

Project Record No. 2610

**THE NITROGEN AND PHOSPHORUS CENTRAL
COMPOSITE SERIES OF TRIALS
RESULTS AFTER SEVEN YEARS**

by

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Report 53

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EXECUTIVE SUMMARY

In 1983 a series of five trials were established at sites throughout New Zealand. The trials were located at Parengarenga, Maromaku, Waimihia, Motueka and Nemona Forests. The trees were aged between 4 and 5 years old, and were kept unthinned and unpruned for the duration of the trial.

The trials used a revolutionary design called a "central composite" to test a wide range of rates of nitrogen and phosphorus fertiliser.

The data presented in this report cover the results to seven years after fertiliser application.

The conclusions to date are:-

1. All sites, except Waimihia, responded to fertiliser.
2. Good responses were achieved with application rates lower than previously tested, indicating that fertiliser rates could be further reduced. However foliage concentrations (1987 data) in the lower rates were lower at the end of the period suggesting that the responses to lower rates might not be as long lived.
3. Parengarenga and Nemona gave better responses when potassium and copper were included in the mix.
4. The trial series results should have a direct impact on fertiliser recommendations for sites similar to these because generally the results indicated multi-element applications at lower rates of any one element were preferable to single element application at the same or even a much higher rate.

THE NITROGEN AND PHOSPHORUS CENTRAL COMPOSITE SERIES OF TRIALS.

RESULTS AFTER SEVEN YEARS.

Introduction

In winter 1983 a series of five trials was established in 4-5 year old, unthinned radiata pine on a range of soil types. These trials were situated at:-

AK976/1, on a podzolised sand in Northern Pulp's Parengarenga Block, Northland.

AK976/2, on a leached to podzolised clay soil in New Zealand Forest Products' Maromaku Block (now Patutahi), west of Whangarei.

RO1889, on a shallow flow tephra from the Taupo erogenic centre in Waimihia Forest, Southern Kaingaroa.

NN518, on a low fertility granite soil in Motueka Forest, Nelson.

WD399, on a "pakihi" site in Nemona Forest, West Coast of the South Island.

The objective of the trials was to determine the effects from applying nitrogen and phosphorus fertiliser to radiata pine growing on soils where radiata pine was expected to respond to these elements.

Methods

Design and Treatments.

The trials were established using a modified "central composite" design. This design tests only a sub-sample of all the possible combinations of fertiliser rates. The central component of the trial is the "best guess" combination of fertilisers, (this we obtained through previous experience). In the case of this trial series, we were sure that 150 kgN/ha and 75 kgP/ha would be our "best guess" central treatment.

The other rates of fertiliser are arranged around the centre in a "star" shape as shown in the following diagram, with a reasonable subset of the possible combinations represented. These range from 0 to 400 kgN/ha and 0 to 200 kgP/ha.

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|-----|------|--------|-------|-------|
| 0 P | | | | | |
| 40 P | | | | | |
| 75 P | | | Centre | | |
| 120 P | | | | | |
| 200 P | | | | | |

The major advantage of this trial design is that it is much smaller than a full factorial. A similar design as a full factorial would result in 25 plots per block which would also need to be replicated, making it very impractical for a field trial. The major disadvantage is that the "best guess" treatment must be picked accurately because the trial design has the highest degree of precision at that point.

In a conventional central composite design there is no control, but for our purposes we included it, as we wanted to be able to quantify the fertiliser response.

The treatment rates were arranged on a scale which is linear in the logarithm of the fertiliser rate. This has the advantage of giving greater weight to lower rates, which had not been widely tested in our previous field experiments.

All the treatments were replicated at least twice, with some treatments being replicated 4 and 8 times, as shown below

These treatments were present at all sites.

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|-----|------|-------|-------|-------|
| 0 P | 4 | | 2 | | |
| 40 P | | 2 | | 2 | |
| 75 P | 2 | | 8 | | 2 |
| 120 P | | 2 | | 2 | |
| 200 P | | | 2 | | |

There were also additional treatments included to test the effect of nutrients that might be marginal at each specific site. This was performed to ensure a response from each site should nitrogen and phosphorus provoke other nutrient deficiencies.

These additional treatments were:-

At AK976/1, AK976/2 and WD399. The central treatment plus 10 kgCu/ha and 80 kgK/ha.

