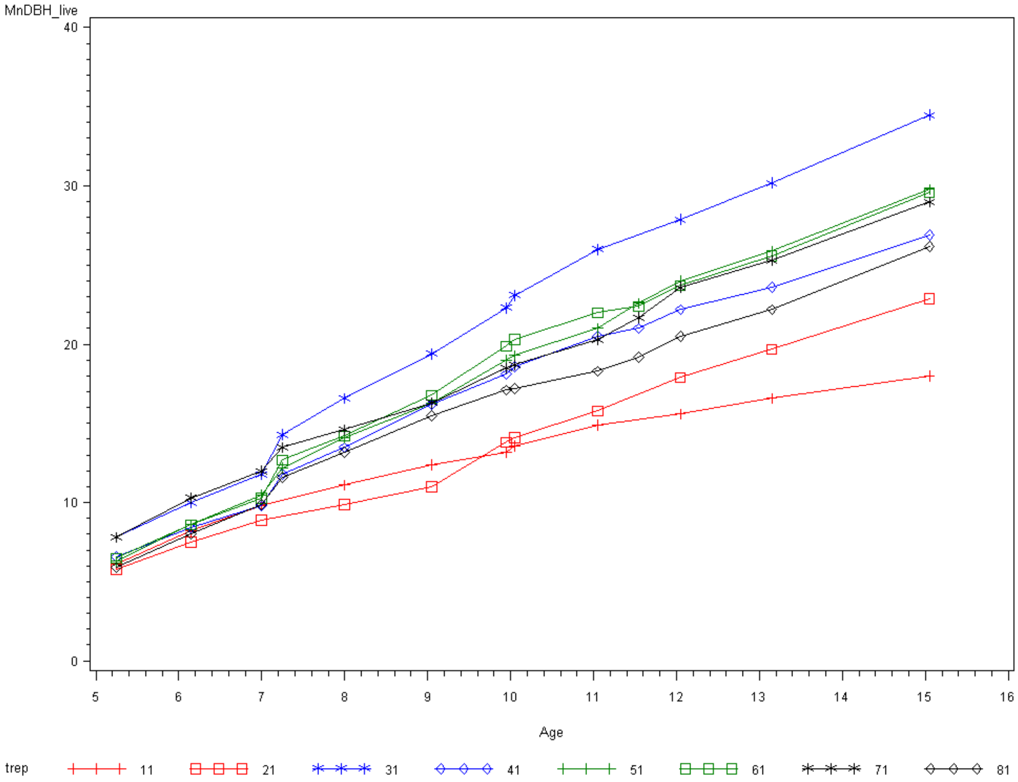
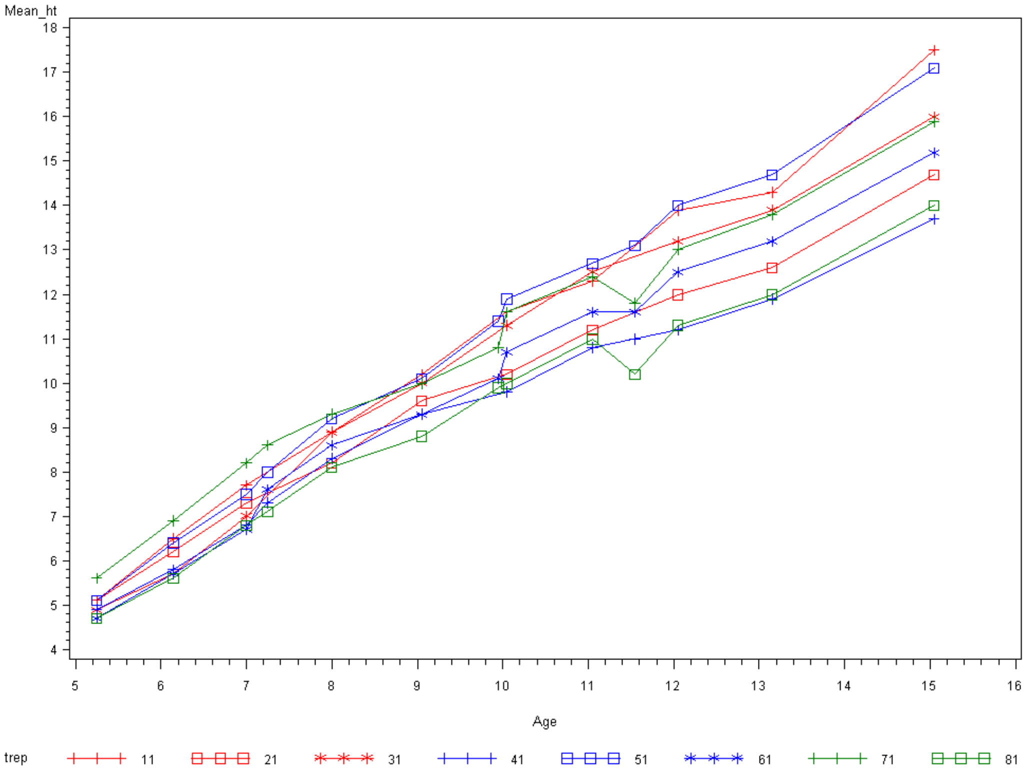


Figure 14. Cumulative height growth (metres) by age for *C. lusitanica* regime trial at Okiwa.



Meads *C. lusitanica* Thinning and Pruning Regime Trial

The trial at Meads property is similar to the Okiwa trial as it has no replication and similar treatments (Table 7). However, the original stocking appears to have been about half the stocking at Okiwa, with one rather unusual plot (treatment 8) at 800 sph at the age of 3, when it also received a prune. The stand was established in 1995 and the trial was installed in 1999.

Table 7. Treatments in Meads trial

	Age of thinning and sph				Height of Pruning				Remarks
Treat-ment	5	7	9	11	3	7	9	12	
11	1200	1100	1000	1000	0	0	0	0	No treatment
21	1300	1100	1100	700	0	0	0	0	One thin, no pruning
31	1100	1000	700	400	0	0	0	0	Two thins, no pruning
41	950	700	400	400	0	1.7	3.4	3.4	Two thins, late, low prune
51	1300	1000	700	400	0	2.4	4.6	6.0	Three thins, late prune
61	1100	1000	700	400	0	3.7	5.5	5.5	Three thins, harder prune
71	1300	1000	780	400	0	3.6	5.4	5.4	Three thins, harder prune
81	800	700	700	400	1.5	3.9	6.0	6.0	One thin, early prune

The higher stocked plots (Figure 15) seem to lose trees from an early age in a similar manner to Tapuwae, possibly due to toppling. The unpruned treatments had higher growth rate (Figure 16) to age 16, but the treatments were not finished until age 12. There are signs that treatment 8 was just starting to catch up from age 14 onwards. Diameter growth (Figure 17) also appears to be in a process of sorting itself out. The unthinned treatment 11 was just starting to lose out on diameter growth, while late thinned treatments like 81 were responding with increased growth. However, later assessments would give a clearer picture of the effects of the later thinning treatments.

Figure 15. Stocking (sph) by age for *C. lusitanica* regime trial at Meads.

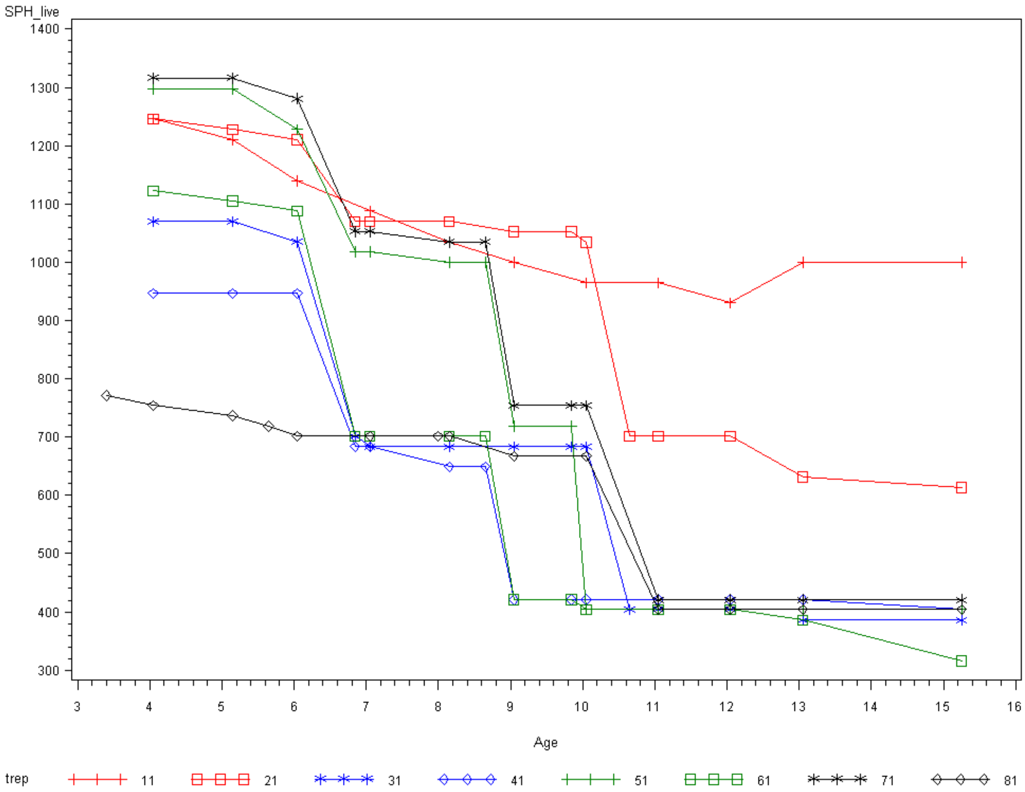


Figure 16. **Cumulative volume growth (m^3 / hectare) by age for *C. lusitanica* regime trial at Meads.**

