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Response to thinning and nitrogen fertiliser six years after treatment in young *Eucalyptus regnans* in Kaingaroa Forest

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NZFRI

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Executive Summary

A trial to quantify the growth response of crop trees (600 s/ha) to thinning and fertiliser was established in a 4-year-old *E. regnans* stand. Preliminary results showed that after one year, thinning and urea treatments interacted to give a large diameter response to the crop tree element. Thinning alone did not significantly increase diameter. There was a significant effect on foliar nutrient levels.

A further assessment 2 years after treatment, showed that the effect of nitrogen on growth increment of the crop element was similar to that of the one year increment. However there was a response to thinning (with or without fertiliser) and height increment was significantly increased by the addition of nitrogen. There was a thinning and fertiliser interaction on diameter and volume but not height. The nutritional status of all treatments 2 years after treatment was similar except for Ca which was lowered where fertiliser and/or thinning had been applied.

Six years after treatment, a third assessment of 4 out of 6 blocks showed statistically significant increases in crop tree basal area increments in the 1990 -1994 period for thinned treatments. There was no benefit from the application of Phosphorus. Six years after treatment, the crop trees that had been thinned and had N applied were 75% larger in volume than the control crop trees, although the main benefit was achieved in the first two years following treatment.

INTRODUCTION

A trial to investigate the effects of thinning and fertiliser on the growth of young *Eucalyptus regnans* was established in 1988 (Knight and Allen, 1990). The object of the trial was to quantify the growth response of crop trees to factorial combinations of thinning and fertiliser in a young *E. regnans* stand at the stage when the stand canopy was almost closed. A crop element of 600 s/ha was selected in a four-year old stand in Cpt 59, Kaingaroa Forest.

METHOD

Trial Design

A randomised complete block design with six blocks and factorial combinations of two levels of stocking, unthinned (about 1667 s/ha) and thinned (600 s/ha) and three levels of urea fertiliser (0, 115, 230 kg N/ha) was established in 1988 in a 4 year-old stand of *E. regnans* in Kaingaroa Forest.

The codes for these treatments are: T_0N_0 T_0N_1 T_0N_2

T_1N_0 T_1N_1 T_1N_2

Where N_0, N_1, and N_2 denote the rate of urea applied (ie 0, 115, 230 kg N/ha respectively) and T_0 and T_1 denote stocking (ie unthinned or thinned).

A supplementary treatment (T_1N_1P) testing the response of phosphorus applied as 'Duraphos' PAPR (75 kg P/ha) in combination with thinning and 115 kg N/ha was included in the trial.

The 19 crop trees (equivalent to 600 s/ha) were assessed in a 18 x 20 m measurement plot within the treatment plot of 30 x 30 m to allow for a buffer. In addition, all remaining trees in the unthinned measurement plots were measured to allow stand growth to be summarised.

History of treatments in trial

Treatments applied and initial measurement: January 1988

Foliage sampling Blocks: 1,3,5: February 1988, March 1990, March 1994.

Trees remeasured: February 1989, February-March 1990, Blocks: 1,2,3,5: March, June 1994.

Foliage samples

In blocks 1, 3 and 5 foliage samples of fully expanded leaves of the current season's growth were collected by shotgun from the upper third of sunlit crowns of 6 dominant trees per plot. Samples were bulked to give 1 composite per plot, oven dried to constant weight and ground sufficiently to pass through a 1 mm screen in a Wiley mill. Subsamples of the ground composite plot samples were digested in sulphuric acid and hydrogen peroxide in the presence of lithium sulphate and selenium. Nitrogen (N) and phosphorus (P) were determined colorimetrically by indophenol blue and vanado-molybdate methods respectively. Potassium (K), calcium (Ca) and magnesium (Mg) were determined by atomic absorption. Boron was determined colorimetrically by a modified curcumin method after dry ashing (Nicholson 1984).

Tree measurements

Diameter at breast height was recorded for all trees in blocks 1, 2, 3 and 5. In each plot the crop element of 19 trees per plot, (equivalent to 528 s/ha) that had been analysed in previous reports were identified and remeasured. In unthinned plots the diameter of the remaining trees were also measured. Heights were measured for trees that had heights recorded at previous assessments, (usually 12 trees).