Also at AK976/1 and WD399. The central treatment plus half rates of Cu and K.
Half the central treatment rate plus full rates of Cu and K.
Half the central treatment rate plus half rates of Cu and K.

At RO1889. The central treatment plus 100 kgMg/ha.

At NN518. The central treatment minus the base dressing (applied to all other plots) of 8 kgB/ha.

Materials used.

Phosphorus was applied as food-grade monocalcium phosphate to avoid any contamination of the treatments due to high levels of micronutrients that can be contained in P fertilisers such as superphosphate.

The other nutrients were applied as normal sources *i.e.* nitrogen (urea), potassium (muriate of potash [potassium chloride]), copper (copper sulphate), boron (sodium borate), and magnesium (dolomite).

Data presented.

All the plots in the trial series were measured in 1983 (at trial establishment) , 1984, 1985, 1986, 1987 and finally in 1990. Diameter at breast height was measured on all trees and total heights on a selection of sample trees.

From the growth data the following parameters have been prepared for this report.

- Total stem volume for 1983 (as covariate) and 1990;
- Mean height for 1983 (as covariate) and 1990;
- Basal area for all measurements.

Statistical analyses.

In the past we have analyzed these trials using "response surfaces"; three dimensional pictures of the responses.

For this report a more detailed study was undertaken using an analysis of variance of treatments that have been unevenly replicated. (The statistical program we used was GENSTAT).

Foliage analyses.

Report No. 37 gives a detailed account of the foliage and soil analyses that have been performed on all five sites. The trials are due to be foliage sampled again in 1991, so an update will be available then.

RESULTS.

AK976/1 PARENGARENGA.

The total volume data for this trial shows a significant response to applications of fertiliser (Table 1). The "extra treatments" with potassium and copper applied showed an even greater volume response (between 36% and 53%), compared with that of only nitrogen and phosphorus applied (maximum of 25%).

The "extra treatments" grew between 13% and 27% more than the central treatment, with the half rate of nitrogen and phosphorus producing slightly higher volumes than the full rate of N and P. This shows that addition of these elements is beneficial on a site like this.

The seven year volume response shows the increased volume to the fertiliser application over and above that of the control (Table 2).

Mean height (Table 3) was improved in all plots except the 400N 75P treatment, which showed signs of copper deficiency after fertilisation. The high rate of nitrogen in addition to a low rate of phosphorus, on this particular site, tended to induce an imbalance in the nutrients. This was also shown at Maromaku, but to a lesser degree.

Basal area analysis showed that after seven years the central treatment was 2.5 m²/ha higher than the control and the best treatment at this site (75N 40P + Cu10 K80) was 6.4 m²/ha more than the control (Figure 1).

Table 1. AK976/1 PARENGARENGA.

Total volume (m³/ha) 1990 plot measurements (adjusted for covariate).

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|-------|-------|-------|-------|-------|
| 0 P | 106.6 | | 126.8 | | |
| 40 P | | 131.0 | | 118.3 | |
| 75 P | 133.8 | | 128.6 | | 110.4 |
| 120 P | | 128.3 | | 103.2 | |
| 200 P | | | 113.5 | | |

Extra Treatments:-

150N 75P + Cu10 K80 = 145.0

150N 75P + Cu5 K40 = 157.0

80N 40P + Cu10 K80 = 163.3

80N 40P + Cu5 K40 = 150.2

Table 2. Seven Year Volume Response (m³/ha) (adjusted for covariate).
(Volume 1990 - Volume 1983)

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|------|------|-------|-------|-------|
| 0 P | 0 | | 20.2 | | |
| 40 P | | 24.4 | | 11.7 | |
| 75 P | 27.2 | | 22.0 | | 3.8 |
| 120 P | | 21.7 | | -3.5 | |
| 200 P | | | 6.9 | | |

Extra Treatments:-

150N 75P + Cu10 K80 = 38.4

150N 75P + Cu5 K40 = 50.4

80N 40P + Cu10 K80 = 56.7

80N 40P + Cu5 K40 = 43.6

Table 3. Mean height (m) (adjusted for covariate) for 1990 plot measurements.