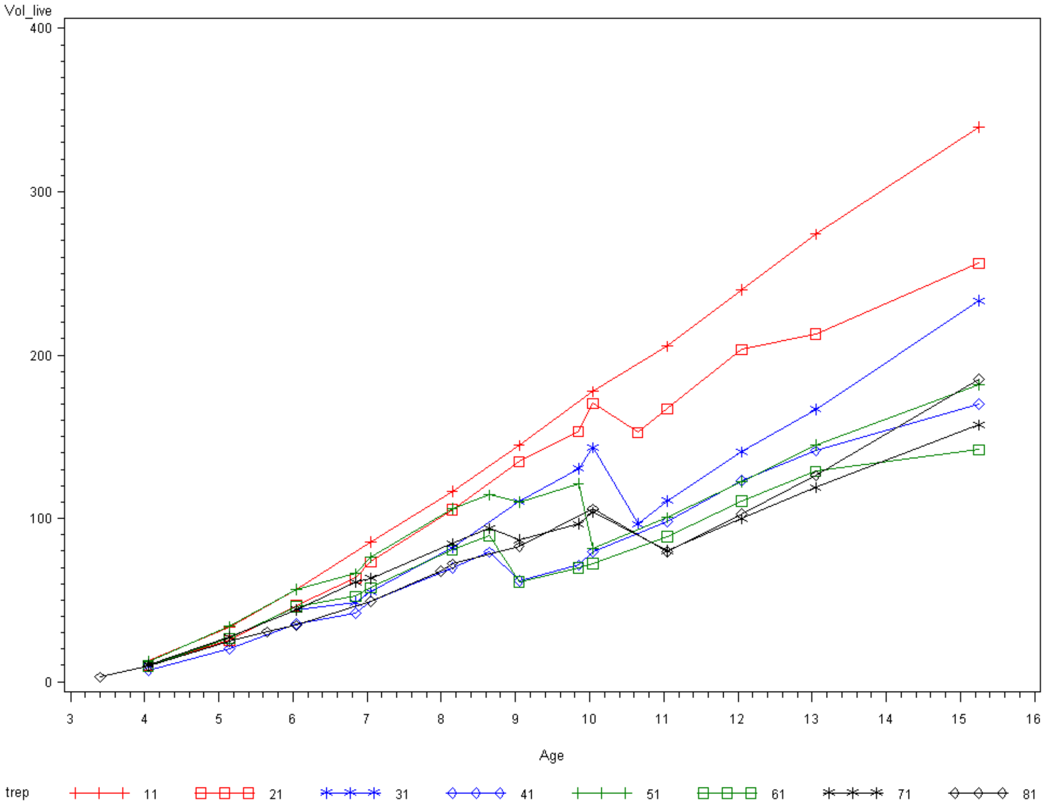
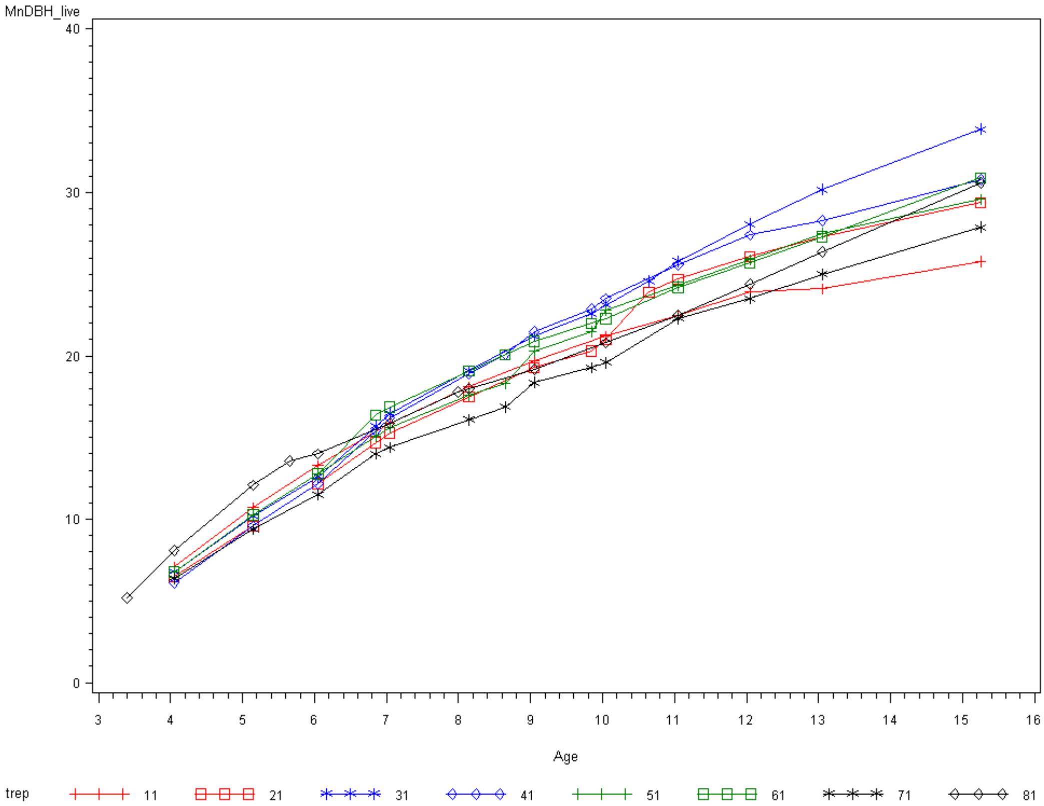


Figure 17. **Cumulative diameter growth (mm) by age for *C. lusitanica* regime trial at Meads.**



Waihou *C. lusitanica* Stocking Regime Trial

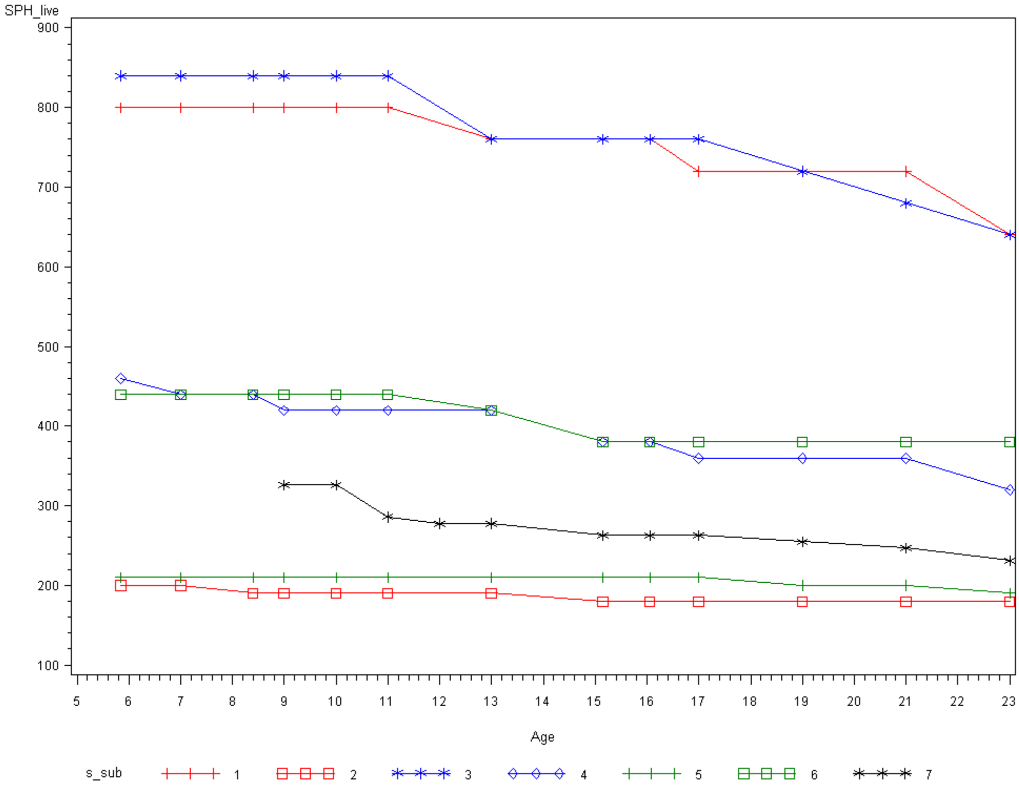
The stand at Waihou was planted in 1985 and the treatments for the trial were set up in 1991. There are no pruning treatments, just one-off thinning treatments (Table 8) to three effective stocking levels, from an original stocking of more than 840 sph.

Table 8. Treatments in Waihou trial

Treatment	Stocking	Remarks
1	800	High stocking
2	200	Low stocking
3	840	High stocking
4	460	Medium stocking
5	210	Low stocking
6	440	Medium stocking
7	326	Medium-low stocking

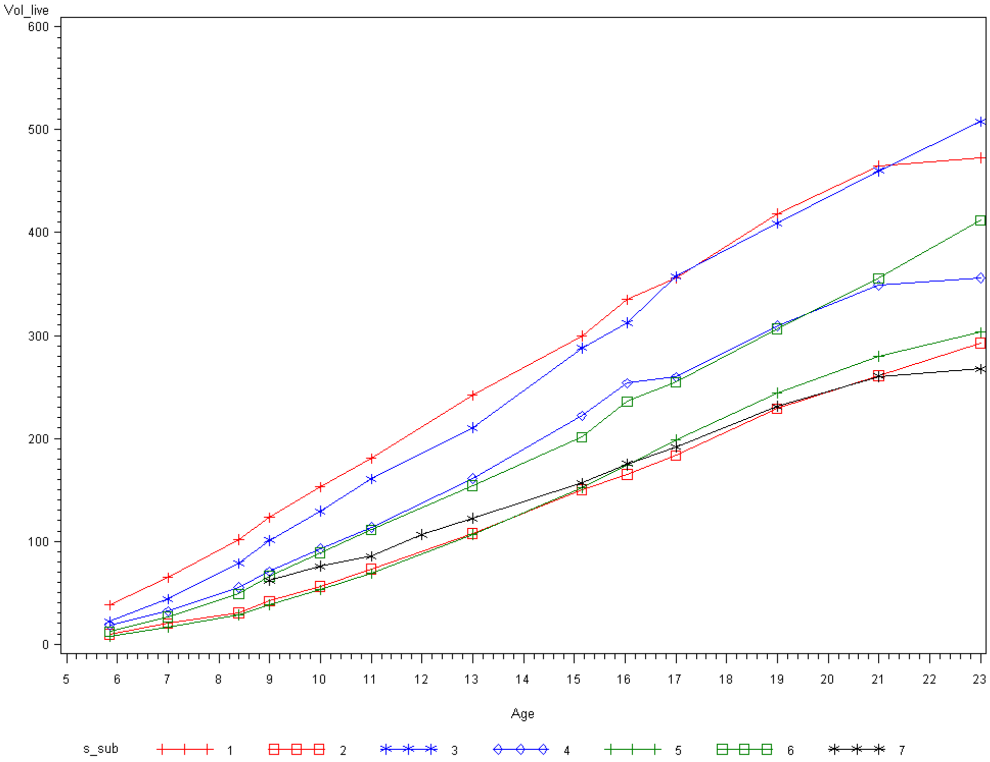
The results are extremely clear cut for this trial. High stockings (Figure 18) give best volume growth (Figure 19), with low stockings (200 sph) having greatest diameter growth (Table 20). The 400 sph stocking was almost exactly in between the high and low treatments. The different treatments had separated themselves widely by age 16 but then tracked out to age 23 in parallel. There is mortality in some of the treatments in this trial, which reduces yield and complicates comparisons. The better diameter growth trajectory of the 400 spa stockings appears to set up the foundation for better volume growth at later ages.

Figure 18. Stocking (sph) by age for *C. lusitanica* regime trial at Waihou.