ANALYSIS

a) Stand growth

Stand parameters were calculated for all plots. Mean tree diameter and basal area corresponded to all trees in the plots. Mean top diameter (MTD) and mean top height (MTH) and volume were calculated using normal mensurational techniques. Tree volume calculated using the *E. regnans* volume function derived for Kinleith Forest, (Hayward, 1987).

b) Crop tree response to fertiliser and thinning.

The mean tree values were based on the same trees for each measurement - trees were removed from the analysis if they did not survive in 1994 or in the case of height values, were not measured on each occasion, for example, due to crown breakage. The analysis of mean tree diameter (cm) and basal area (cm^2) growth was based on the plot mean of the crop trees (19 per plot unless mortality had occurred). The analysis of tree height for each plot was based on the average height of the trees measured in each plot (12 trees per plot unless mortality or breakage occurred). Volume (dm^3) for each tree was calculated using the *E. regnans* volume function derived for Kinleith Forest, (Hayward, 1987). Data collected in 1988, 1990 and 1994 for blocks 1, 2, 3 and 5 were used.

Analysis of variance was undertaken for each plot value for the 1994 measurement. As noted in the previous report (Oliver and Hong, 1991) there were significant differences prior to treatment so for this reason ANOVA of increments in plot mean tree values were used. Least Significant Difference (LSD) test was used to compare treatment means.

In 1994 only 4 of the six blocks were measured, where as previously, all 6 blocks had been measured and analysed. The ANOVA in this report includes only the four blocks measured in 1994. The 1988 and 1990 data were reanalysed using the same four blocks for the periods 1988-1990, 1990-1994 and 1988-1994.

Foliar nutrients

Analysis of Variance was undertaken for all the elements and N/P ratio.

RESULTS

Previous results (one and two years after treatment))

Results from previous analyses have been reported by Knight and Allen, (1990) and Oliver and Hong, (1991). Their analyses were based on six blocks and are summarised here for comparison with the results from the 1994 assessment of four blocks. Detailed results are available in the previous reports. The new results in this report (Appendix 1) are based on a reanalysis of the data collected earlier for the same four blocks measured in 1994.

a) One year after treatment (six blocks)

Preliminary results showed that thinning and urea treatments interacted to give a large diameter response to the crop tree element in the first year after treatment (Knight and Allen, 1990). There was a small but significant increase in crop tree volume growth in the nitrogen fertilised unthinned treatments. Thinning without nitrogen fertiliser did not significantly increase volume. Applying P in addition to N had no additional effect on mean diameter and significantly depressed mean height. The thinning x nitrogen combination stimulated diameter increment at the expense of height growth.

The standard foliage sample collected one month after treatment showed that urea fertiliser had significantly increased foliar levels of N, P, S, Cu and Zn, but had depressed levels of K and Mg. Thinning had significantly decreased levels of Mg and Cl in the foliage.

b) Two years after treatment (six blocks)

The analysis following a second measurement and foliar collection 2 years after treatment (Oliver and Hong, 1991), showed that there was a diameter, basal area and volume response to thinning. Height increment was significantly increased by the addition of nitrogen, but there was no difference between the two nitrogen application rates. There was a thinning and fertiliser interaction on diameter and volume but not height. The higher rate of nitrogen and thinning combined to give 2.5 times the diameter increment of the control (6.3 cm compared with 2.5 cm, Appendix 1, in Oliver and Hong, 1991)).

The nutritional status of all treatments 2 years after treatment was similar except for Ca which was lowered where fertiliser and/or thinning had been applied.

An analysis of the data from all trees in the stand (ie not just the crop element in unthinned treatments) showed that volume increase in the thinned plots with the lower N application rate was 80% of the corresponding unthinned treatment although there was a third the number of stems.

Latest Results - two years and six years after treatment (four blocks)

The following is the new analysis undertaken following the 1994 assessment.

a) Stand growth in 1994 (four blocks).