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|------|------|-------|-------|-------|
| 0 P | 11.3 | | 11.8 | | |
| 40 P | | 12.2 | | 11.7 | |
| 75 P | 12.6 | | 12.5 | | 11.2 |
| 120 P | | 13.0 | | 11.9 | |
| 200 P | | | 12.1 | | |

Extra Treatments:-

150N 75P + Cu10 K80 = 13.1

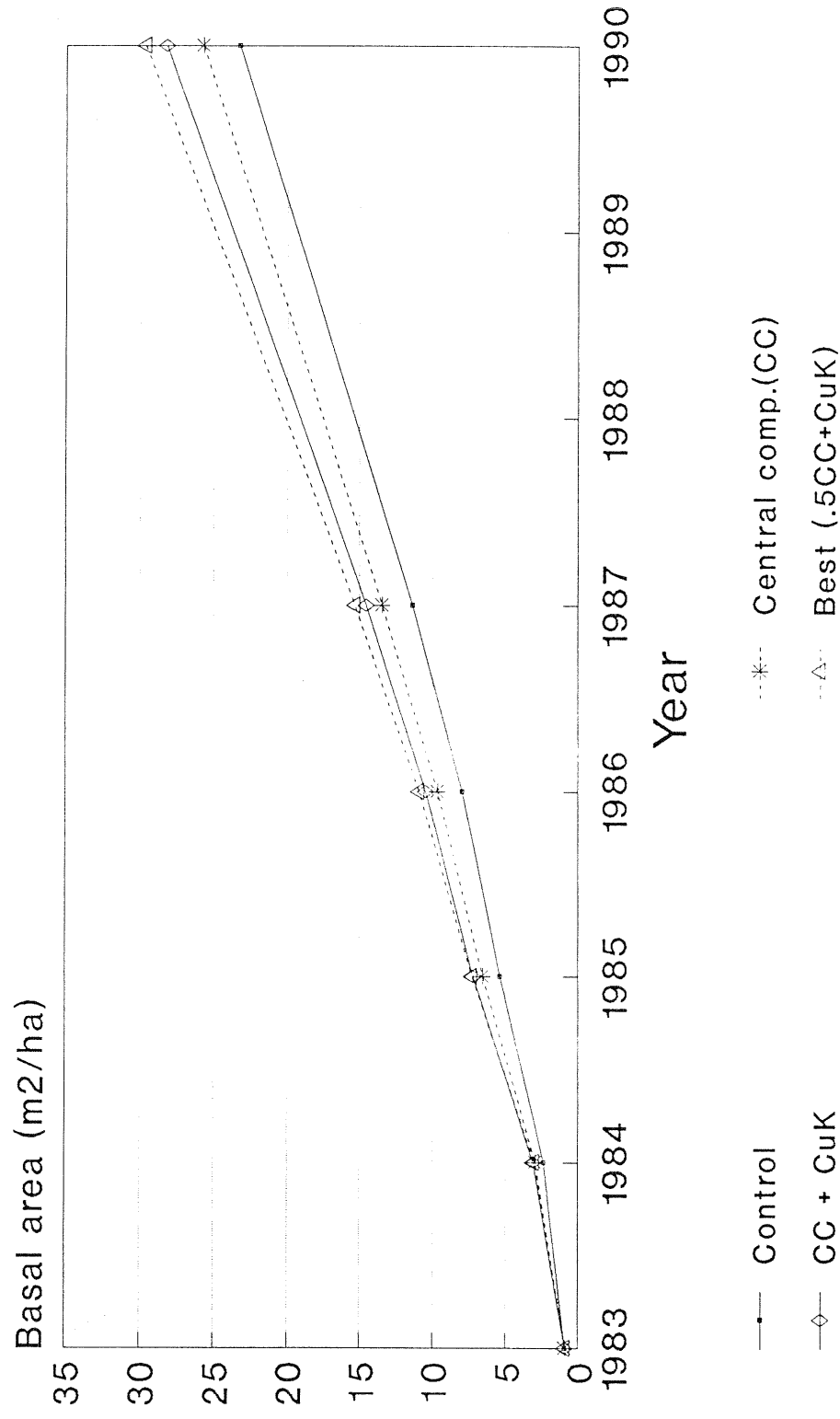
150N 75P + Cu5 K40 = 12.9

80N 40P + Cu10 K80 = 13.8

80N 40P + Cu5 K40 = 13.4

AK976/1 Parengarenga

Basal area (adjusted for covariate)



AK976/2 MAROMAKU

This site had the highest standing volume of all the sites.