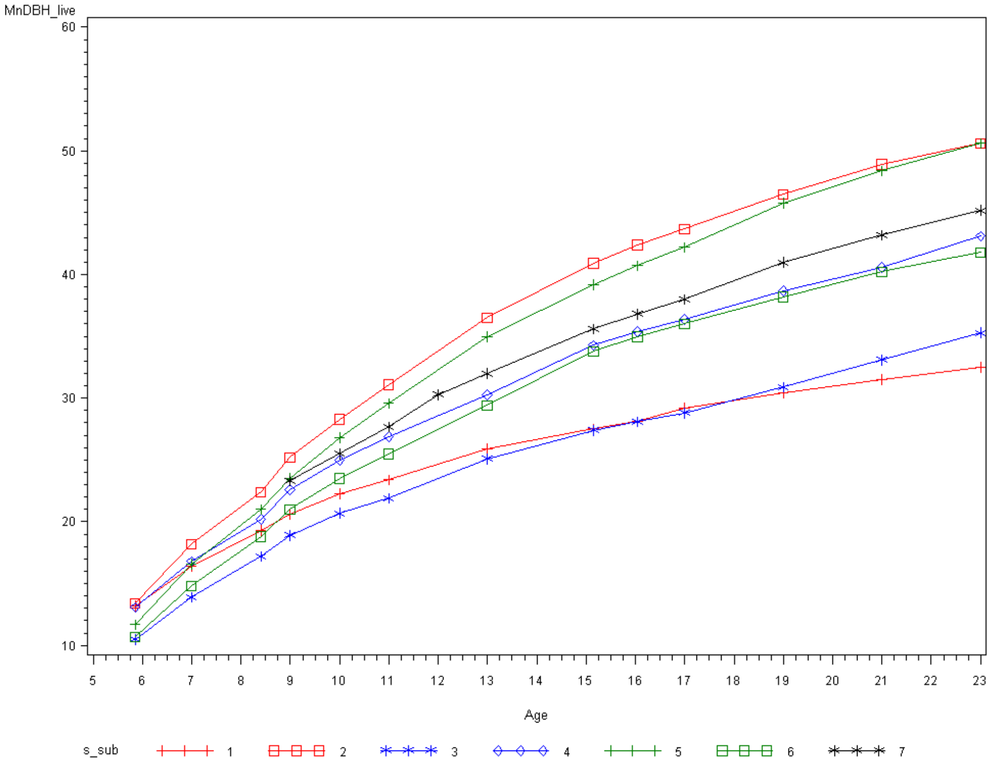
Treatment	1	2	3	4	5	6	7
Stocking	800	200	840	460	210	440	326

Figure 19. Cumulative volume growth (m^3 / hectare) by age for *C. lusitanica* regime trial at Waihou.



Treatment	1	2	3	4	5	6	7
Stocking	800	200	840	460	210	440	326

Figure 20. Cumulative diameter growth (mm) by age for *C. lusitanica* regime trial at Waihou.



Treatment	1	2	3	4	5	6	7
Stocking	800	200	840	460	210	440	326

Cupressus macrocarpa

The cypress canker fungi (*Seiridium cupressi*, *Seiridium cardinale*) have attacked *C. macrocarpa* so badly on warm sites that many plantings have not been able to form stands. The Rotoehu spacing trial was wiped out by the age of 12 years and even its early growth was affected by mortality and poor growth from diseased crowns. The trial at Kinleith also had moderate levels of canker infection but was helped by thinning out diseased trees.

The Hanmer stand had grown for 60 years at a high stocking with no silviculture. It had not responded with improved growth following thinning, so an analysis of the data would have been misleading.

Otago Coast *C. macrocarpa* Regime Trial

The Otago Coast trial was remarkably free from canker, resulting in virtually no mortality. There are three different stockings (Table 8 & Figure 21), with the lower stockings presumably derived by thinning the original stand at an early age. Pruning did not start until age seven, so all pruning treatments were relatively mild.

There are three replicates for each treatment, so treatment means were well estimated. An analysis of variance was run on the individual tree data for each assessment of diameter and height. This showed no significant difference between treatments for three years after the trial started, so the stand must have been growing evenly. Significant differences began to develop from then on to highly significant differences for diameter, while differences for height growth were only just significant.

Volume growth (Figure 22) was better for the higher stockings to age 23, although the 1150 stem treatment had about the same volume as the 800 stockings. The 400 sph stocking had lower early volume growth, but appears to be on track to catch up to the higher stockings.

The 400 sph stocking is by far the best for diameter growth (Figure 23.). The rate of diameter growth slowed from around age 12 for all stockings, but particularly for the 1150 sph stocking. Interestingly, branch death as measured by green crown height (Figure 25) did not start until age 20.

Table 8. **Treatments in Otago Coast trial**

	Stocking	Pruning (metres of stem)				Remarks
Treat		7	8	9	10	
1	400	1.2	2.5	2.5	4.0	Low stocking, 3 lift prune to 4 m
2	400	0	2.1	2.1	3.6	Low stocking, 2 lift prune to 3.5 m
3	400	0	3.2	3.2	4.5	Low stocking, 2 lift prune to 4.5 m
4	800	1.6	3.2	3.2	4.5	Mid stocking, 3 lift prune to 4.5 m
5	800	1.6	1.6	1.6	3.3	Mid stocking, 2 lift prune to 3.3 m
6	800	1.2	1.2	1.2	3.0	Mid stocking, 2 lift prune to 3.0 m
7	800	0	2.1	2.1	2.1	Mid stocking, 1 prune to 2.1 m
8	1200	0	0	2.1	2.1	High stocking, 1 late prune to 2.1 m

Figure 21. **Stocking (sph) by age for *C. macrocarpa* regime trial on the Otago coast.**

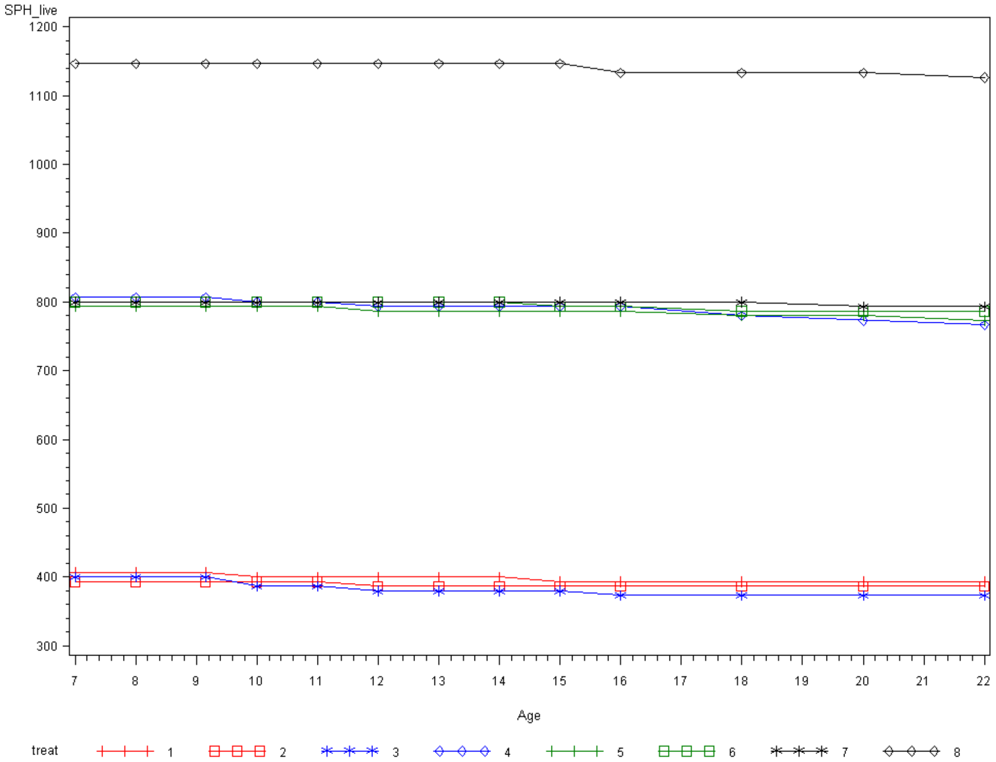


Figure 22. **Cumulative volume growth (m^3 / hectare) by age for the *C. macrocarpa* regime trial on the Otago coast.**

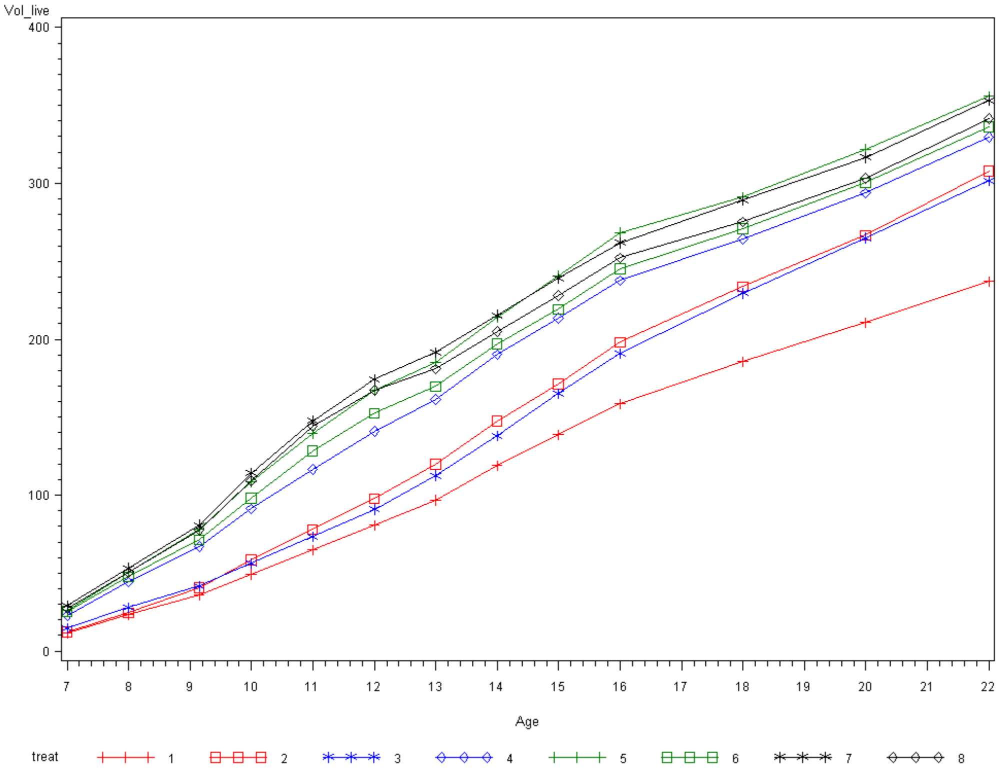


Figure 23. Cumulative diameter growth (mm) by age for the *C. macrocarpa* regime trial on the Otago coast.