By 1994 there was an average of 16 % mortality in the unthinned stands but very little in the thinned stands. The stand parameters are shown in Table 1. The greatest stand total tree volume was produced in the unthinned plots (T_0N_0, T_0N_1, T_0N_2): 60 % more volume than the thinned plot without fertiliser (T_1N_0) which had the least volume of all treatments. Thinned treatments with fertiliser (T_1N_1, T_1N_2 , T_1N_1P) produced 30% more volume than the thinned treatment without fertiliser.

Table 1: Stand parameters based on all trees in each plot (blocks 1, 2, 3 and 5) in 1994.

Treatment	Stocking	Mortality since 1988	Mean dbh	MTD*	MTH	Basal area	Volume
	s/ha	%	cm	cm	m	m^2/ha	m^3/ha
T_0N_0,	1618	16	13.1	20.6	19.1	21.8	131.5
T_0N_1	1458	18	13.3	21.1	19.2	19.8	121.7
T_0N_2	1597	15	13.6	21.3	20.5	23.1	139.7
T_1N_0	528	0	17.2	22.0	18.7	12.3	81.2
T_1N_1	514	7	19.9	25.0	20.7	16.0	115.3
T_1N_2	486	5	19.9	25.9	20.3	14.7	102.6
T_1N_1P	514	1	18.9	23.4	19.6	14.6	101.6

*Mean Top Diameter based on 100 largest diameter trees per hectare.

b) Crop tree response to fertiliser and thinning (four blocks).

The plot mean crop tree diameter, basal area, volume and height at age 11 years and increments for, the first two years (age 4.5-6.5) after treatment, following 4 years and the combined 6 years are shown in Appendix 1. Plot mean crop tree diameter and volume increments for age 4.5 - 11 years are shown in Figures 1 and 2. ANOVA on the increment of plot means showed a highly significant difference for treatment effect for tree diameter, basal area and tree volume ($P>0.001$). There was no significant difference for any treatment in height increment. Means that significantly differ in any column are indicated by letters (LSD test).

The increments of diameter, basal area and volume for the period 1988-1994 were largest in the treatments that were fertilised and thinned (T_1N_1, T_1N_2, T_1N_1P). These treatments were not significantly different from each other, but for diameter and basal area, were significantly different from all other treatments. Volume increment for T_1N_1P was not significantly different from T_0N_2.

Where differences in increments of the various parameters were significant for the 1988-1994 period, they were mainly a result of growth rate between 1988-1990. For example, whilst the diameter increment of the thinned and unfertilised treatment (T_1N_0) was significantly different to the thinned and fertilised treatment (T_1N_1) for the period 1988-1994 and for the period 1988-1990, the increment in the 1990-1994 period was not significantly different.

In a second example the situation is reversed. The diameter increment of trees in the thinned and unthinned treatments with no fertiliser, (T_1N_0,T_0N_0) were **not** significantly different for the periods 1988-1994 and 1988-1994 but in the period 1990-1994 diameter increment of trees in the thinned treatment (T_1N_0) ranked second of all treatments and was not significantly different to all treatments with thinning and fertiliser (T_1N_1, T_1N_2, T_1N_1P).

There was an interaction between fertiliser and thinning. In the period 1988-1994 the growth of trees (height, diameter, basal area and volume) in the treatment with fertiliser and thinning was greater than the sum of growth in the treatments with fertiliser or thinning alone, in each case compared to the control (Table 2). When combined with thinning, the amount of urea fertiliser used in the trial and the addition of P made no significant difference to growth. In 1994 the crop tree volumes in the treatments with thinning and N fertiliser were almost 200 dm^3 compared with 113 dm^3 for the control treatment. For a crop tree element of 600 s/ha, this corresponds to 119 m^3/ha compared to 68 m^3/ ha, a difference of 51 m^3/ ha or 75%.

The mean concentrations of foliar elements in 1994 are shown in Appendix 2. There were no statistically significant differences between treatments.