The total volume data (Table 4) for this trial shows a response to all fertiliser treatments, except one, with a maximum volume response of 29% to fertiliser in the 150N 200P treatment. The "extra" treatment of copper and potassium showed an additional increase of 9% over the central treatment.

The seven year volume response (Table 5) shows that there was a greater response for the higher applications of fertiliser, but a negative gain to applications of nitrogen alone.

The mean height, relative to the control, had generally increased, but not markedly. The the greatest increase was 2 metres to 80N 120P. It should be noted that due to Cyclone Bola in 1988 there was extensive damage to about a third of the trial. The height trees measured in 1990 were not necessarily the same ones measured previously, and in some plots there were barely enough trees to measure that weren't damaged in some way. This could account for the decrease in height for the 150N 0P treatment. Both replicates of this treatment were damaged and perhaps trees that were previously subdominant were measured for height in 1990.

Basal area showed the central treatment was 4 m²/ha better than the control and "best" treatment (N400 P75) ahead of the control by 7.3 m²/ha after seven years (Figure 2).

Table 4. AK976/2 MAROMAKU.

Total volume (m³/ha) 1990 plot measurements (adjusted for covariate).

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|-------|-------|-------|-------|-------|
| 0 P | 267.0 | | 230.0 | | |
| 40 P | | 296.0 | | 302.0 | |
| 75 P | 268.0 | | 296.0 | | 323.0 |
| 120 P | | 322.0 | | 315.0 | |
| 200 P | | | 345.0 | | |

Extra Treatments:-

150N 75P + Cu10 K80 = 321.0

**Table 5. Seven Year Volume Response (m³/ha) (adjusted for covariate).
(Volume 1990 - Volume 1983)**

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|-----|------|-------|-------|-------|
| 0 P | 0 | | -37.0 | | |
| 40 P | | 29.0 | | 35.0 | |
| 75 P | 1.0 | | 29.0 | | 56.0 |
| 120 P | | 55.0 | | 48.0 | |
| 200 P | | | 78.0 | | |

Extra Treatments:-

$$150\text{N } 75\text{P} + \text{Cu}10 \text{ K}80 = 54.0$$

Table 6. Mean height (m) (adjusted for covariate) for 1990 plot measurements.