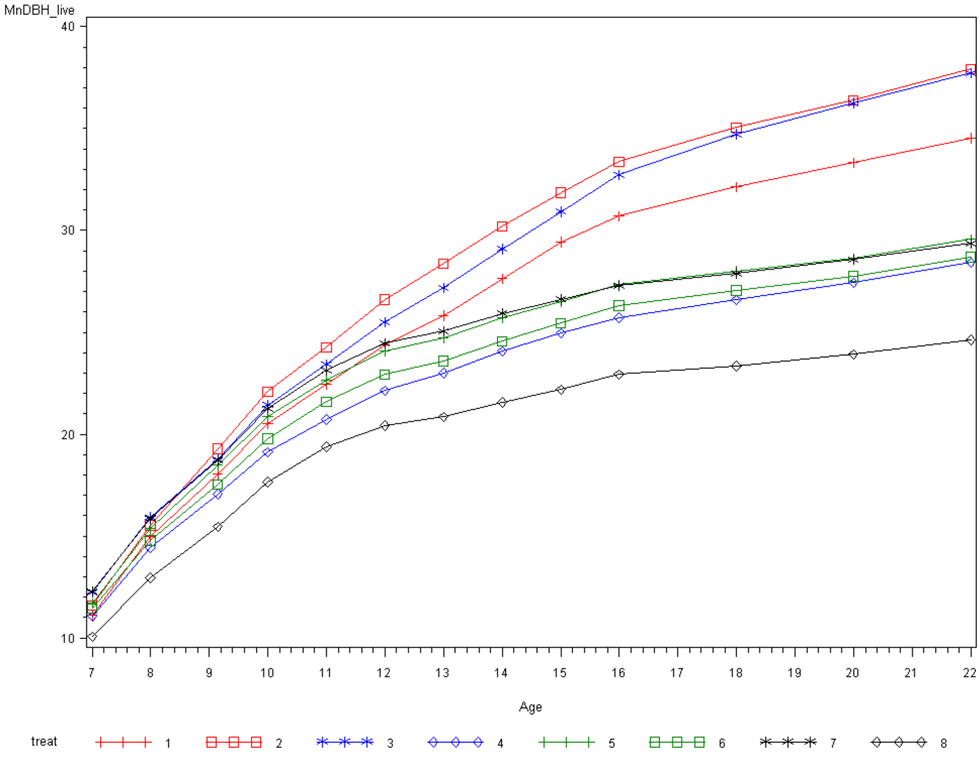


Figure 24. Cumulative height growth (metres) by age for the *C. macrocarpa* regime trial on the Otago coast.

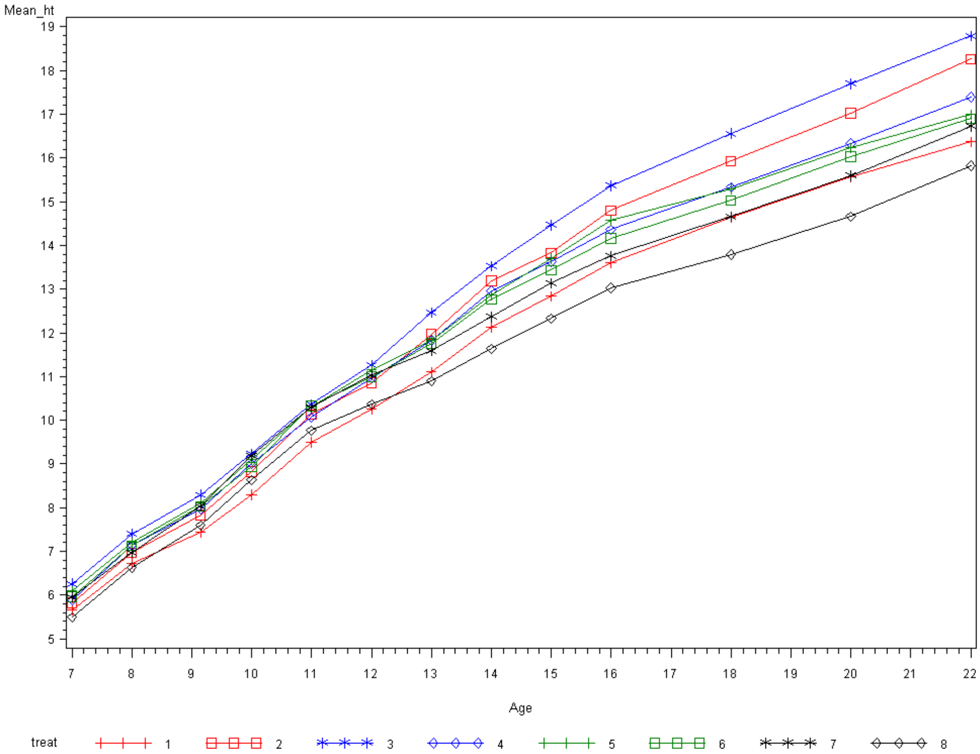
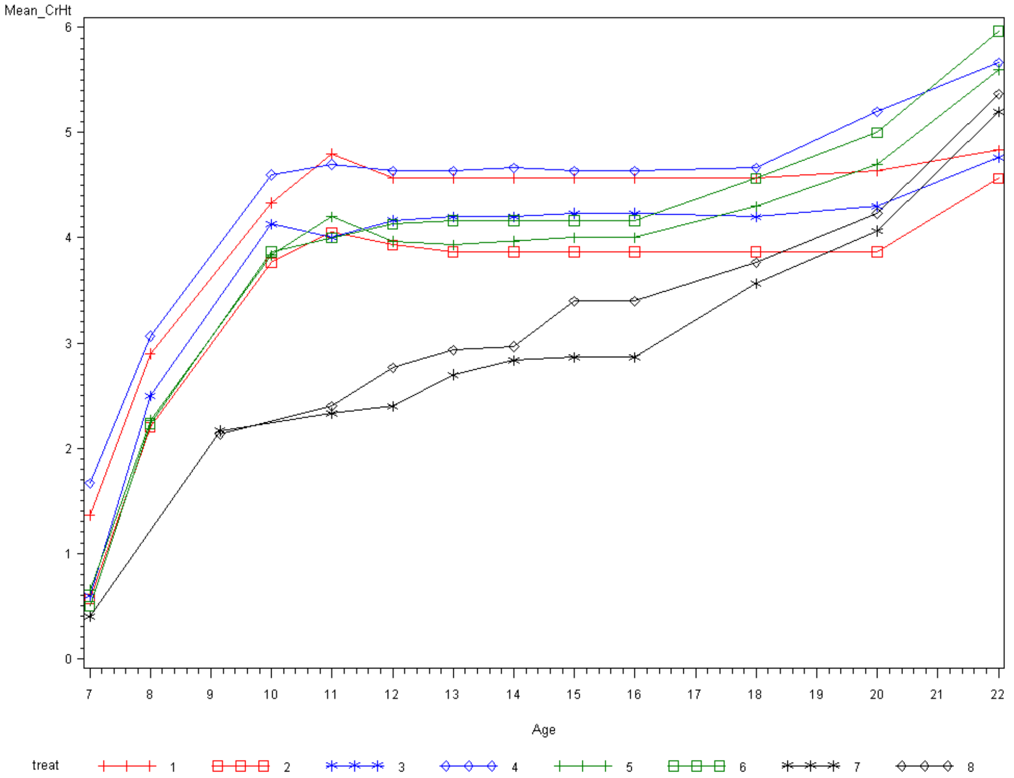


Figure 25. Cumulative crown height (metres) by age for the *C. macrocarpa* regime trial on the Otago coast.



Kinleith *C. macrocarpa* Regime Trial

The Kinleith site would have rated as a very well-growing stand when the trial was installed. The trees had managed slightly more than one metre of height growth per year and the high initial stocking provided scope for evaluating thinning treatments. However, cypress canker symptoms began to spread and may have altered the plans as all treatments (Table 9) were thinned to 400 sph by age 15. Treatments 4 & 6 seem to have thinned themselves (Figure 26), as each year saw a reduction in stocking, from 1000 sph to 700 over five years.

The unpruned treatments fared best for volume growth (Figure 27) and it may be because the pruning stresses *C. macrocarpa* trees and makes them more susceptible to infection by canker[6]. The hardest pruning treatment (5) reduced volume growth initially, but growth rate has recovered.

Diameter growth (Figure 28) was best with unpruned treatments and also responded well to early thinning to 400 sph. The high level of cypress canker on this site may have compromised the results for different treatments.

Table 9. Treatments in Kinleith trial

	Age of thinning and sph			Height of pruning			Remarks
Treat	6	11	15	6	9	12	
1	1333	700	400	0	0	0	3 thins, no pruning
2	700	400	400	0	0	0	2 early thins, no pruning
3	700	400	400	1.6	3.9	6.0	2 early thins, 3 lift pruning
4	1000	700	400	1.6	3.5	6.0	2 later thins, 3 lift pruning
5	700	400	400	3.2	5.2	6.0	2 early thins, hard prune
6	1000	700	400	2.8	5.2	6.0	3 thins, hard prune

Figure 26. Stocking (sph) by age for *C. macrocarpa* regime trial at Kinleith.

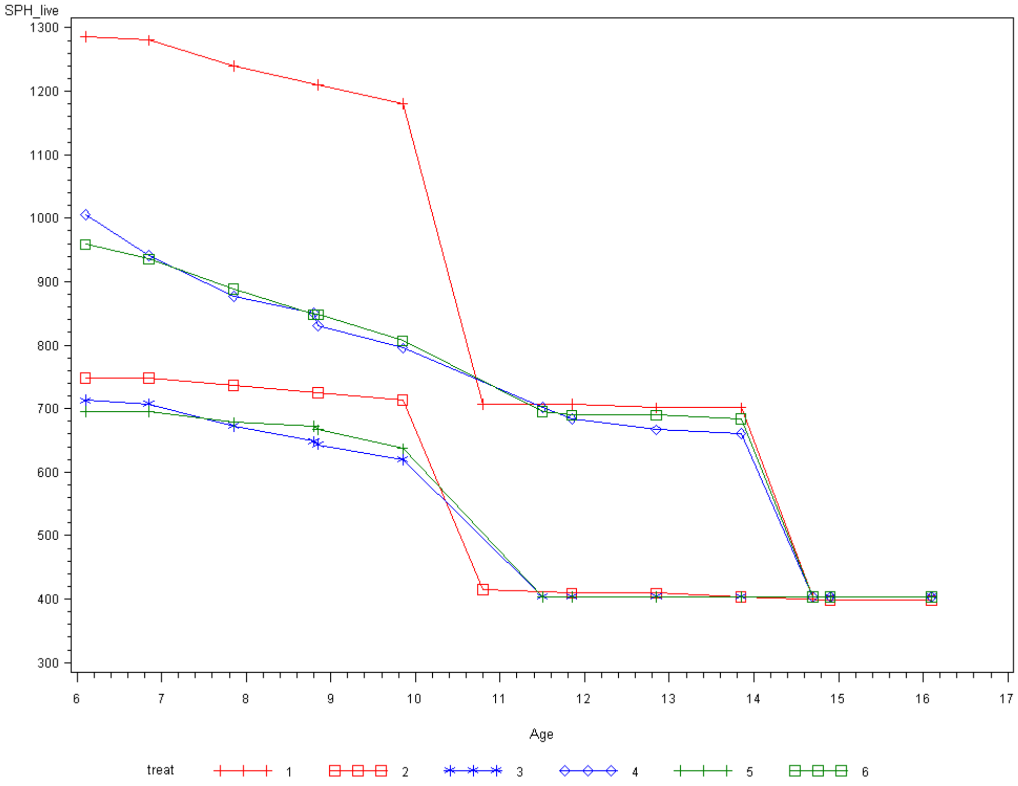


Figure 27. Cumulative volume growth (m^3 / hectare) by age for *C. macrocarpa* regime trial at Kinleith.

