ANALYSIS OF EYREWELL WEED COMPETITION EXPERIMENT AT AGE SEVEN

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EXECUTIVE SUMMARY

The Eyrewell weed competition trial was analysed to age seven. The following results were obtained:

- In weed-free plots, trees showed a strong growth response to both irrigation and fertiliser, and particularly to the combination of both fertiliser and irrigation. This indicates that the site is well below the optimum for radiata in terms of both moisture and nutrient supply.

- The addition of fertiliser greatly increased the competitive effect of weeds. Irrigation generally slightly reduced the weed competition effect.

- In the fertilised plots, all weed types produced high losses in growth, particularly grass and voluntary weeds. Competition remained intense at age 7, with 3 to 4 years' growth lost to competition.

- Competition was much less in the unfertilised plots with only 1 to 2 years' growth loss by age 7. Competition from grass and legumes had largely ceased by age 4. Competition from other weeds continued longer but was generally diminishing by age 7.

- Broom behaved slightly differently to other weeds, producing its most severe competition in the irrigated, unfertilized plots.

Description of trial

This report describes the analysis to age seven of the Eyrewell weed competition experiment. Clinton et al (1997) describes the trial in detail while a similar trial in Rotorua is described by Richardson et al (1996). The Eyrewell trial consists of a factorial design with three treatment factors – weed type, fertiliser and irrigation. The trial was planted in 1992 in compartment 23/10, Eyrewell forest.

The irrigation and fertiliser treatments effectively created four soil nutrient and water availability environments:

- low-water, low-nutrient (unirrigated and unfertilised)
- low-water, high nutrient (unirrigated and fertilised)
- high-water, low-nutrient (irrigated and fertilised)
- high-water, high-nutrient (irrigated and fertilised)

Within each environment, six different weed species or mixtures of weeds were planted and maintained:

- no weeds
- broom
- gorse
- legumes (a mixture in which Maku lotus became dominant)
- voluntary weeds
- grass

Radiata seedlings were planted at 1.5 metre spacings (4444 stems/ha). Weed treatments were applied to 5x5 tree plots, with the inner nine trees monitored, and the outer trees used as buffers. The trial contained three replicates of each treatment combination.

The analysis described in this report is based on annual measurements of height and collar diameter carried out every winter for seven years. Analyses of height, diameter, and per hectare stem volumes (estimated from diameters and heights), were performed.

Weed-free treatments

Sigmoidal growth curves were fitted to the height, diameter and volume measurements for the no-weed treatments in each of the four environments (Figs. 1-3). Irrigation gave significantly better growth in volume, diameter and height, particularly after age 3. There was a somewhat lesser, but still highly significant response to fertilizer for volume and diameter, but not height growth. The combination of both fertilizer and irrigation gave a particularly strong response. These results indicate that the site is well below the optimum for radiata in terms of both moisture and nutrient supply.

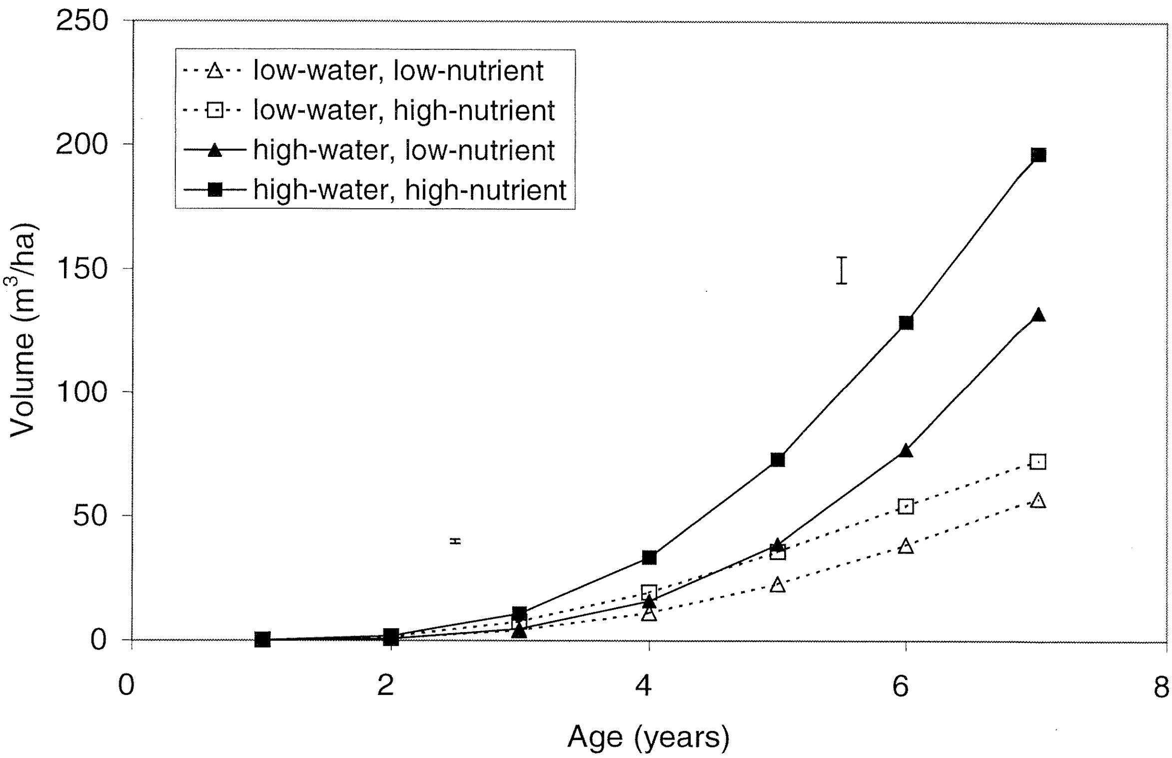

Figure 1. Stem volumes in weed-free treatments. Least significant differences (LSDs) are shown at two ages in this and subsequent graphs. When differences between lines are greater than the LSD, they are statistically significant at p=0.05.

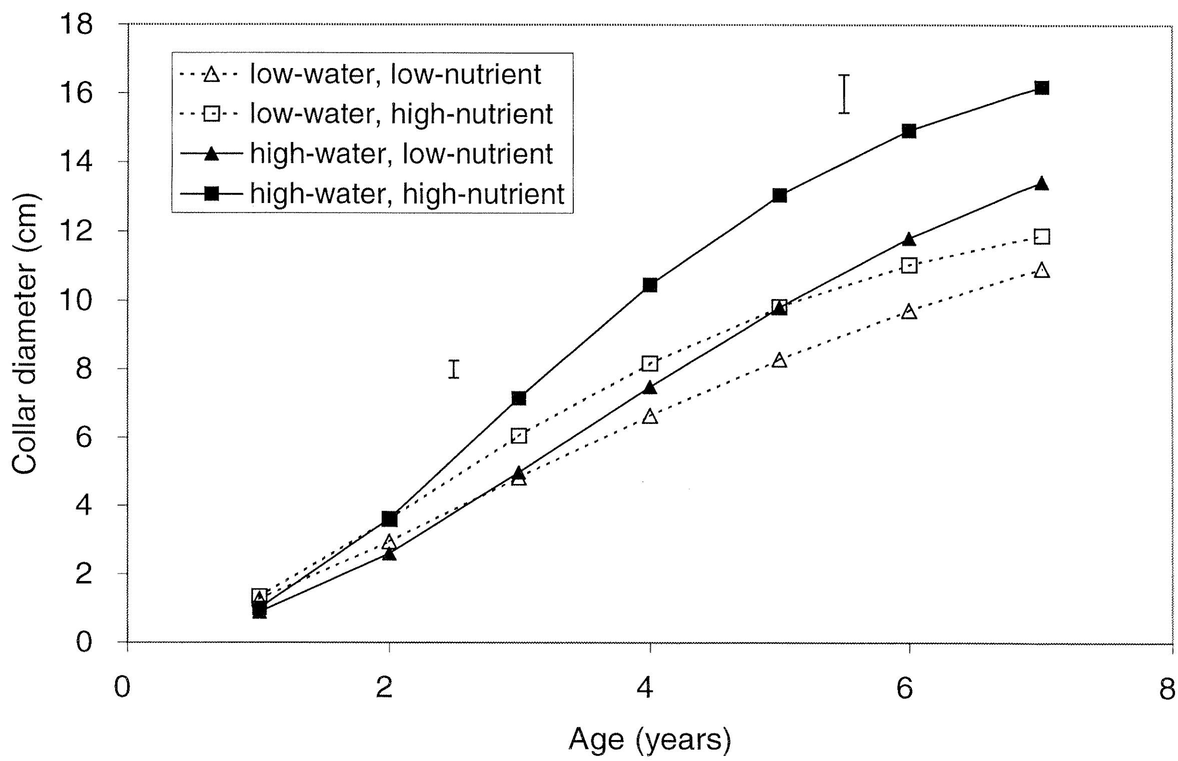

Figure 2. Collar diameters in weed-free treatments.