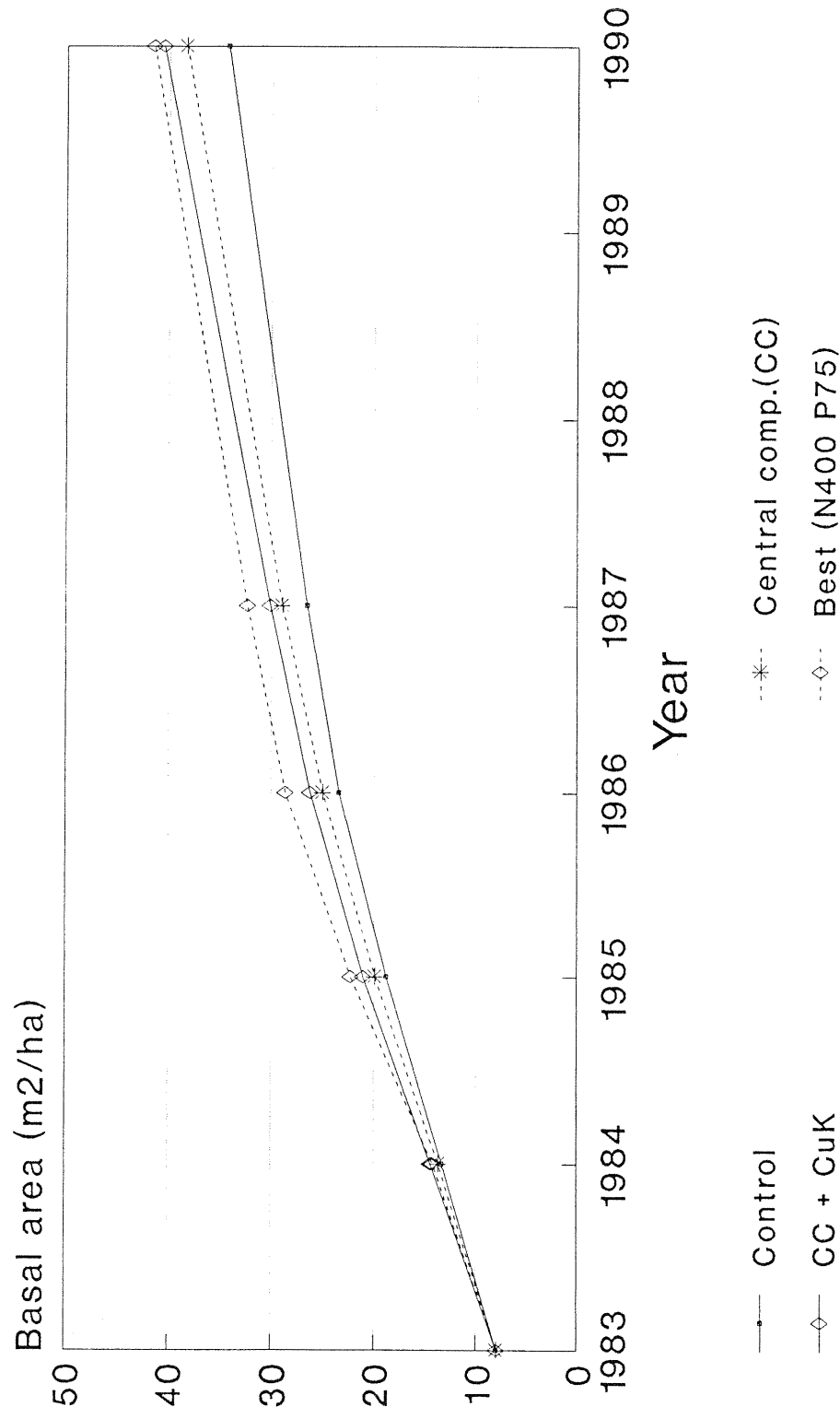
| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|------|------|-------|-------|-------|
| 0 P | 20.2 | | 18.2 | | |
| 40 P | | 20.9 | | 20.9 | |
| 75 P | 20.8 | | 20.3 | | 21.3 |
| 120 P | | 22.2 | | 20.7 | |
| 200 P | | | 20.5 | | |

Extra Treatments:-

$$150\text{N } 75\text{P} + \text{Cu}10 \text{ K}80 = 21.1$$

AK976/2 Maromaku

Basal area (adjusted for covariate)



RO1889 WAIMIHIA.

This trial showed no volume response to applied fertiliser, in fact a negative response to nearly all treatments (Table 7).

The control plots had the second highest volume of the five sites.

The seven year response (Table 8) showed up to a 15% negative response to N and P fertiliser, with the worst treatment being that of the central treatment plus magnesium (16%).

Fertiliser applications had no effect on height growth. (Table 9)

The basal area (Figure 3) data shows that the central treatment was almost 2 m²/ha behind that of the control, and the "best" treatment (N240 P 120) only 0.2 m²/ha ahead of the control.

Table 7. RO1889 WAIMIHIA.

Total volume (m³/ha) 1990 plot measurements (adjusted for covariate).

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|-------|-------|-------|-------|-------|
| 0 P | 204.0 | | 176.0 | | |
| 40 P | | 181.8 | | 189.5 | |
| 75 P | 182.1 | | 186.1 | | 173.7 |
| 120 P | | 195.1 | | 202.2 | |
| 200 P | | | 211.3 | | |

Extra Treatments:-

150 N 75P + Mg100 = 171.3

Table 8. Seven Year Volume Response (m³/ha) (adjusted for covariate).
(Volume 1990 - Volume 1983)

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|-------|-------|-------|-------|-------|
| 0 P | 0 | | -28.0 | | |
| 40 P | | -22.2 | | -14.5 | |
| 75 P | -21.9 | | -17.9 | | -30.3 |
| 120 P | | -8.9 | | -1.8 | |
| 200 P | | | 7.3 | | |

Extra Treatments:-

$$150\text{N } 75\text{P} + \text{Mg}100 = -32.7$$

Table 9. Mean height growth (m) (adjusted for covariate) for 1990 plot measurements.