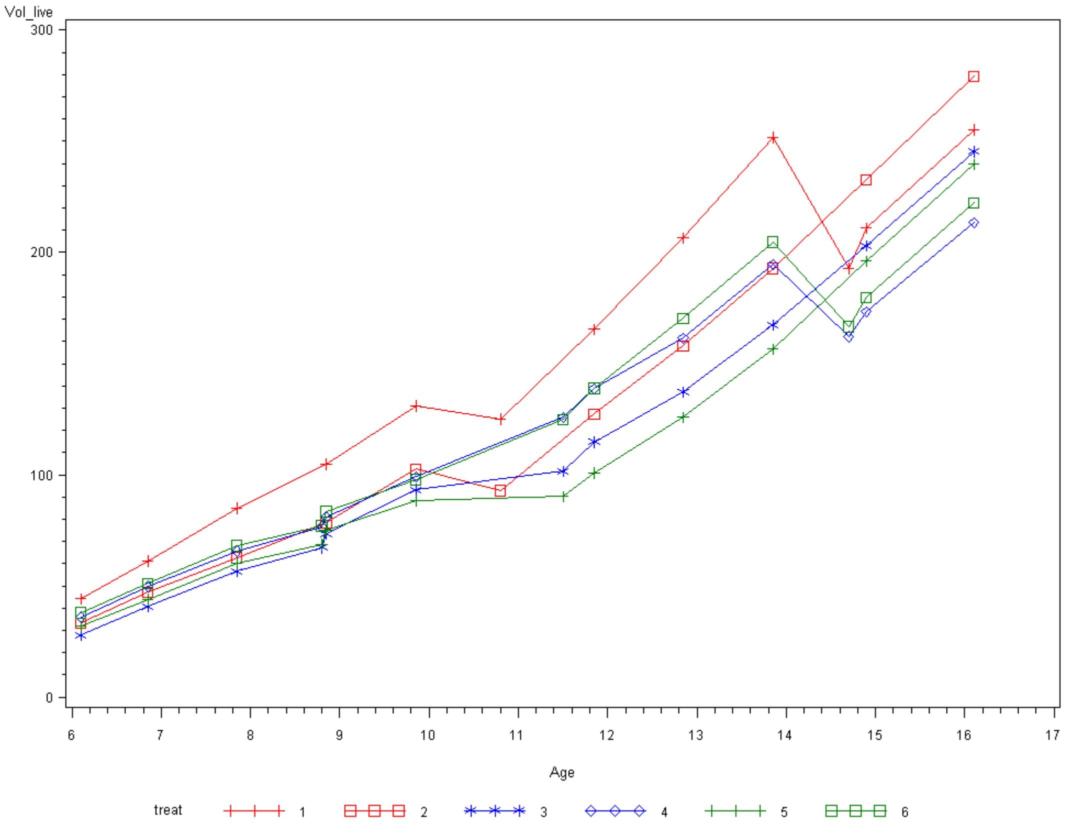
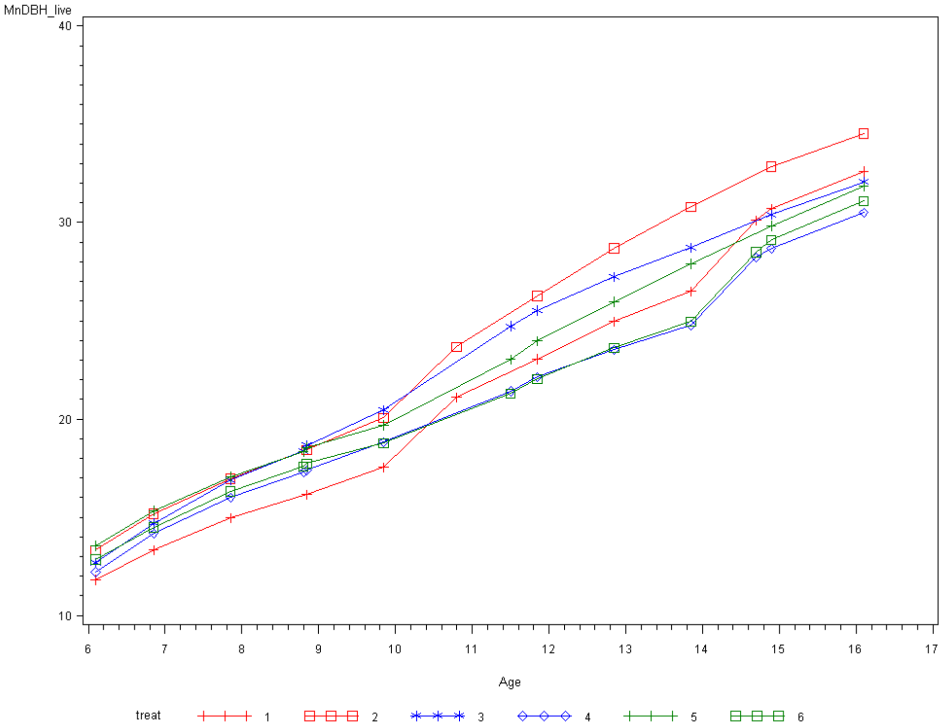


Figure 28. Cumulative diameter growth (mm) by age for *C. macrocarpa* regime trial at Kinleith.



Frasers *C. macrocarpa* Regime Trial

The trial on the Frasers property was laid out with just one plot per treatment. All stockings were to commence at 800 sph as the result of an early thinning, and only two were to be thinned to 400 sph at age 10. Pruning was minimal, with three treatments having no pruning and none being pruned to more than 3.2 metres.

The graph of actual stocking over time (Figure 29) reveals the sort of mortality seen on the Kinleith site, and the cause is also likely to be cypress canker. Again, the unpruned treatments have an edge in volume growth (Figure 30), albeit only to age 14.

The graph of diameter growth over time (Figure 31) also documents better diameter growth for unpruned treatments. However, treatment 5 appears to be making a charge with diameter growth taking off from about the time of the age 10 thinning.

Table 10. Treatments in Frasers property

	Age of thinning & sph		Height of pruning		Remarks
Treat	4	10	4	6	
1	800	400	1.6	1.6	2 thins, light early pruning
2	800	800	0	3.2	1 thin, hard late pruning
3	800	800	0	1.3	1 thin, light, late pruning
4	800	800	0	0	1 thin, no pruning
5	800	400	0	3.0	2 early thins, hard prune
6	800	800	0	0	1 thin, no pruning
7	800	800	0	3.0	1 thin, hard late prune
8	800	800	0	0	1 thin, no pruning

Figure 29. **Stocking (sph) by age for *C. macrocarpa* regime trial at Fraser**.

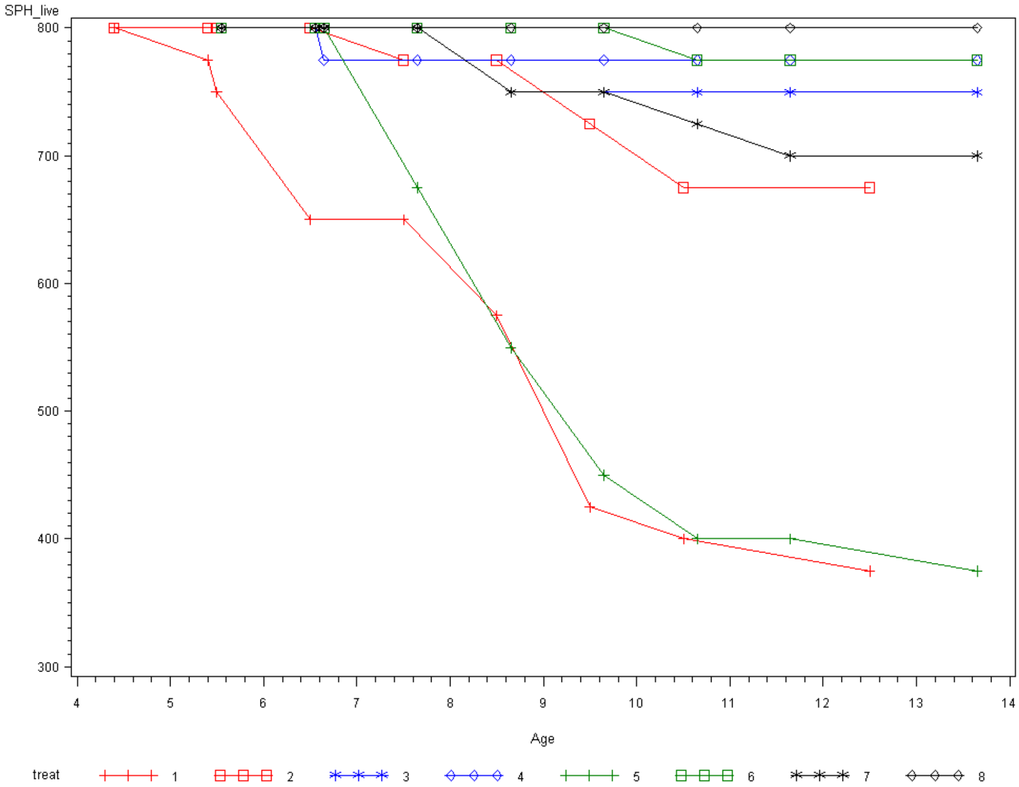


Figure 30. **Cumulative volume growth (m^3 / hectare) by age for *C. macrocarpa* regime trial at Fraser.**