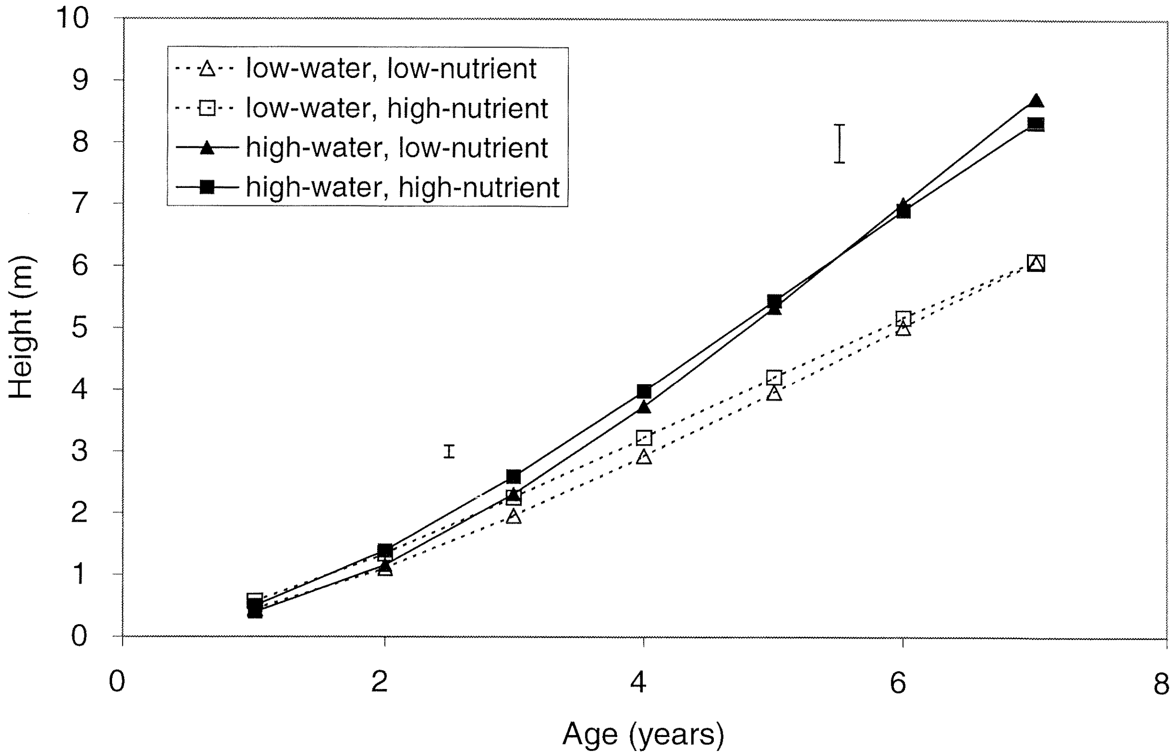

Figure 3. Heights in weed-free treatments.

Competitive effects of weeds

To quantify the competitive effects of each weed treatment, the proportion of growth lost within each year compared with the no-weed plots was calculated annually. By summing these, the cumulative total of years growth lost was calculated. This method of analysis is described in greater detail in Appendix 1.

The results of this analysis for volume are presented here in several ways. The cumulative loss in growth provides a measure of the overall effect of weed competition for each of the four environments is shown in Figs. 4-7. An alternative presentation of the same results is shown in Figs. 8-12 where the four environments are compared for each of the five weed treatments. Although the cumulative losses presented in Figs. 4-12 provide a good idea of the overall effect of weed competition up to a given age, they tend to mask the current level of competition within any individual year. We have therefore also presented the proportion of volume growth lost in each individual year (Figs. 13-16). From these, the age of peak competition, and the age when competition ceases to be significant, can be readily determined. Cumulative growth losses for diameter and height are shown in Appendix 2.

It is possible that for some of the more recent measurements, competition from trees in neighbouring plots (for example, shading), may have affected tree growth, particularly of severely suppressed trees. This could exaggerate the apparent competitive affects of weeds somewhat although it will have been largely controlled by the buffer trees surrounding each plot.

The results are briefly summarised below:

- Growth loss was generally greater in the fertilized plots (Figs 5 & 7), and lower in the unfertilized plots (Figs 4 & 6). This was particularly true of grass (Fig 12), voluntary weeds (Fig 11), legumes (Fig 10) and, to a lesser extent, gorse (Fig 9).

- The effects of irrigation on weed competition were less marked than the effects of fertilizer. Irrigation reduced the competitive effect of grass (Fig 12), voluntary weeds (Fig 11) and legumes (Fig 10), but had little effect on gorse (Fig 9) or broom (Fig 8).

- Grass, legumes and voluntary weeds generally behaved similarly, with fertilizer strongly increasing their competitive effects, and irrigation slightly reducing it (Figs 10, 11 & 12). Competition from gorse was increased by fertilizer, but not affected by irrigation (Fig 9). Broom produced its most severe competition in the irrigated, unfertilized plots (Fig 8).

- In the fertilized plots, losses were greatest for grass and voluntary weeds (Figs. 5 & 7). Competition from all weed types remained intense at age 7, with 3 to 4 years' growth lost to competition, although there was some evidence of a lessening in competition in the irrigated, fertilized plots (Fig 7).

- In the unfertilized plots there was generally only 1 to 2 years' growth loss by age 7. Competition from grass and legumes had largely ceased by about age 4 (Figs. 4 & 6). Competition from other weeds continued longer but was generally diminishing by age 7. The exception was broom, which had a continuing severe effect on growth at age 7 in the irrigated, unfertilized plots (Fig. 6).

- Competition from grass, legumes and voluntary weeds all peaked at ages 2-3 across all environments and subsequently diminished. Gorse competition peaked at ages 3-4 and declined only slowly thereafter. Broom has no clear peak age of competition, and showed little reduction in competition at age 7 (Figs 13-16).

Figure 4. Years volume lost to weed competition, low-water, low-nutrient environment.

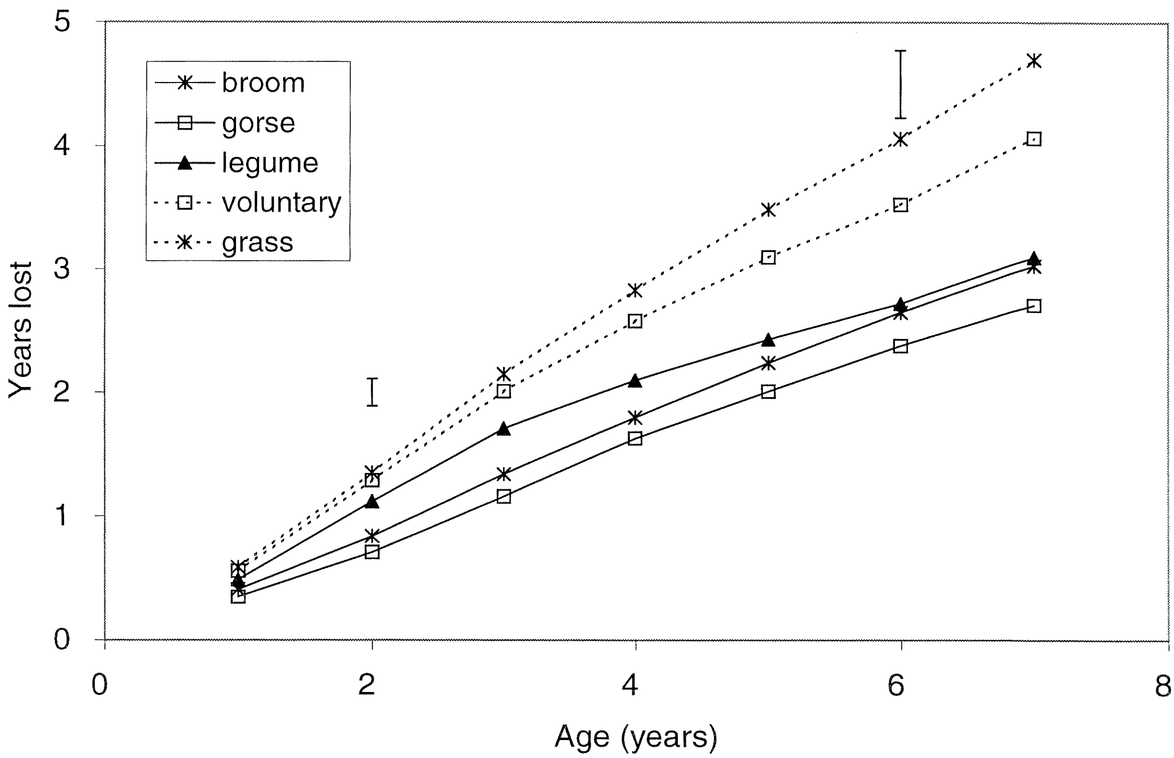

Figure 5. Years volume lost to weed competition, low-water, high-nutrient environment.

Figure 6. Years volume lost to weed competition, high-water, low-nutrient environment.