Table 2: Increase in growth of a)the treatment with thinning and fertiliser combined (T_1N_1) and of b) the sum of the two treatments with thinning and fertiliser applied separately (T_0N_1,T_1N_0), when compared with growth of the control (T_0N_0) over the period 1988-1994.

	Tree diameter increase (cm)	Tree height increase (m)	Tree basal area increase (cm^2)	Tree volume increase (dm
a) Thinning and fertiliser combined (T_1N_1)	4.2	1.6	116.9	85.8
b) Sum of thinning and fertiliser (T_0N_1 + T_1N_0)	2.6	0.4	53	15.5

DISCUSSION

The reduction in the number of blocks measured reduced the effectiveness of the 1994 remeasurement in detecting statistically significant differences so that the results were slightly different to the previous report (Oliver and Hong, 1991). For example, whilst the range of plot means for tree height increments from 1988-1990 was 3.6 to 4.7 for 6 blocks and statistical differences were detected, in the new analysis of 4 blocks the means ranged from 3.6 to 4.4 and no differences were detected.

In the 1990 -1994 period there were statistically significant increased increments in basal area and volume, compared to increments of controls, where fertiliser and thinning had been combined when the plots were treated in 1988. This results differs from that found by Messina (1992) in a 7-year-old *E. regnans* stand thinned to 150 and 350 s/ha with applications of 230 and 460 kg N/ha where no interaction between fertiliser and thinning was found 2.5 years later.

The beneficial effect of thinning was more apparent in the assessment six years after treatment. It is possible that the benefit of fertiliser could be insignificant by harvesting. The plots were too small to give accurate results over a longer time period. Trials that can be measured from time of treatment to time of harvest are required in order to evaluate the gain in the longer term. For a pulpwood crop this could be age 18 years and for a sawlog crop, age 30 years. The financial benefit of any improvement in growth from thinning and fertiliser, each alone and in combination could then be determined.

The fertiliser treatment with the addition of P showed no benefit derived from the additional element being applied at this site but this may not be the case on other sites.

The analysis of foliar nutrients has shown that there are no differences between treatments. This indicates that the treatments did not have much impact on foliar nutrients. The analysis of foliar nutrients as a guide to fertiliser requirements is not well developed. The information gathered can be added to the database of information that is being accumulated for eucalypts in New Zealand.

CONCLUSION

Thinning combined with nitrogen fertiliser treatment improved the growth of the crop element of the stand (600 stems/ha). There was no benefit from the application of Phosphorus at this site. The assessment 6 years after treatment indicated that thinning was having the greatest effect on growth. The relative importance of thinning and fertiliser in promoting growth should be evaluated in larger plots over a longer period of time in order to determine the benefit of the operations.

REFERENCES

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Messina, M. G. 1992: Response of *Eucalyptus regnans* F. muell. to thinning and urea fertilization in New Zealand. Forest Ecology and Management 51 (269-283).

Nicholson, G. 1984: Methods of soil, plant and water analysis. NZ FRI Bulletin No. 70.