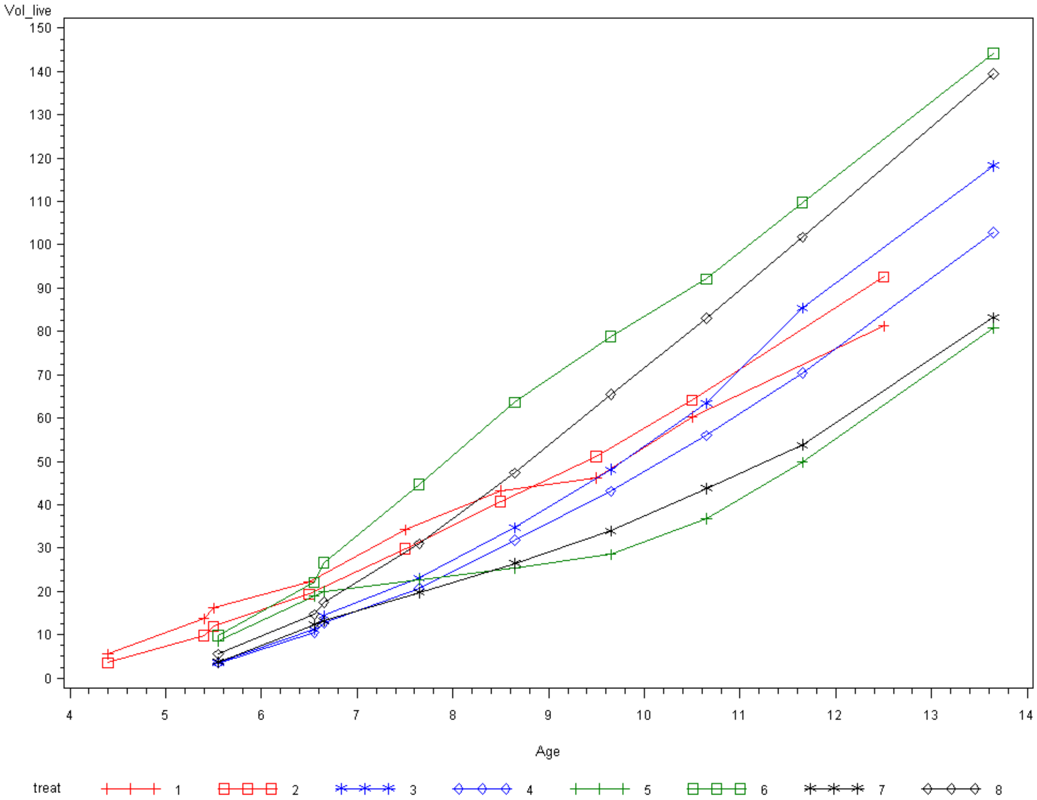
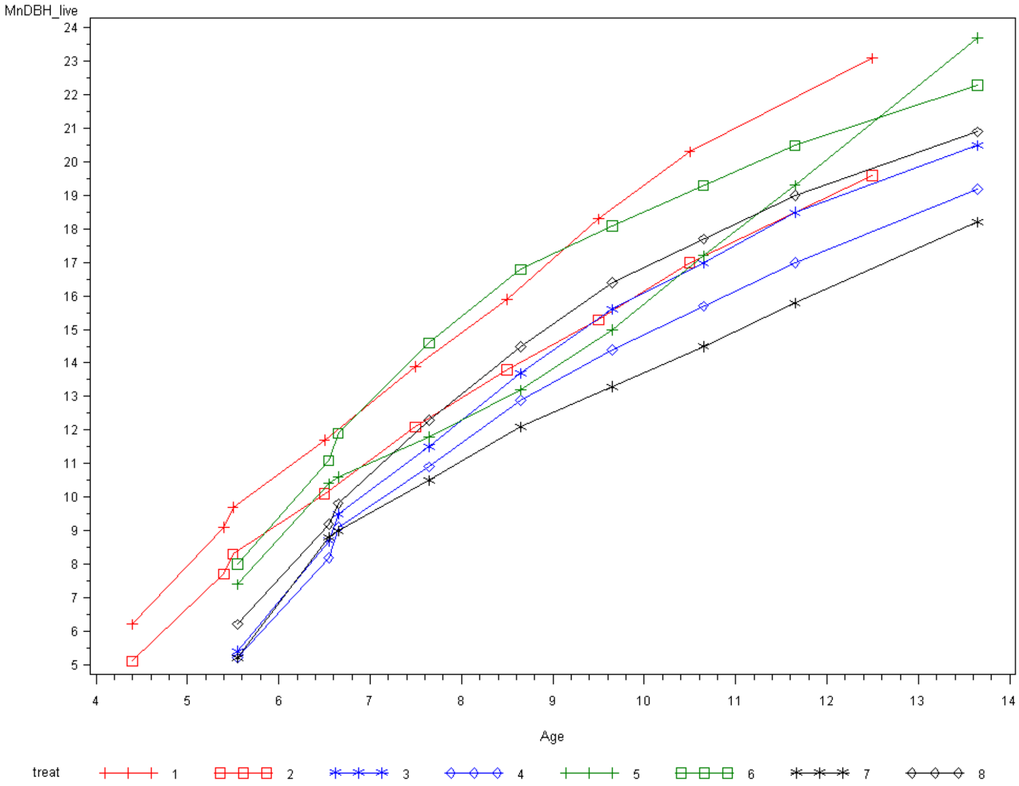


Figure 31. **Cumulative diameter growth (mm) by age for *C. macrocarpa* regime trial at Fraser.**



Ferguson *C. macrocarpa* Regime Trial

The Ferguson trial also has only one plot per treatment and only four treatments (Table 11). However, mortality (Figure 32) is less than the Kinleith or Fraser trial, so it should provide useful data. The pruned 800 sph treatment has greater volume (Figure 33) than the unpruned 800 sph treatment, but it is possible that late-ish pruning may actually help the trees by removing shaded foliage that is actually a drain on resources, rather than contributing to growth[6].

Diameter growth (Figure 34) appears to be enhanced by thinning, although the short time between thinning and the last assessment is not enough for the pruned and thinned treatments to catch up to the unthinned treatment 4. There was an increase in diameter growth after thinning.

Table 11. Treatments in Ferguson trial

	Age of thinning & sph		Height of pruning			Remarks
Treatment	6	13	8	11	13	
1	800	800	0	0	0	1 thin, no pruning
2	800	500	2.0	2.0	6.0	2 thins, 2 lift pruning
3	800	600	3.7	3.9	6.0	2 thins, 3 lift pruning
4	800	800	1.6	3.5	6.0	1 thin, 3 lift pruning

Figure 32. **Stocking (sph) by age for *C. macrocarpa* regime trial at Ferguson.**

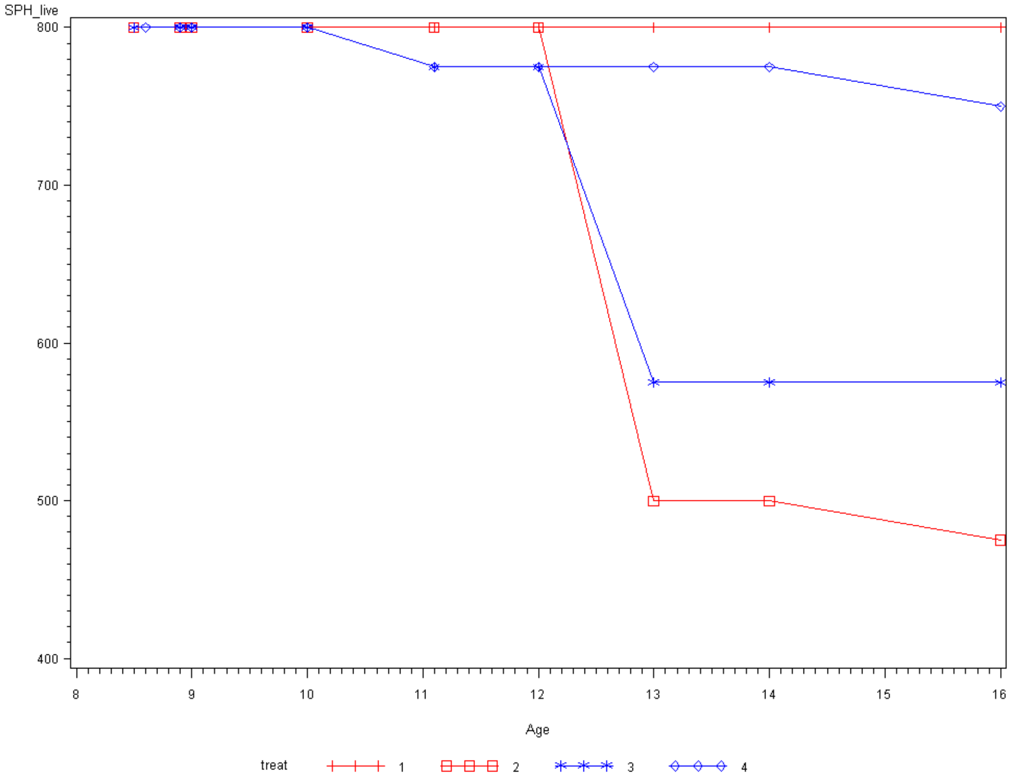


Figure 33. **Cumulative volume growth (m^3 / hectare) by age for *C. macrocarpa* regime trial at Ferguson.**

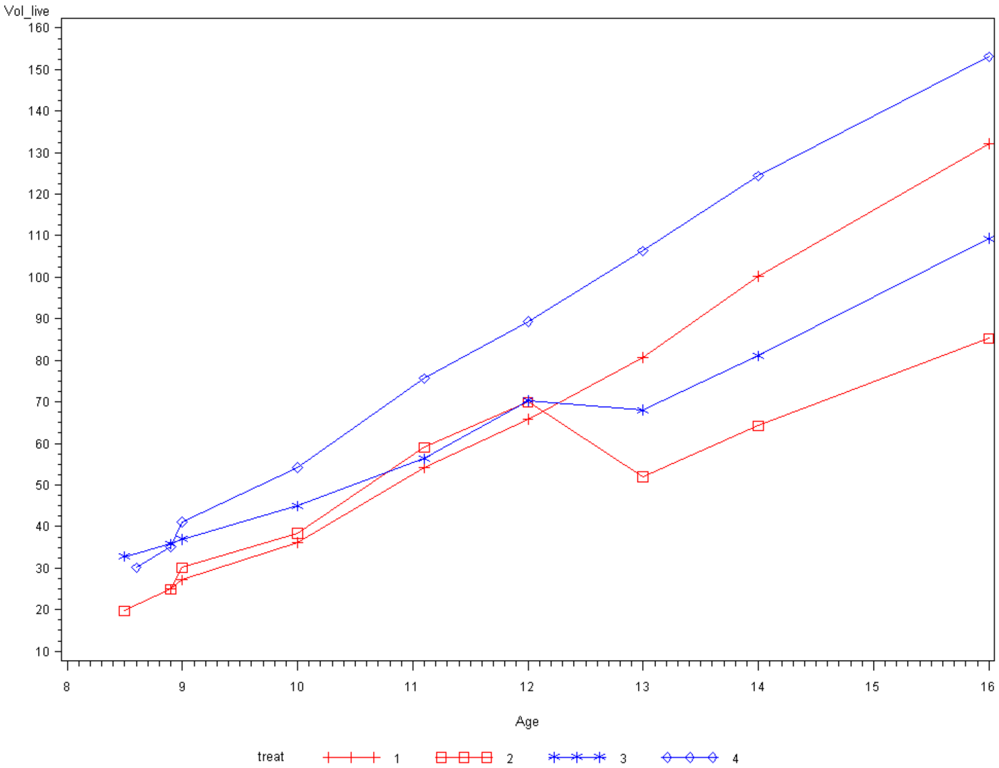
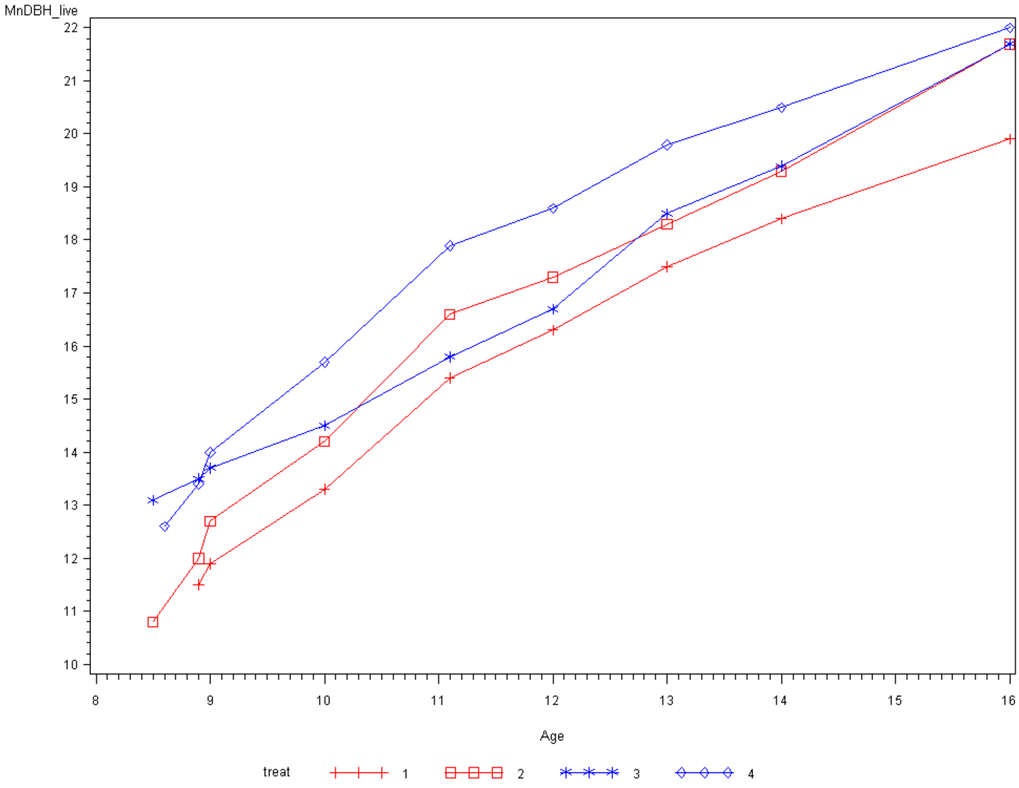