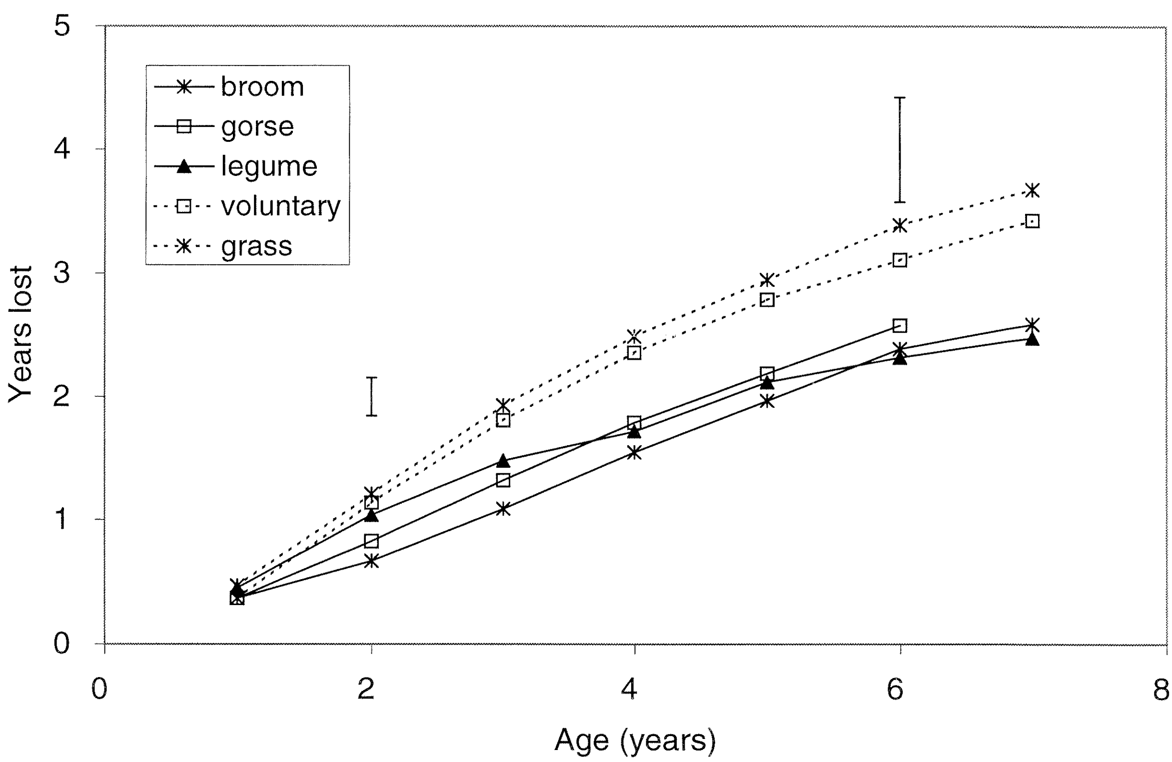

Figure 7. Years volume lost to weed competition, high-water, high-nutrient environment.

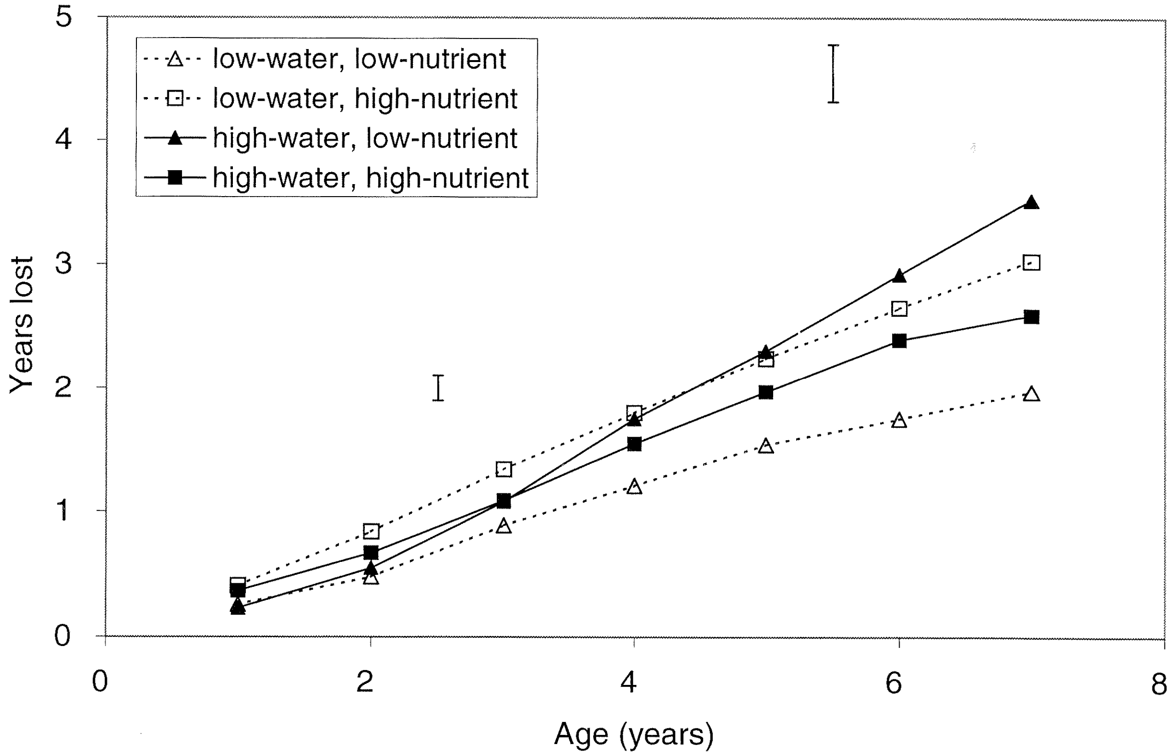

Figure 8. Years volume lost to competition from broom.

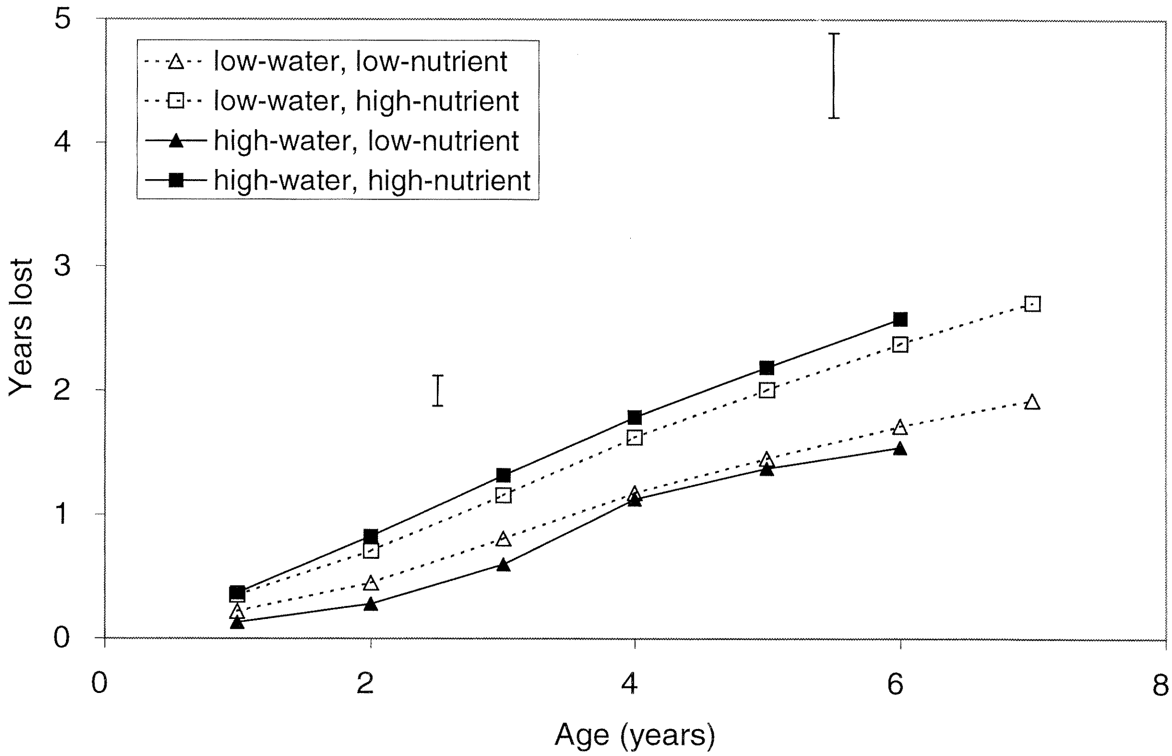

Figure 9. Years volume lost to competition from gorse.