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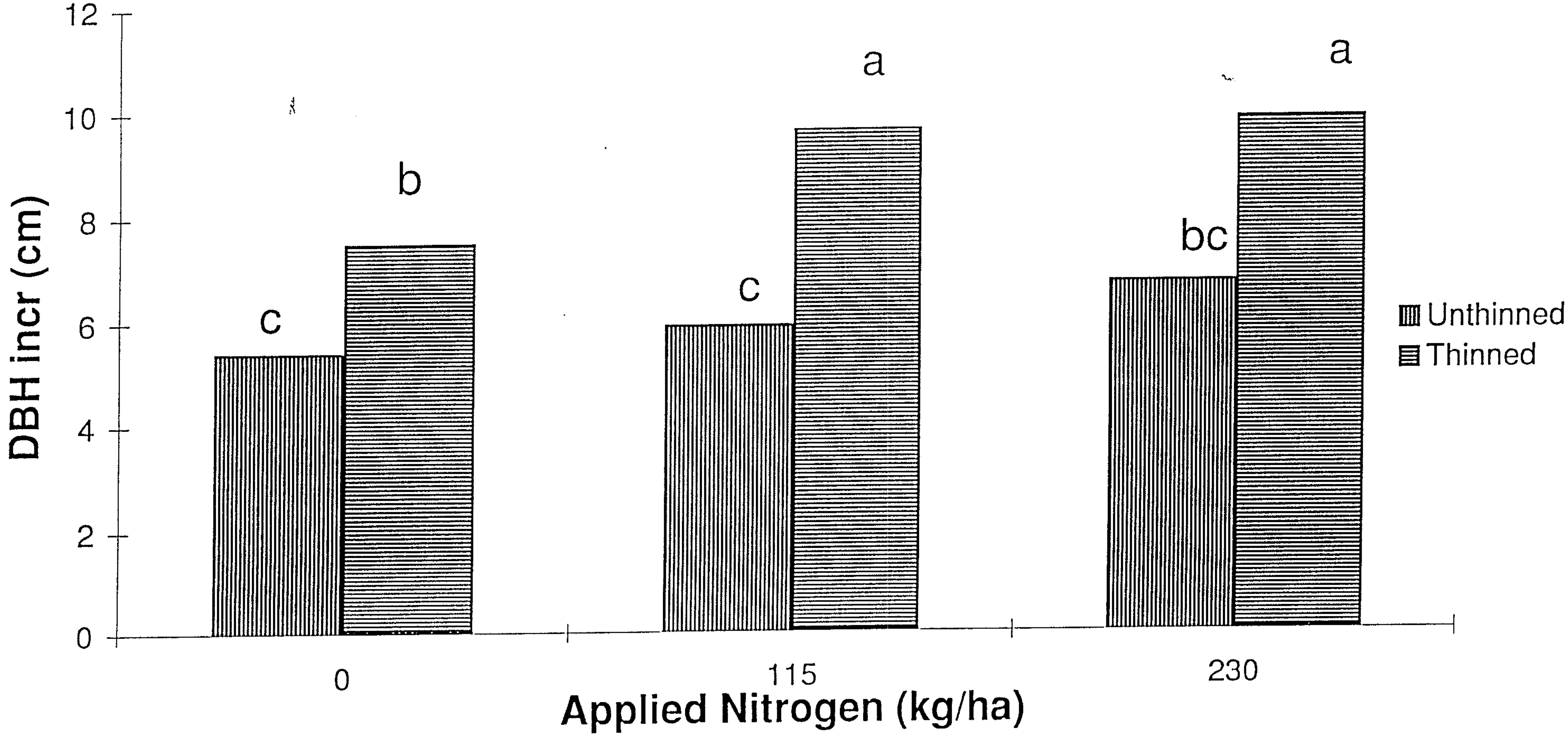
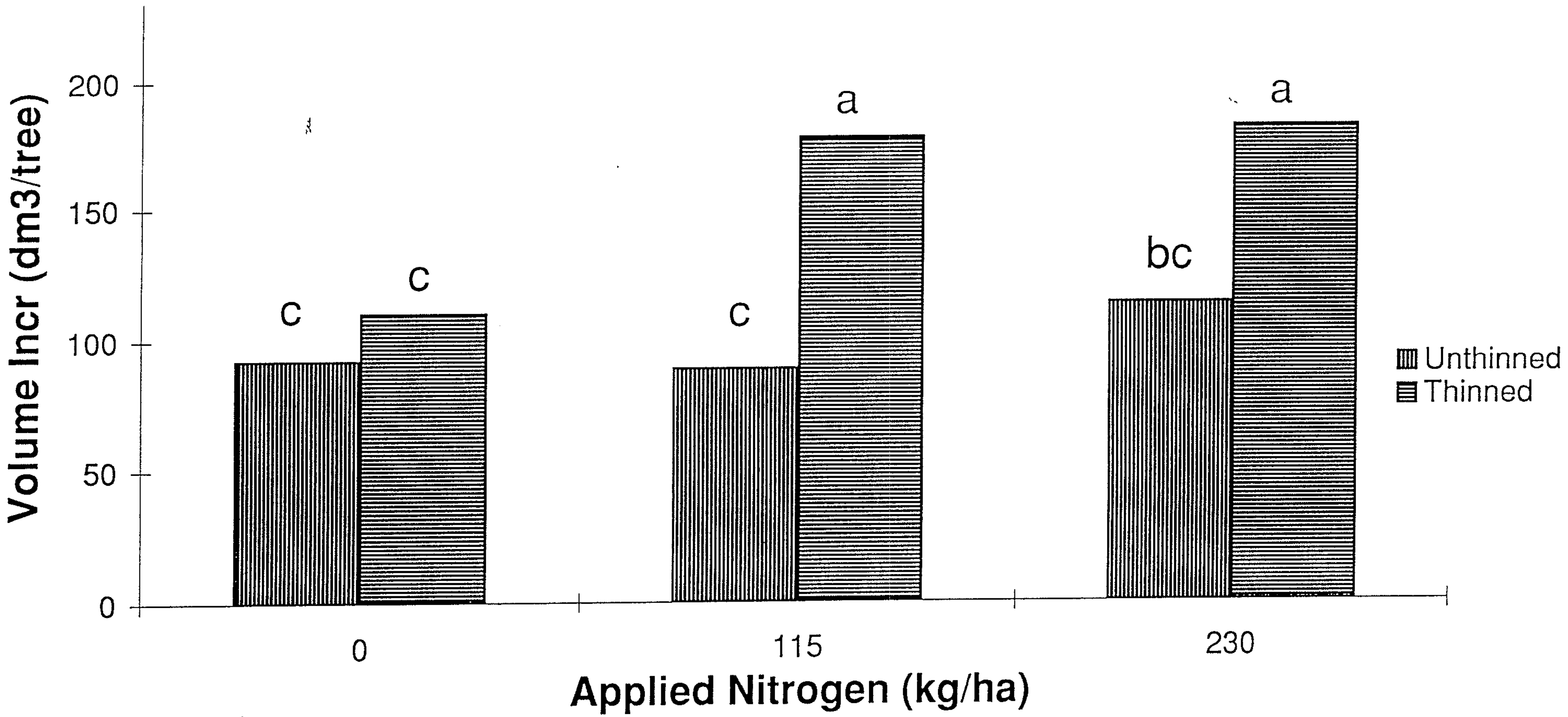
Figure 1: Diameter Increment 1988-94