Figure 34. Cumulative diameter growth (mm) by age for *C. macrocarpa* regime trial at Ferguson.



Hybrids and Other Species

There is only one PSP in a stand of Leyland cypresses that can be compared to two nearby PSPs of *C. lusitanica*. These are on a property owned by Geoff Brann, near Rotoehu forest, and were all pruned. The Leyland plot was pruned to 6.7 metres, the higher stocked of the two C. lusitanica plots was pruned to 4.2 metres and the lower stocked plot was pruned to 5.5 metres.

The stands were thinned to final crop before PSPs were installed (Figure 35). Stocking was comparable at 300 sph for the Leyland plot (clone Leighton Green) 255 sph for one plot of *C. lusitanica* and 340 dropping to 310 for the other.

Diameter growth (Figure 36) is extremely good at almost 2 cm per year for all plots. It is best for the lower stocked *C. lusitanica* plot, a little slower for the higher stocked *C. lusitanica* plot and the Leyland plot is a little slower again. All plots are well sited, but there may be microsite differences. Volume growth (Figure 37) has the position of the *C. lusitanica* plots reversed, and the Leyland plot further behind *C. lusitanica* than it was for diameter growth.

Height growth is also good at one metre per year for 22 years, with the *C. lusitanica* again having a slight edge. Green crown length was much greater for the Leyland plot, however, so this may drive improved growth in years to come.

Figure 35. ***C. lusitanica* and Leyland stocking (sph) by age for plots at Branns.**

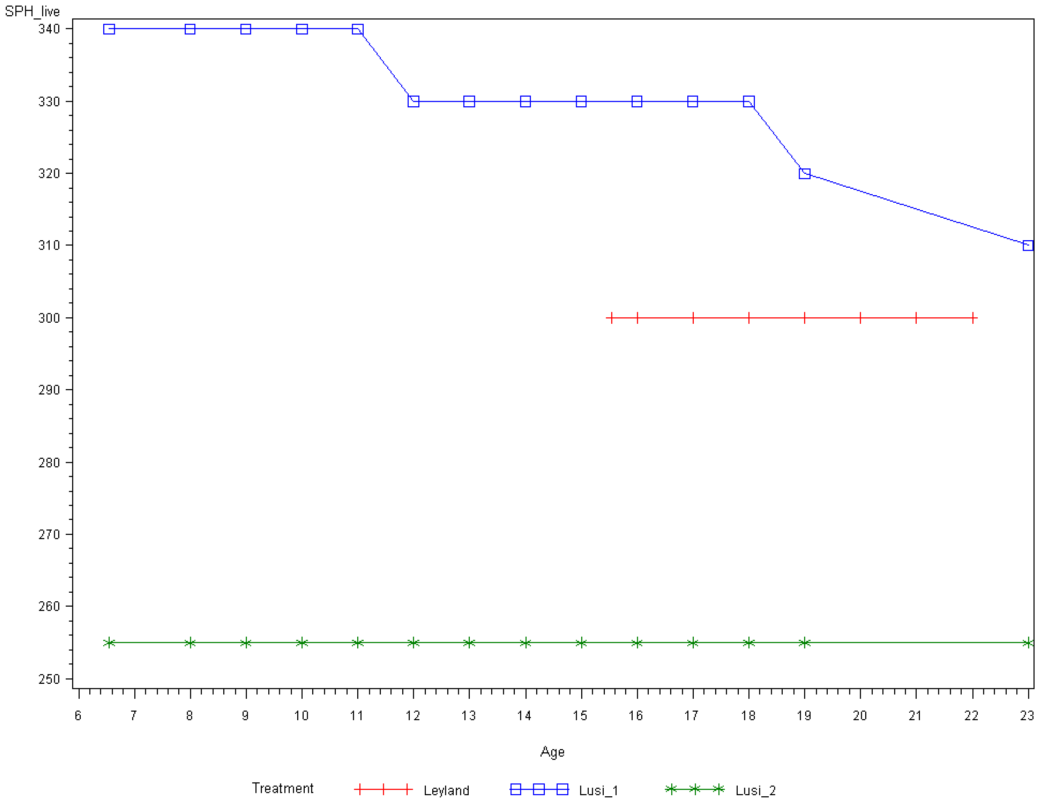


Figure 36. ***C. lusitanica* and Leyland cumulative diameter growth (mm) at Branns**

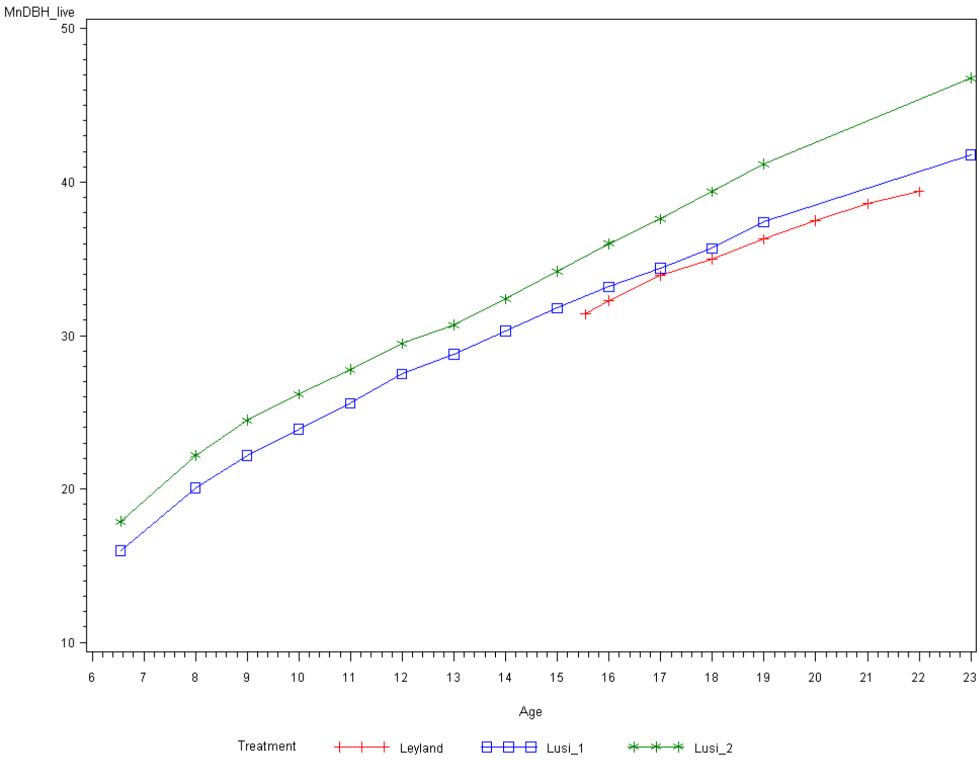


Figure 37. ***C. lusitanica* and Leyland cumulative volume growth (m^3/hectare) at Branns**

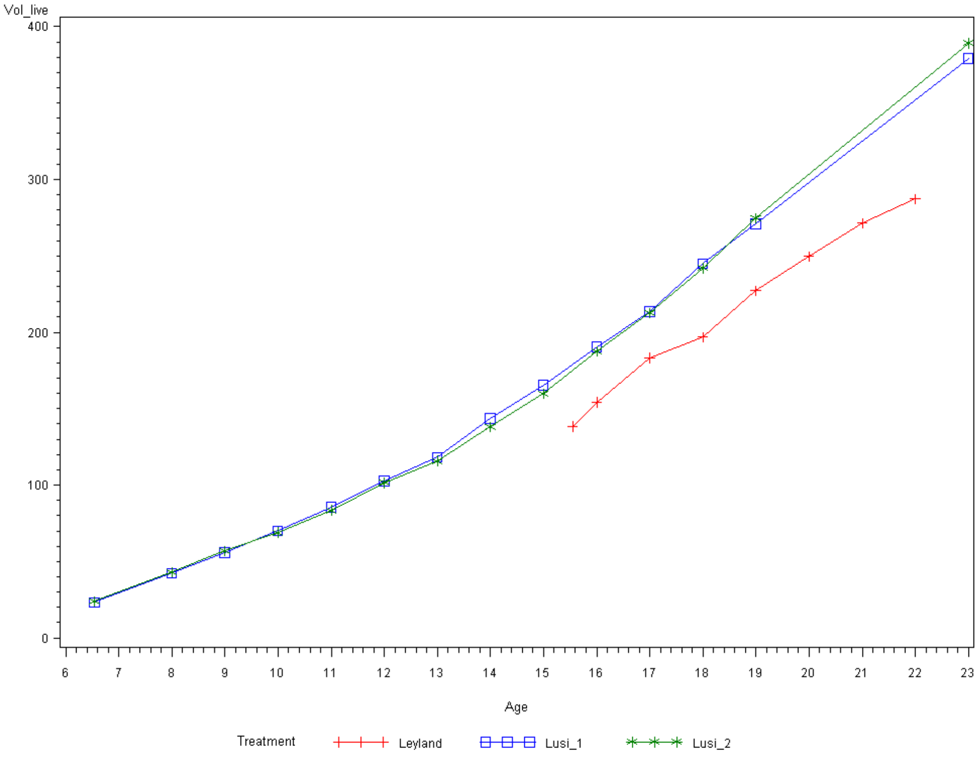


Figure 38. ***C. lusitanica* and Leyland cumulative height (metres) by age at Branns.**