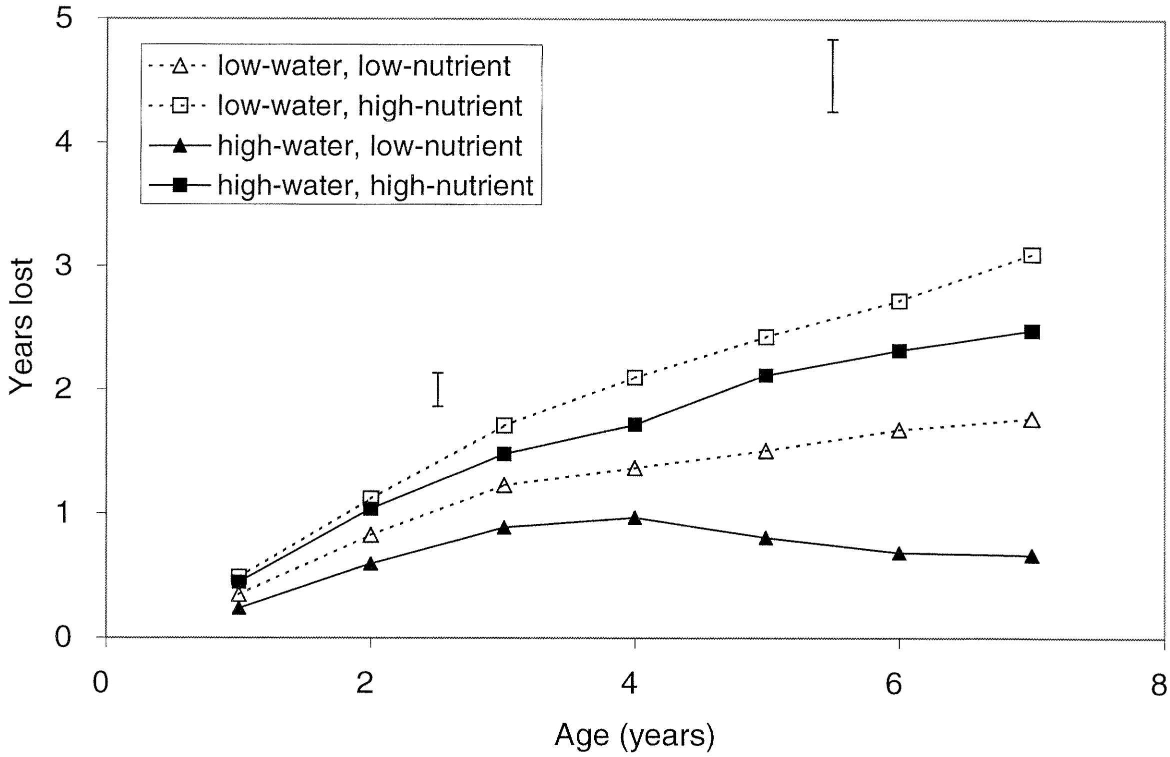

Figure 10. Years volume lost to competition from legumes.

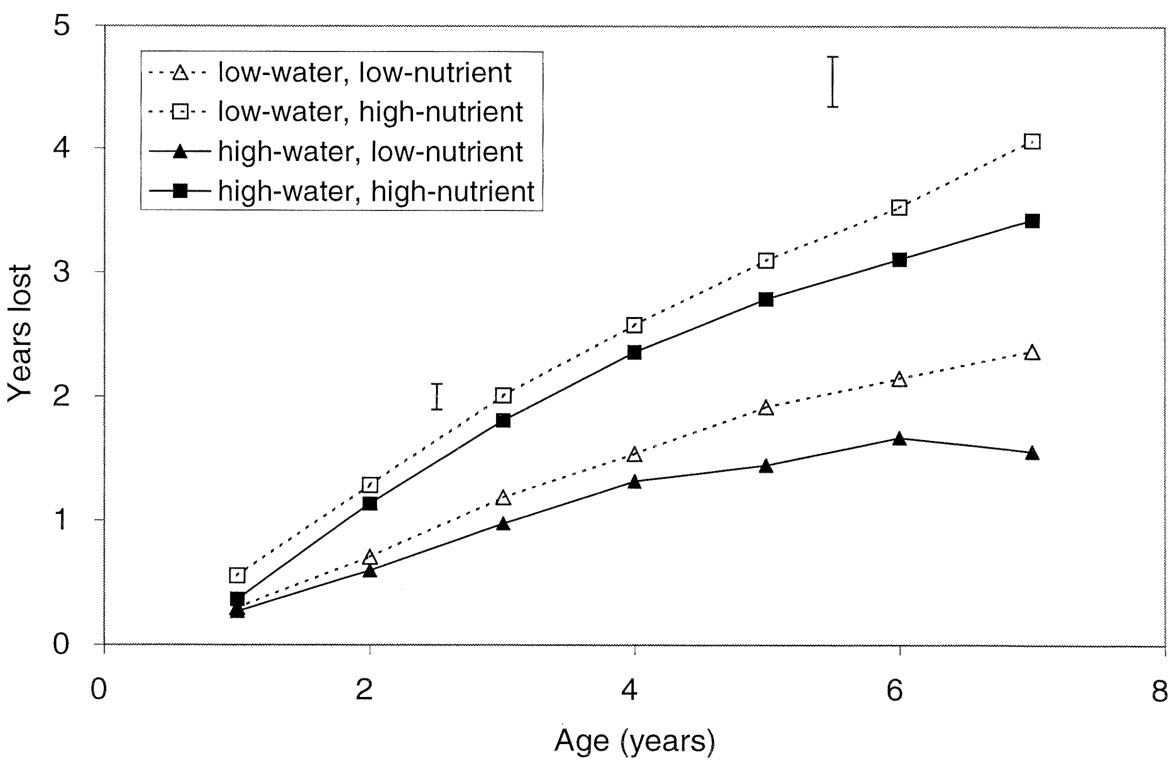

Figure 11. Years volume lost to competition from voluntary weeds.

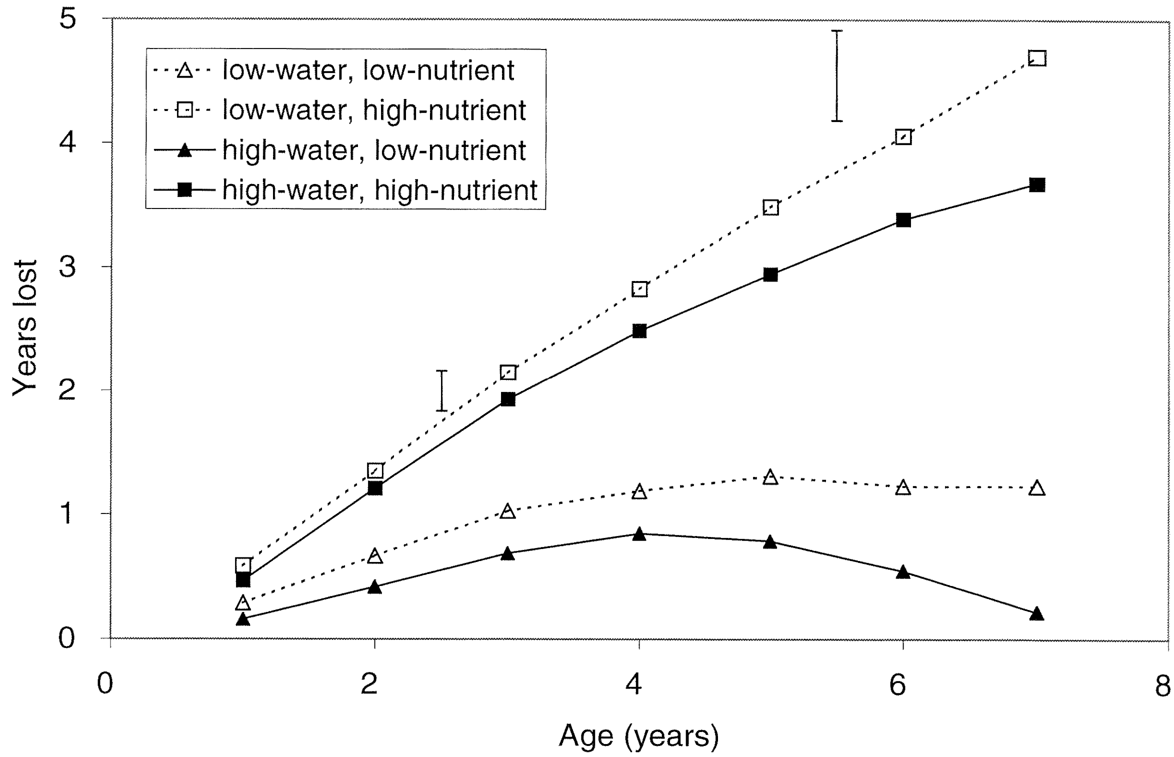

Figure 12. Years volume lost to competition from grass.