Treatments with the same letter are not significantly different

Figure 2: Volume increment 1988-94



Treatments with the same letter are not significantly different

Appendix 1: Plot mean tree diameter, basal area, volume and height of crop trees at age 11 years (1994), and increments for 1994, 1988-1994, 1988-1990 and 1990-1994.

Treatment means with the same letter are not significantly different

Mean crop tree diameter (cm)

Treatment	1994	T group		incr 88-94	T group		incr 88-90	T group		Incr 90-94	T group
T_1N_1	19.2	A	T_1N_2	9.8	A	T_1N_2	6.3	A	T_1N_1	4.3	A
T_1N_2	18.8	A B	T_1N_1	9.6	A	T_1N_1P	5.6	B	T_1N_0	4.2	A
T_1N_1P	18.4	A B	T_1N_1P	9.1	A	T_1N_1	5.4	B	T_1N_2	3.6	A B
T_1N_0	16.8	C B	T_1N_0	7.5	B	T_0N_2	4.0	C	T_1N_1P	3.5	A B C
T_0N_2	16.0	C D	T_0N_2	6.7	B C	T_0N_1	3.4	C	T_0N_0	3.1	B C D
T_0N_0	14.9	C D	T_0N_1	5.9	C	T_1N_0	3.3	C	T_0N_2	2.7	C D
T_0N_1	14.7	D	T_0N_0	5.4	C	T_0N_0	2.3	D	T_0N_1	2.5	D

Mean crop tree height (m)