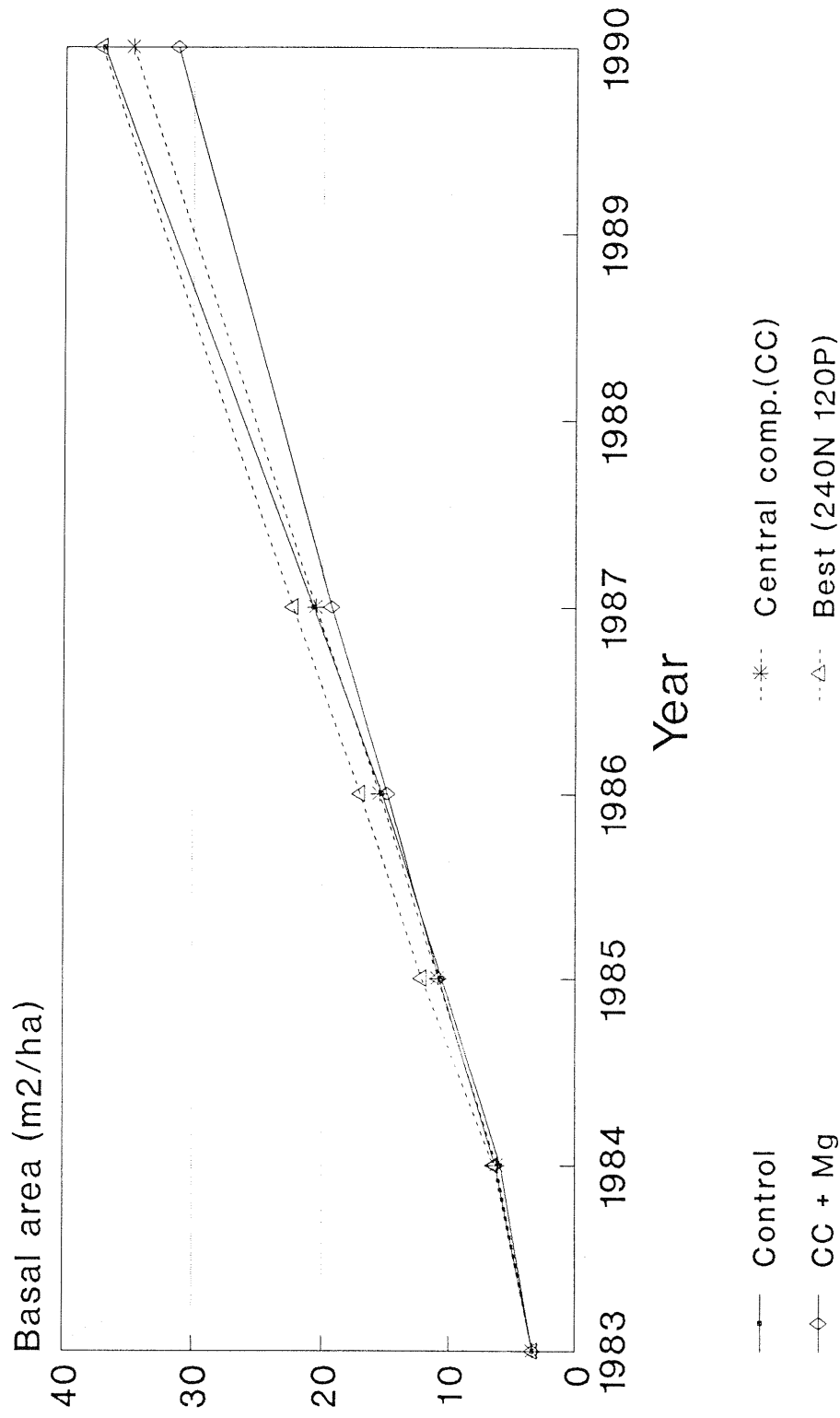
| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|------|------|-------|-------|-------|
| 0 P | 14.8 | | 14.5 | | |
| 40 P | | 14.5 | | 14.8 | |
| 75 P | 14.3 | | 14.3 | | 14.0 |
| 120 P | | 14.7 | | 14.6 | |
| 200 P | | | 14.8 | | |

Extra Treatments:-

$$150\text{N } 75\text{P} + \text{Mg}100 = 14.3$$

RO 1889 Waimihia

Basal area (adjusted for covariate)



NN518 MOTUEKA.