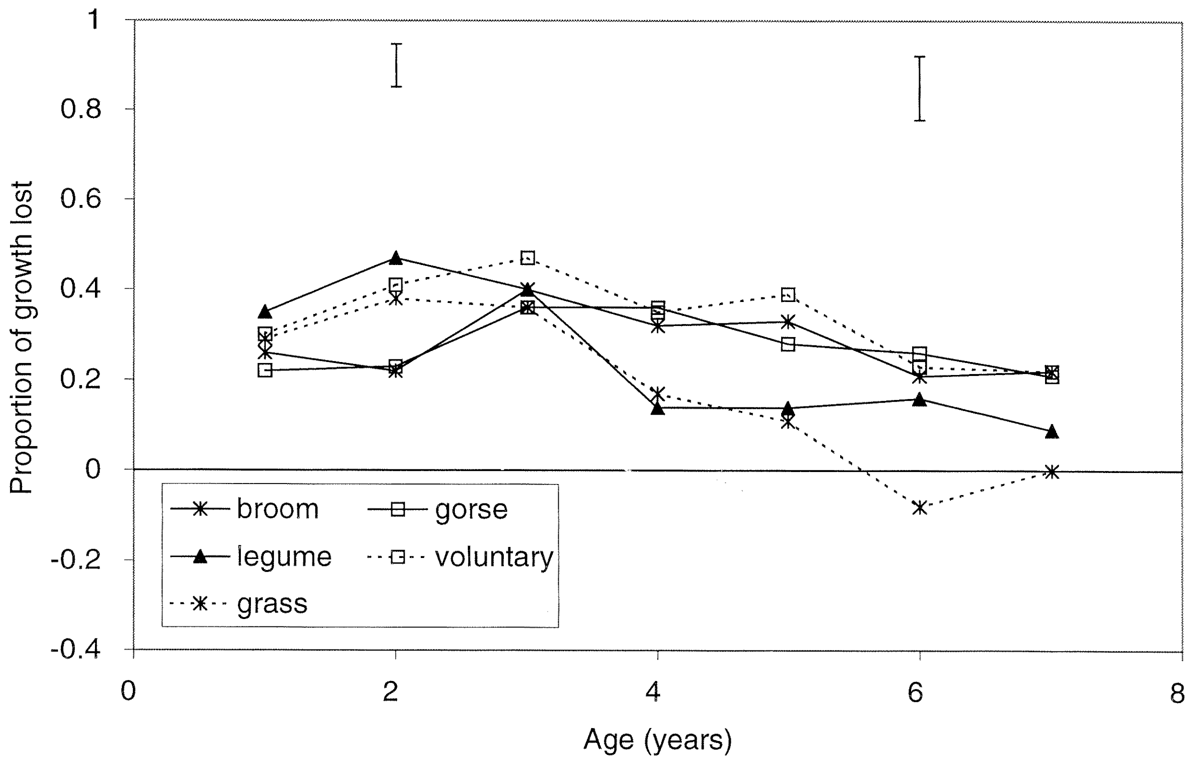

Figure 13. Annual proportion of volume growth lost, low-water, low-nutrient environment.

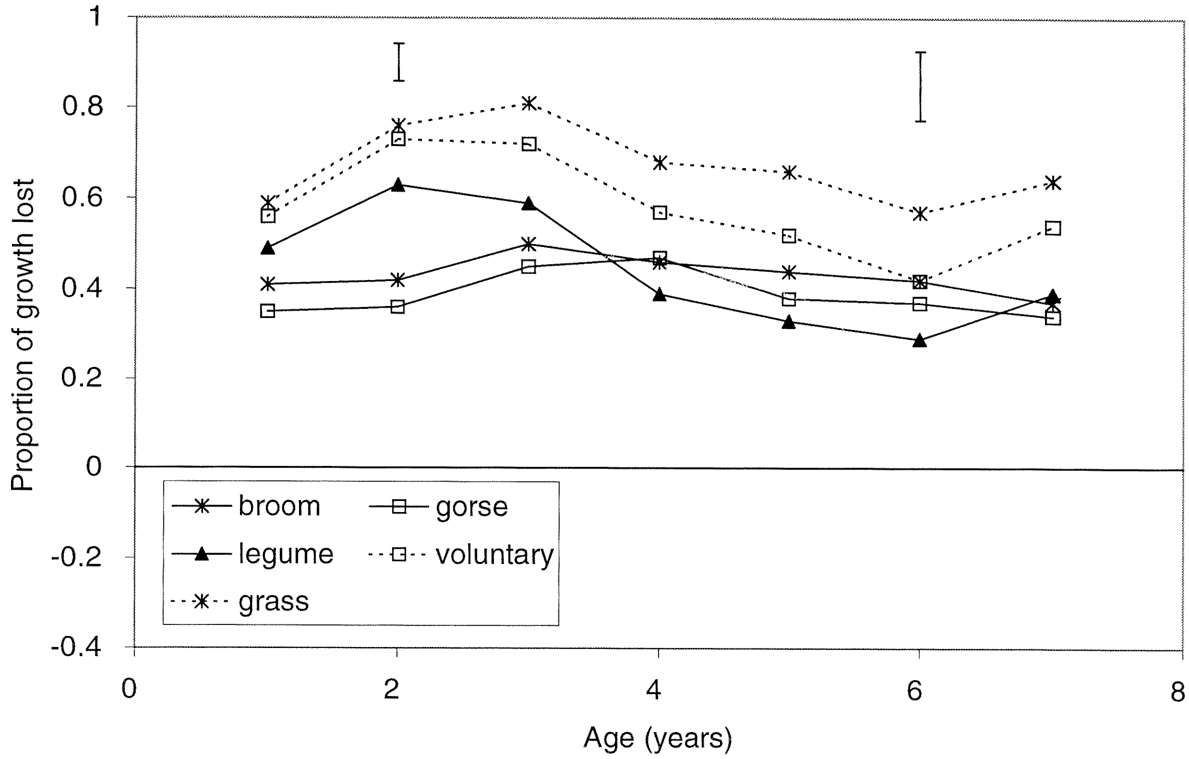

Figure 14. Annual proportion of volume growth lost, low-water, high-nutrient environment.

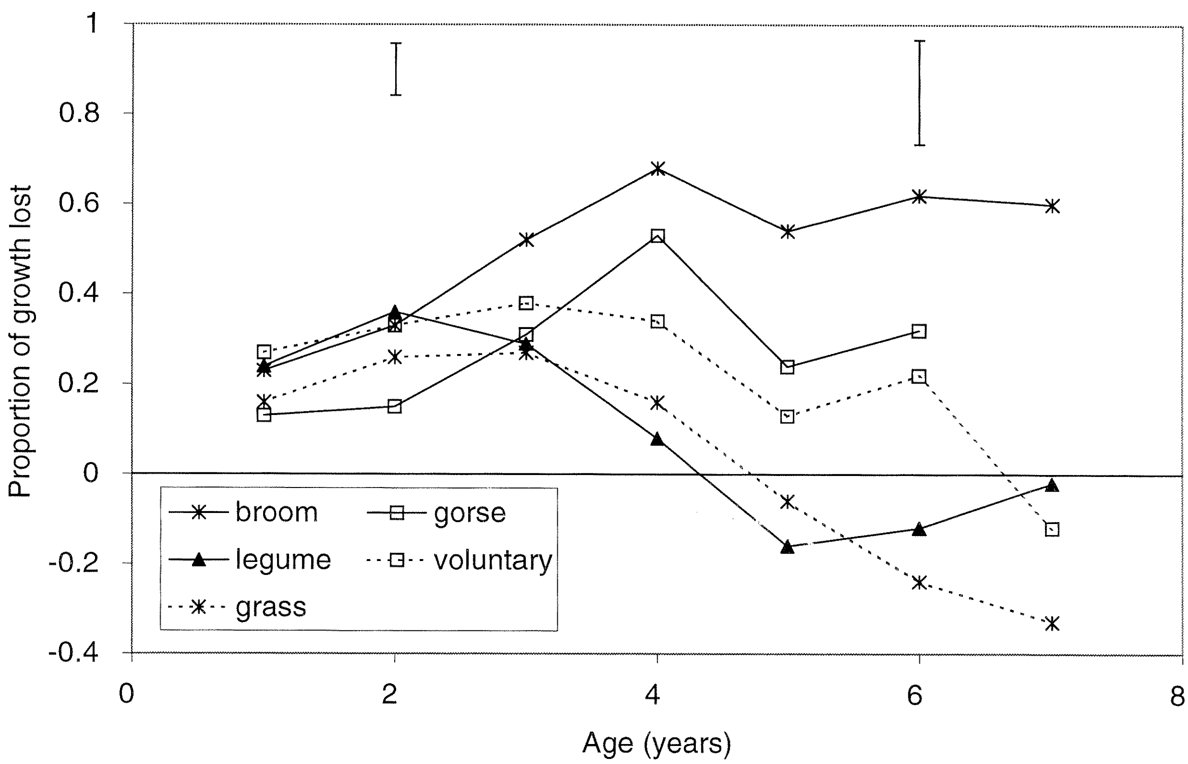

Figure 15. Annual proportion of volume growth lost, high water, low-nutrient environment.