Treatment	1994	T group		incr 88-94	T group		incr 88-90	T group		Incr 90-94	T group
T_1N_1	18.9	A	T_1N_1	10.0	A	T_1N_1P	4.4	A	T_1N_1	5.6	A
T_1N_1P	18.2	A	T_1N_1P	9.5	A	T_1N_1	4.3	A	T_1N_2	5.6	A
T_0N_2	18.2	A	T_1N_2	9.5	A	T_0N_2	4.3	A	T_0N_2	5.1	A
T_1N_2	17.9	A	T_0N_2	9.5	A	T_0N_1	4.1	A	T_1N_1P	5.0	A
T_0N_0	17.2	A	T_0N_1	8.7	A	T_1N_2	3.8	A	T_1N_0	4.9	A
T_0N_1	17.0	A	T_1N_0	8.5	A	T_0N_0	3.8	A	T_0N_0	4.6	A
T_1N_0	17.0	A	T_0N_0	8.4	A	T_1N_0	3.6	A	T_0N_1	4.5	A

Mean crop tree basal area (cm^2)

Treatment	1994	T group		incr 88-94	T group		incr 88-90	T group		Incr 90-94	T group
T_1N_1	304.4	A	T_1N_2	234.4	A	T_1N_2	126.1	A	T_1N_1	123.0	A
T_1N_2	300.6	A	T_1N_1	230.4	A	T_1N_1P	109.6	A B	T_1N_2	108.3	A
T_1N_1P	281.1	A B	T_1N_1P	210.4	A	T_1N_1	107.3	B	T_1N_0	104.0	A
T_1N_0	234.5	B C	T_1N_0	163.5	B	T_0N_2	72.6	C	T_1N_1P	100.8	A B
T_0N_2	211.6	C	T_0N_2	141.0	B C	T_1N_0	59.4	C	T_0N_0	72.2	B C
T_0N_0	187.5	C	T_0N_1	116.5	C	T_0N_1	58.0	C D	T_0N_2	68.4	C
T_0N_1	180.0	C	T_0N_0	113.5	C	T_0N_0	40.8	D	T_0N_1	58.5	C

Mean crop tree volume (dm^3)

Treatment	1994	T group		incr 88-94	T group		incr 88-90	T group		Incr 90-94	T group
T_1N_1	199.9	A	T_1N_2	182.1	A	T_1N_2	64.8	A	T_1N_1	118.8	A
T_1N_2	198.9	A	T_1N_1	177.9	A	T_1N_1P	58.3	A	T_1N_2	116.1	A
T_1N_1P	171.6	A B	T_1N_1P	151.4	A B	T_1N_1	58.0	A	T_1N_1P	92.8	A B
T_0N_2	134.4	C B	T_0N_2	114.4	C B	T_0N_2	42.4	B	T_1N_0	79.4	C B
T_1N_0	130.2	C	T_1N_0	110.4	C	T_0N_1	33.4	B C	T_0N_2	70.8	C B
T_0N_0	113.0	C	T_0N_0	92.1	C	T_1N_0	31.1	B C	T_0N_0	64.9	C
T_0N_1	107.4	C	T_0N_1	89.3	C	T_0N_0	27.3	C	T_0N_1	54.7	C

Appendix 2: Foliar Nutrient levels in 1994

Treatment	N	P	K	Ca	Mg	B	Mn	Zn	Cu	N/P
			%			ppm				
T_0N_0	1.78	0.12	0.76	0.60	0.21	15.0	1608	13.0	5.37	14.8
T_0N_1	1.85	0.12	0.78	0.60	0.20	15.3	1776	14.3	5.50	15.1
T_0N_2	1.83	0.13	0.82	0.56	0.20	15.7	1548	13.7	5.70	14.2
T_1N_0	1.80	0.12	0.80	0.53	0.20	13.3	1226	14.0	5.90	15.1
T_1N_1	1.74	0.11	0.75	0.52	0.18	15.3	1379	13.7	5.30	15.7
T_1N_1P	1.79	0.12	0.82	0.52	0.19	15.3	1323	12.3	5.70	14.5
T_1N_2	1.69	0.12	0.80	0.56	0.19	16.0	1464	12.0	5.50	14.6