The total standing volume shown in Table 10 shows a significant response to applied fertiliser. Table 11 shows the magnitude of that response. The largest response was to the 400N 75P treatment with a 72% increase in volume. Nitrogen fertiliser alone decreased growth, but applications of phosphorus alone, and in conjunction with nitrogen increased growth markedly.

The weed control was almost the same as the central treatment and was not significant. It should also be noted that in the gorse free plots there was a considerable amount of wind toppling, resulting in a lower stocking for those plots. All plots, except one treatment, received a base dressing of boron. This treatment was 6.5 % lower in volume than the central treatment, and not statistically significant.

Mean height (Table 12) showed an increase in all plots except where nitrogen was applied alone. The largest increase of just over 2 m was to 150N 200P.

Basal area (Figure 4) showed an 11 m²/ha increase to the central treatment, and a 16 m²/ha increase to the "best" treatment (N400 P75).

Table 10. NN518 MOTUEKA.

Total volume (m³/ha) 1990 plot measurements (adjusted for covariate).

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|-------|-------|-------|-------|-------|
| 0 P | 161.1 | | 134.5 | | |
| 40 P | | 267.9 | | 224.4 | |
| 75 P | 267.1 | | 242.8 | | 276.5 |
| 120 P | | 227.1 | | 239.4 | |
| 200 P | | | 244.0 | | |

Note all plots have a base dressing of Boron at 8 kgB/ha.

Extra Treatments:-

150N 75P minus B = 227.8

150N 75P + weed control = 245.1

Table 11. Seven Year Volume Response (m³/ha) (adjusted for covariate).
(Volume 1990 - Volume 1983)

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|-------|------|-------|-------|-------|
| 0 P | 0 | | -26.6 | | |
| 40 P | | 24.4 | | 63.4 | |
| 75 P | 106.0 | | 81.7 | | 115.4 |
| 120 P | | 66.0 | | 78.3 | |
| 200 P | | | 82.9 | | |

Note all plots have a base dressing of Boron at 8 kgB/ha.

Extra Treatments:-

150N 75P minus B = 66.7

150N 75P + weed control = 84.0

Table 12. Mean height (m) (adjusted for covariate) for 1990 plot measurements.

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|------|------|-------|-------|-------|
| 0 P | 16.2 | | 15.0 | | |
| 40 P | | 18.0 | | 17.9 | |
| 75 P | 17.6 | | 17.8 | | 17.9 |
| 120 P | | 17.3 | | 17.3 | |
| 200 P | | | 18.5 | | |

Note all plots have a base dressing of Boron at 8 kgB/ha.