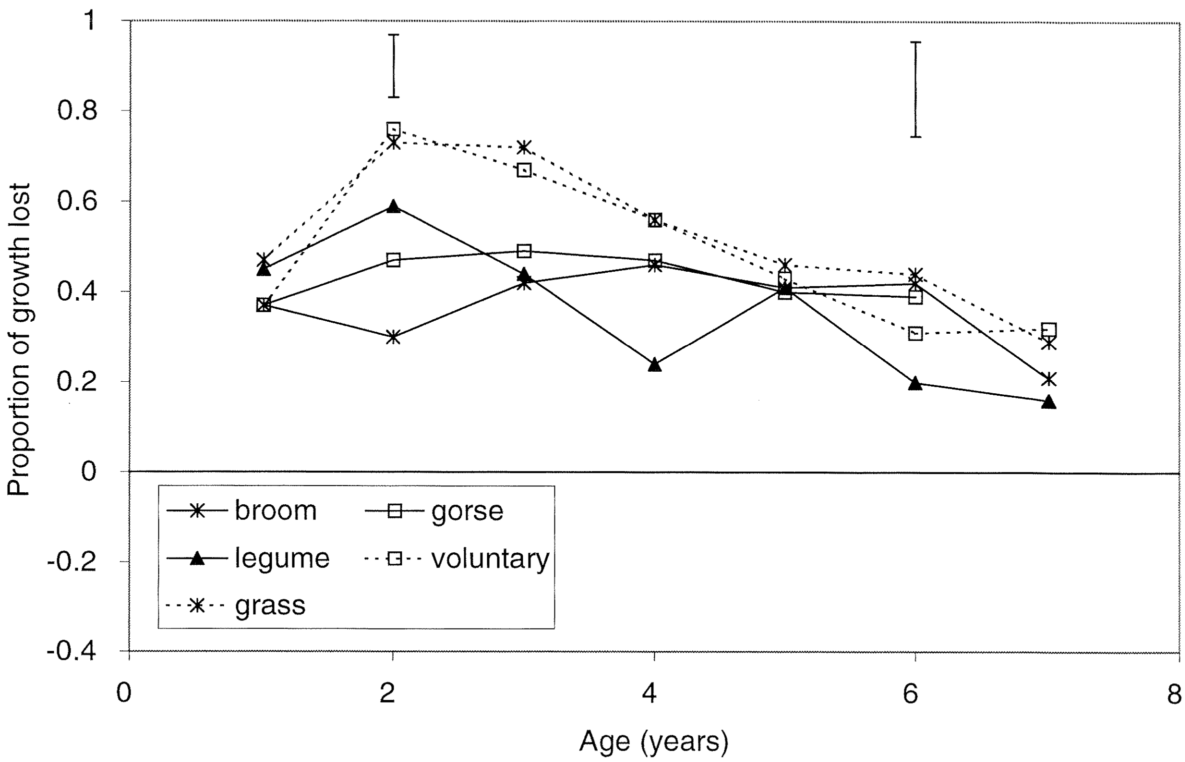

Figure 16. Annual proportion of volume growth lost, high water, high-nutrient environment.

References

Clinton, P.W.; Sun, O.J.; Payn, T.W.; Leckie, A.C. 1997: Impacts of understorey vegetation on growth and foliage chemistry of four-year-old radiata pine. *New Zealand Forest Site Management Cooperative Report No. 89.*

Richardson, B; Vanner, A; Ray, J; Davenhill, N.; Coker, G. 1996: Mechanisms of *Pinus radiata* growth suppression by some common weed species. *New Zealand Journal of Forestry Science* 26: 421-37.

Appendix 1. Methods used for analysing weed competition effects on tree growth.

The analysis described in this report used annual measurements of height and diameter. Diameters were measured at collar height up to age 5, and thereafter at breast height. A linear regression based on the age 5 collar and breast height diameters, was used to estimate collar diameter for ages 6 and 7 in order to maintain consistency over the entire measurement period. Under-bark stem volumes of trees were estimated using a simple relationship suggested by P. Beets (pers com), $V = 0.25D^2H\pi/4$. These were summed over surviving trees in each plot to give per hectare volume estimates.

We assumed that the growth variables follow the Chapman-Richards growth function for the weed-free plots in each of the four environments:

$$y = a + b\left(1 + e^{-ct}\right)^d$$

where *y* is height, diameter or log(volume), and *a*, *b*, *c* and *d* are equation parameters. The first step in the analysis was to fit this equation using nonlinear regression, to each of the weed-free plots.

An important aspect of this equation, is that the parameter *c* is a time scale multiplier. For example, if *a*, *b* and *d* are held constant but *c* is halved, *y* will take twice as long to reach a given value.

The Chapman-Richard function can be expressed as a difference form in which *y* at time *i* is predicted from *y* at time *i*-1 as follows:

$$y_i = a + b\left(1 - \left[1 - \left\{\frac{y_{i-1} - a}{b}\right\}^{1/d}\right]e^{-c}\right)^d$$

from which *c* can be expressed:

$$c = \ln\left(1 - \left\{\frac{y_{i-1} - a}{b}\right\}^{1/d}\right) \Big/ \ln\left(1 - \left\{\frac{y_i - a}{b}\right\}^{1/d}\right)$$

Now, it is reasonable to assume that *c* should fluctuate slightly from year to year to account for annual variations in growth. It can also be assumed that the competitive effect of each weed type can be accommodated by a modification to *c*, and that this weed effect will probably vary from year to year. Thus, within each of the experimental blocks and environment types in the trial it would seem reasonable to modify *c* as follows:

$$c_{ij} = c(1 + a_i)(1 + w_{ij})$$

where a_i is the annual growth affect in the i_{th} year (averaging about zero), and w_{ij} is the competitive affect of the j_{th} weed type in the i_{th} year. The w_{ij} terms will generally fall between 0 and 1. A value of zero signifies no competition, and a value of one, severe competition (in fact zero growth).

We estimated values of a_i for each weed-free plot using:

$$a_i = \ln\left(1 - \left\{\frac{y_i - a}{b}\right\}^{1/d}\right) \Big/ \ln\left(1 - \left\{\frac{y_{i-1} - a}{b}\right\}^{1/d}\right) - 1$$

For each weed competition plot we now estimated w_{ij} using:

$$w_{ij} = \ln\left(1-\left\{\frac{y_i - a}{b}\right\}^{1/d}\right) \Bigg/ (1+a_i)\ln\left(1-\left\{\frac{y_{i-1} - a}{b}\right\}^{1/d}\right) - 1$$

with the value of a_i being obtained from the weed-free plot in the same experimental block.

The values of w_{ij} give the current proportion of growth lost to competition from the j_{th} weed within the i_{th} year. Means of these values are presented for volume in Figs. 13-16. The estimates of years lost at a given age, were obtained for each plot by summing the w_{ij} values up to and including that age and are presented for volume in Figs. 4-12.

Both current and cumulative losses were subsequently analysed using repeated measures analyses of variance, to test for environment and weed type effects and interactions, and to derive the LSD bars shown in the graphs. This analysis was performed using the SAS procedure PROC MIXED.

The method of analysis presented here has several advantages over more conventional analyses, such as a direct comparison between volumes or volume increments of weed versus weed-free plots. Because the analysis directly computes the effect of weed competition in terms of time lost, the economic effects can be readily evaluated. For example, if the analysis indicates that weed competition will cause three years loss in growth, this will imply that rotation lengths will have to be extended by three years to reach a target tree size or stand volume. Alternatively, tree size and volume will be reduced by the equivalent of three year's growth for a fixed rotation age. The economic consequences of this loss at harvesting should be relatively easy to calculate, and compared with the cost of weed control early in the rotation.

More subtly, the analysis also takes account of the natural growth trajectories of trees. For example, Fig. 1 shows that rate of volume growth in the weed-free plots is continuing to accelerate at age seven. Because of this, even if competition in a weed treatment ceased after a few years, the growth rates in the weed-free plots would continue to be greater than in the weed competition plots, simply because they will have progressed further along their natural growth trajectory for any given age. A simple comparison between volume increments will therefore always suggest that the competition effects continue longer than they actually do. On the other hand, the reverse of this effect could occur if diameter increment is analysed. Diameter growth peaks in the weed-free plots at about ages 3-4 (Fig. 2). An analysis of diameter increments could therefore indicate a spurious convergence in growth between the weed-free and weed competition plots beyond age 4. In contrast, the method of analysis used in this report can directly determine the age of peak competition, and the age at which competition ceases.

Appendix 2. Competition loss graphs for diameter and height.

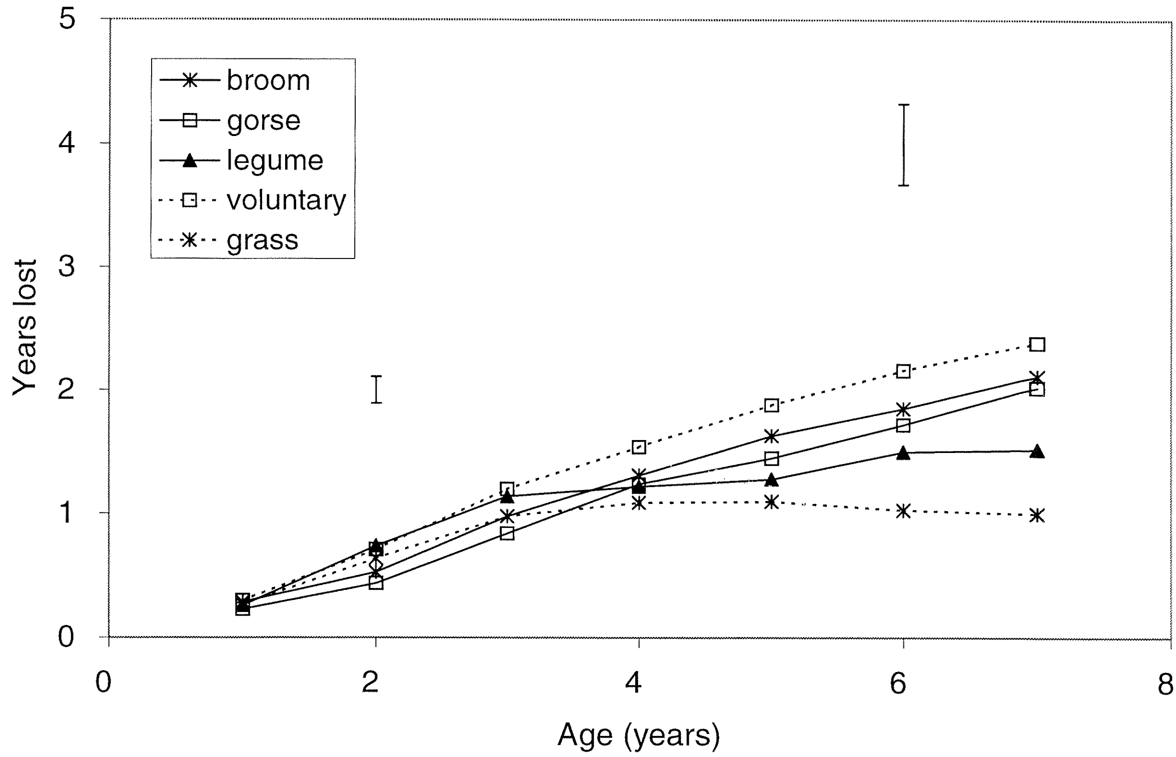

Figure A1. Years collar diameter lost to weed competition, low-water, low-nutrient.