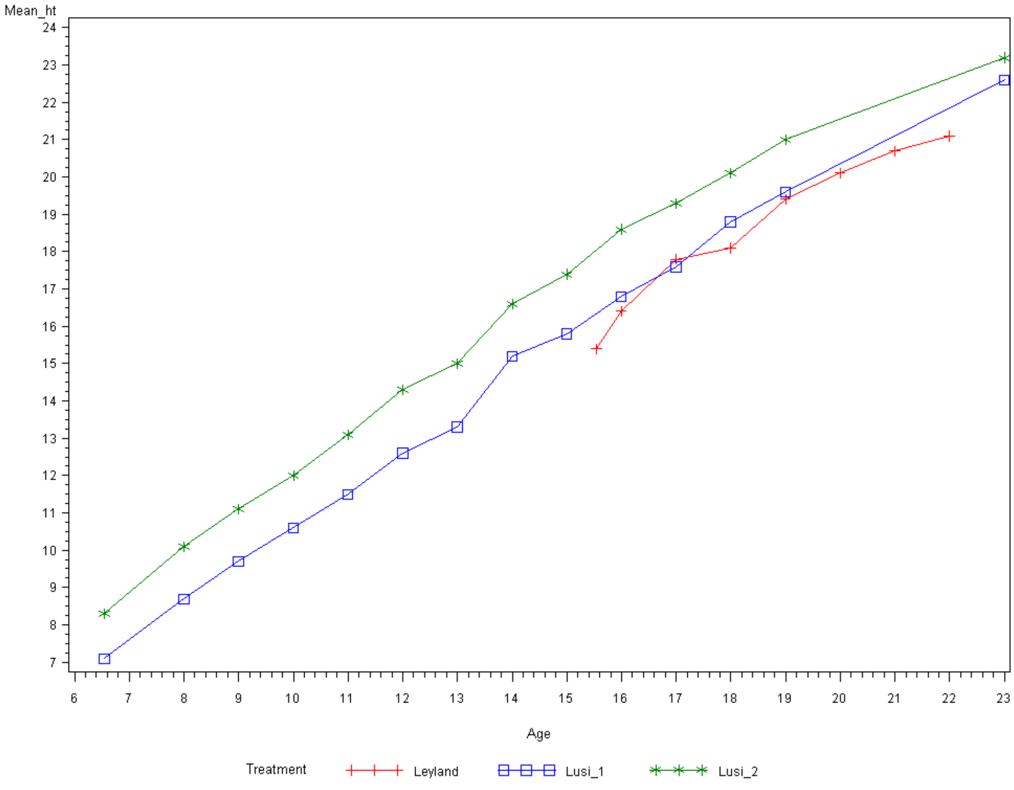
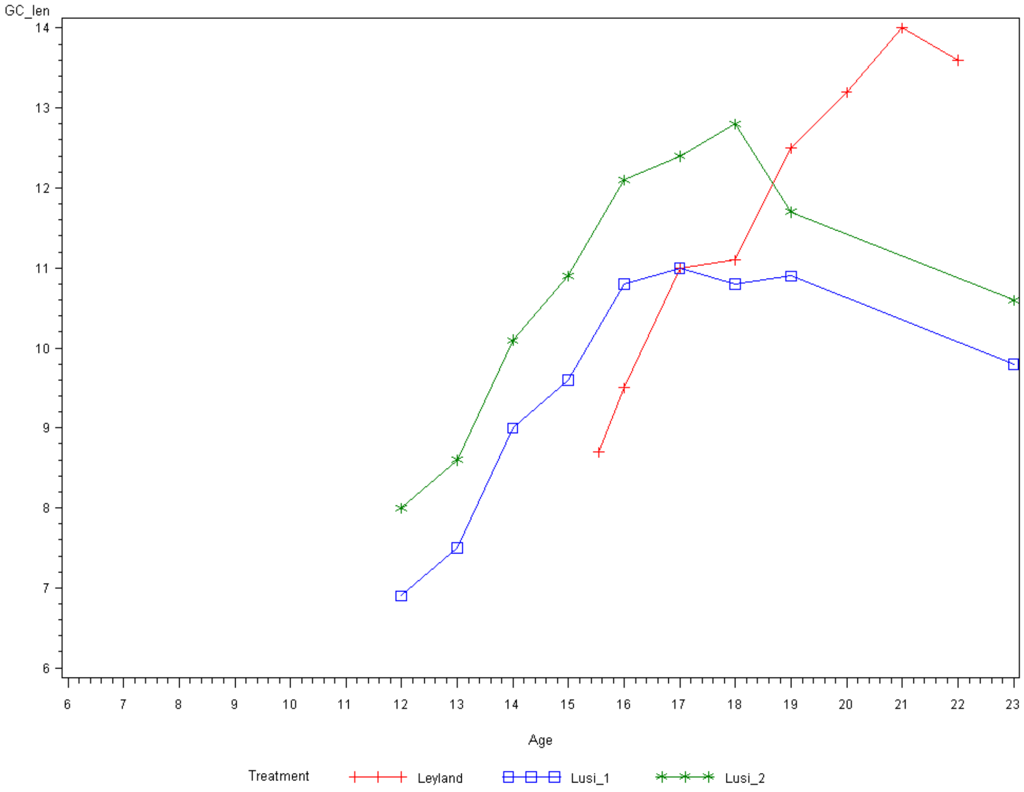


Figure 39. ***C. lusitanica*** **and Leyland green crown length (metres) by age at Branns.**



CONCLUSIONS

Cupressus lusitanica.

Most of the *C. lusitanica* trials were installed in areas that were suited to growing cypress species and showed clear responses to silviculture on sites where trees could grow more than one metre of height per year.

The Rotoehu spacing trial was extremely valuable as it showed that *C. lusitanica* can grow happily at much higher stockings than radiata pine out to twenty years. The higher stockings do affect diameter growth, so there is a tradeoff to grow a smaller volume of large logs, which may be more profitable than a larger volume of small logs. The low stockings of 200 sph were too low for a species that is comfortable with higher stockings.

Management Implications

A stocking of 800 sph gave best volume growth out to age 23. By this age stockings that were higher than 800 sph were suffering mortality. Thinning early appeared to result in the least volume loss. The Northland trial suffered from a lot of mortality in the higher stockings, likely to be caused by toppling, which made it difficult to see the effects of different spacings.

There were many treatments that resulted in a stocking of 400 sph. These kept deeper crowns than the higher stockings so the trees could catch up to the higher stockings, but at an older age than was available in the data.

Aggressive pruning resulted in reduced diameter growth the following year, but the trees appear to recover from this in the second year. Later pruning can actually enhance diameter growth over unpruned trees where the shaded foliage might have been more of a hindrance to growth than a benefit. As there are good premiums paid for clear heartwood and pruned logs, pruning would be recommended.

All of these trials were installed in stands planted from 1984 to 1992. The seed sources that were available then were better than some that have been planted, but did not produce trees as vigorous and as well-formed as trees grown from the seed orchard seed available now. Some PSPs should be installed into the 2002 *C. lusitanica* clonal trials and 2006 progeny trials to reflect the true growth potential of seed that is currently available.

Recommendations to Industry

The results of the analyses (without testing production thinning) suggest that the best regime would be to plant 1100 sph, start pruning when the trees reach six metres in height, prune 4-500 sph to six metres, and thin for a final stocking of 400 sph at the conclusion of the pruning (around age eight or ten metres in height). Northland sites can lose trees to toppling and possums can damage dominants severely, so thinning to 500 would allow attrition down to 400 at harvest. The trees should be large enough to harvest by age 30 and would produce 800 cubic metres on good sites.

Cupressus macrocarpa

Cypress canker has affected the growth of *C. macrocarpa* severely on warmer sites where it would have been expected to grow well. The regime trial sites that were analysed in this report were in cooler areas where the trees were reasonably healthy, but not at the full potential for growth.

Management Implications

C. macrocarpa also produces highest volumes at high stocking – 800 sph produced best volume growth as stockings higher than this were beginning to reduce their growth rate by age 20. Again there were a number of treatments that were thinned to 400 sph. These had good diameter growth and may well be best in the longer term, but the volume growth was running parallel to that of the 800 sph, rather than closing the gap.

The pruning treatments were less aggressive than those applied to *C. lusitanica,* and were applied later. However, there were signs that diameter growth was more badly affected than it was in the *C. lusitanica* trials. Certainly, the unpruned treatments had consistently better growth and it may be that the stress imposed by pruning has allowed some attack by cypress canker.

As with the *C. lusitanica*, there have been improvements to the quality of *C. macrocarpa* seed since the regime trials were planted. There have also been extensive *C. macrocarpa* stands established in the late 1990s on good sites in Southland, notably in Dunsdale forest. More PSPs should be installed into these stands, including the 1999 progeny trial in Dunsdale and the 2003 *C. macrocarpa* clonal trial on Scion campus.

Recommendations to Industry

The recommended regime for *C. macrocarpa* would be similar to that for *C. lusitanica*. All *C. macrocarpa* stands were affected by canker to some extent. On a healthy site this would be only one or two trees per hundred, and sites where 10 to 20 trees were affected could still produce profitable stands. Pruning should be less aggressive if the stand was in the latter class and thinning would then be to no less than 500 sph to allow for some mortality to canker. The trees should be large enough to harvest by age 30 and would produce 800 cubic metres on good sites.

Chamaecyparis species

The only regime trial of *Ch. lawsoniana* was put into an old, unmanaged stand and the trees have not responded. The species has produced good stands and the timber is highly regarded, but volume growth is half that of *C. lusitanica* or *C. macrocarpa*, so rotation lengths would need to be much longer.

Ch. nootkatensis (Alaska yellow cedar) and *Ch. obtusa* (Hinoki) are in a similar category to *Ch. lawsoniana*. Their timber is even more highly regarded in global timber markets than that of *Ch. lawsoniana* and growth rates in New Zealand are much the same. There may be some scope for growing *Ch. nootkatensis* on hard, high altitude sites where *C. macrocarpa* and *C. lusitanica* would not grow well, as *Ch. nootkatensis* is mainly found on such sites in its natural range.

Cypress Hybrids

The only hybrid PSP that could be compared with *C. lusitanica* was slightly slower in growth, but well ahead of trees from pure *Chamaecyparis* species origin. Scion has remade some new Leyland and Ovensii crosses along with new hybrids using *Cupressus guadalupensis* as one of the parents for its canker resistance. The first trials of these were planted in 2008 and they look good so far, but are too young for any conclusions to be drawn just yet.

ACKNOWLEDGEMENTS

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