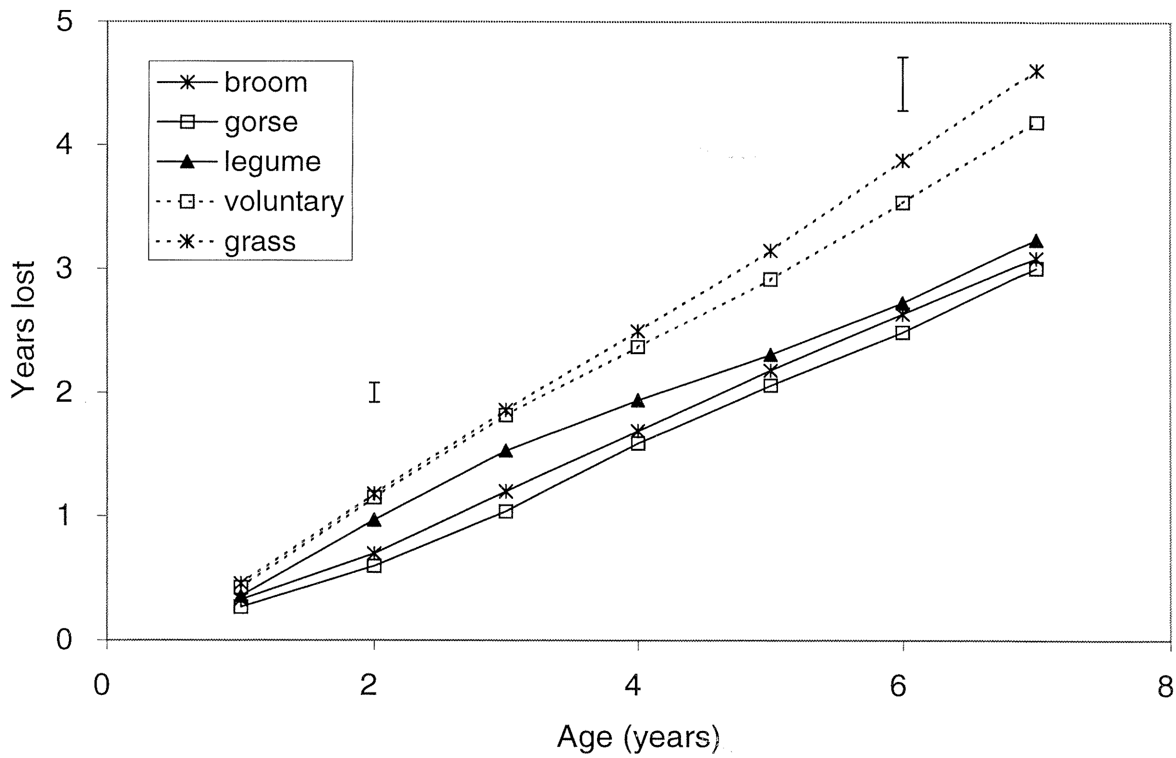

Figure A2. Years collar diameter lost to weed competition, low-water, high-nutrient.

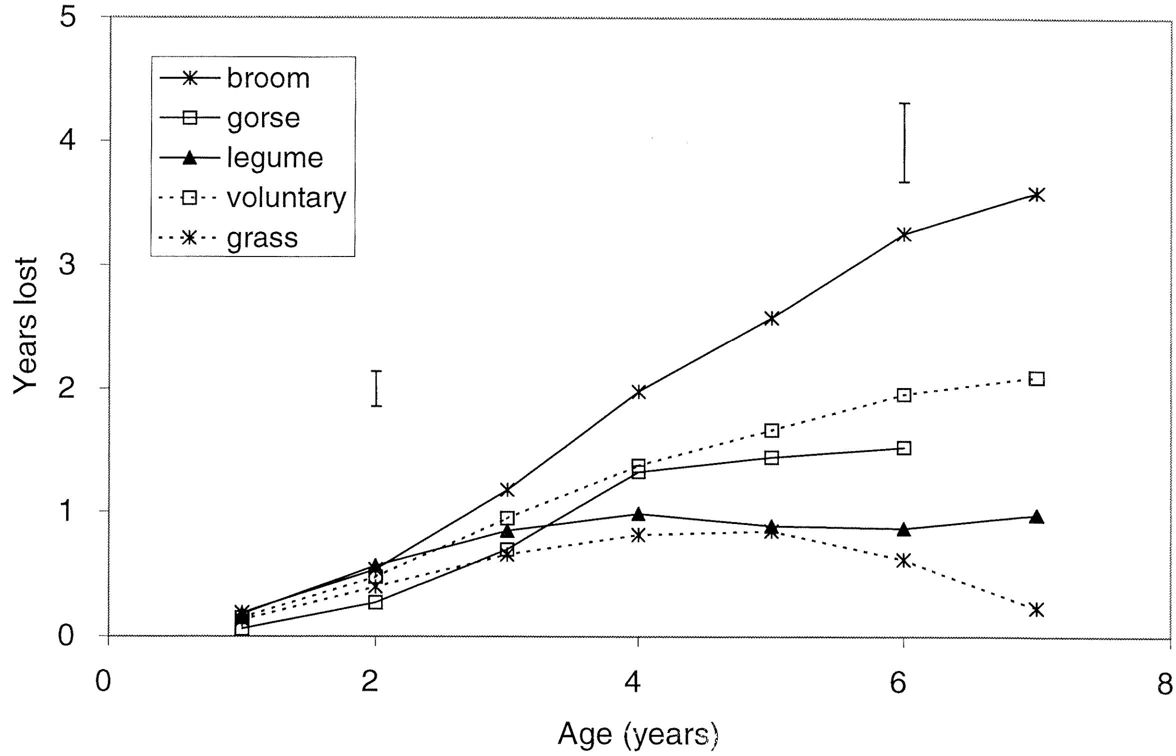

Figure A3. Years collar diameter lost to weed competition, high-water, low-nutrient.

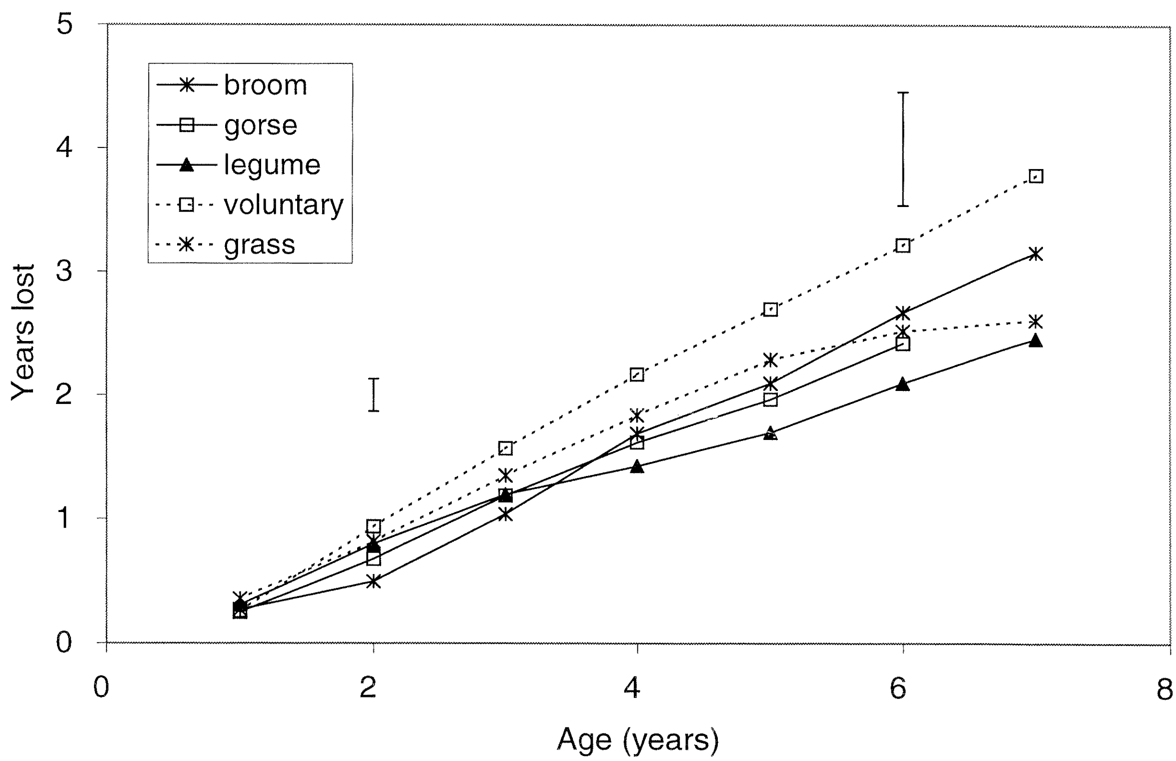

Figure A4. Years collar diameter lost to weed competition, high-water, high-nutrient.

Figure A5. Years height lost to weed competition, low-water, low-nutrient.

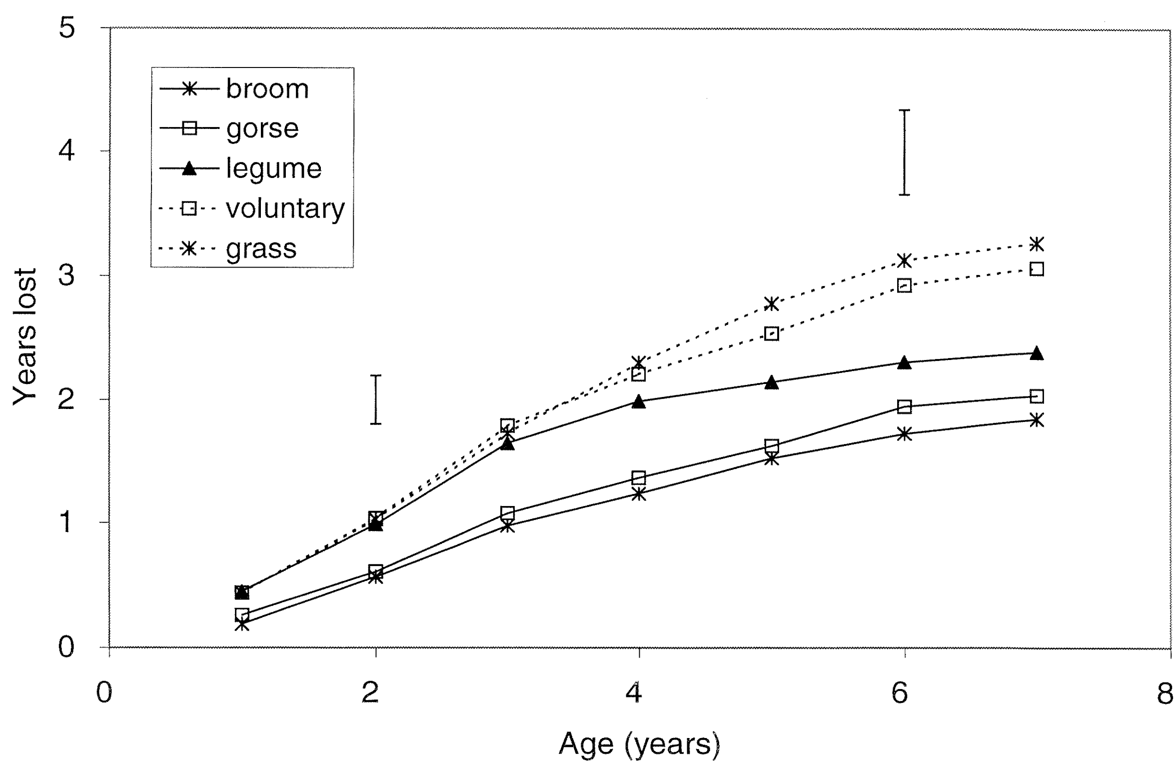

Figure A6. Years height lost to weed competition, low-water, high-nutrient.

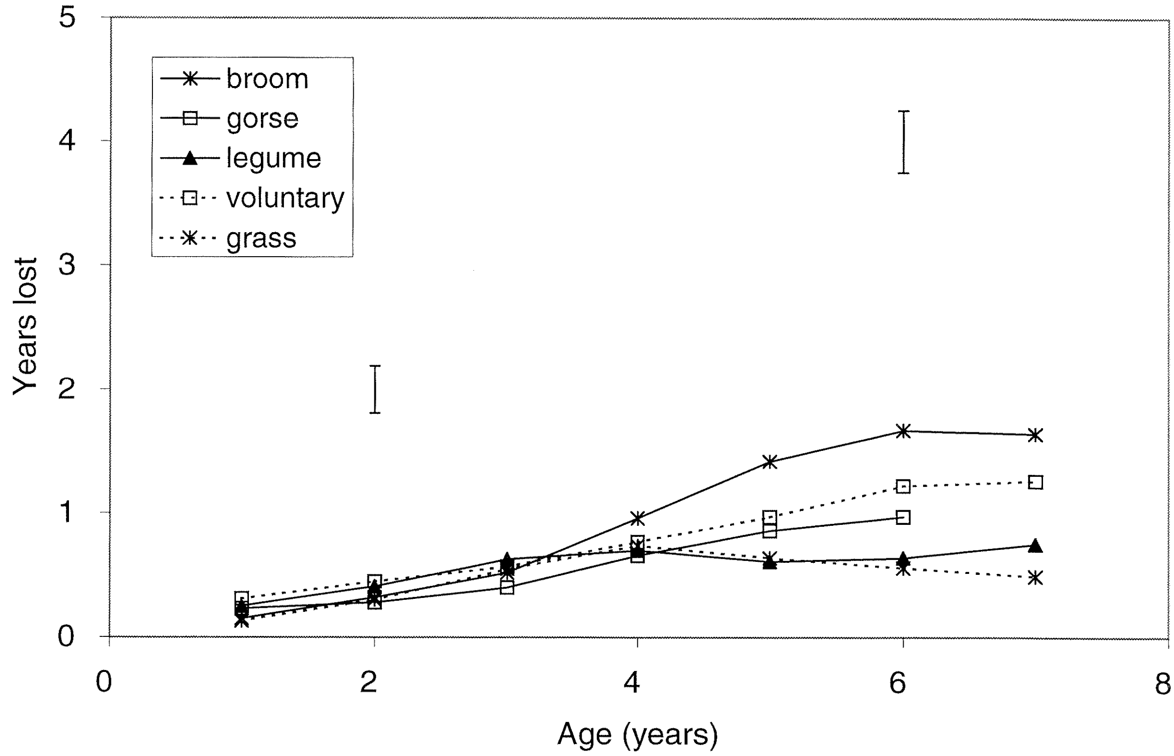

Figure A7. Years height lost to weed competition, high-water, low-nutrient.

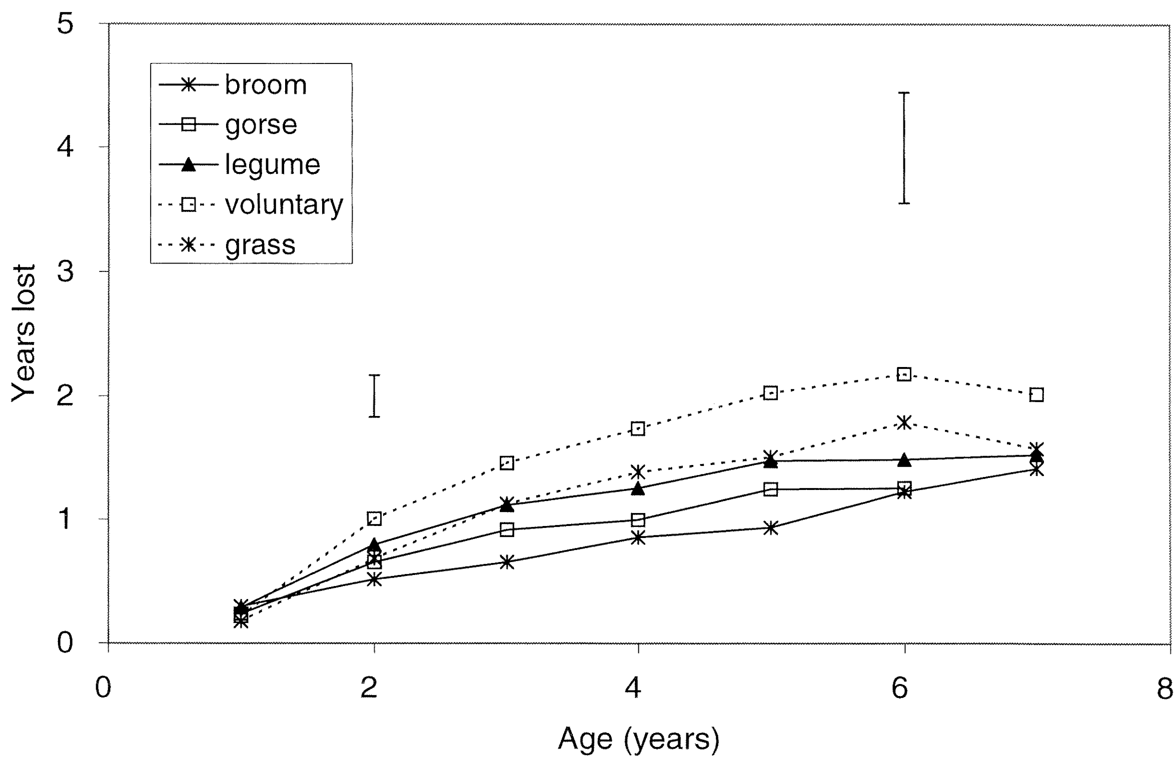

Figure A8. Years height lost to weed competition, high-water, high-nutrient.