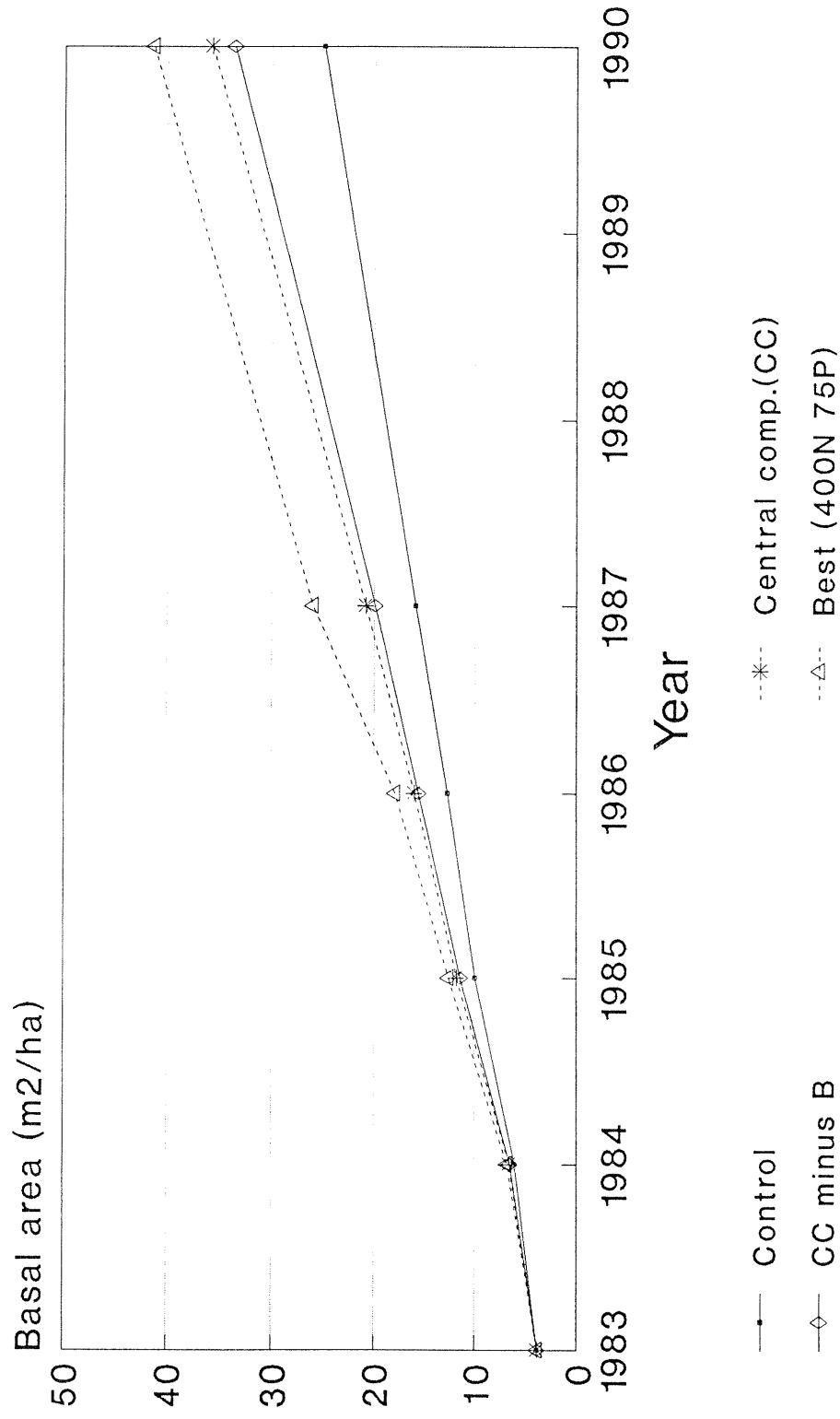
Extra Treatments:-

150N 75P minus B = 17.7

150N 75P + weed control = 18.2

NN 518 Motueka

Basal area (adjusted for covariate)



WD399 NEMONA.

The total volume figures (Table 13) show that there was a significant response to nitrogen and phosphorus fertiliser. Nitrogen alone showed no benefit at all. Table 14 shows the magnitude of these responses over the control. The "best" treatment on this site was 240N 120P which gave almost twice the response of any of the other combinations. The high levels of phosphorus and nitrogen gave the best response. The "extra" treatments with copper and potassium showed a better response when applied at the half rate of 5 kg/ha of copper and 40 kg/ha of potassium.

The mean height data shows that again the high rates of N and P had the best height growth. Fertiliser applications increased height growth in all plots.

The basal area data (Figure 5) shows the central treatment to be 27% higher than the control. The "best" treatment (240N 40P) was 16 m²/ha (62 %) higher than that of the control.

Table 13. WD399 NEMONA.

Total volume (m³/ha) 1990 plot measurements (adjusted for covariate).

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|-------|-------|-------|-------|-------|
| 0 P | 138.7 | | 138.3 | | |
| 40 P | | 190.0 | | 186.0 | |
| 75 P | 178.4 | | 185.5 | | 190.9 |
| 120 P | | 189.9 | | 254.7 | |
| 200 P | | | 217.0 | | |

Extra Treatments:-

150N 75P + Cu10 K80 = 194.8

150N 75P + Cu5 K40 = 211.6

80N 40P + Cu10 K80 = 174.8

80N 40P + Cu5 K40 = 202.5

Table 14. Seven Year Volume Response (m³/ha) (adjusted for covariate).
(Volume 1990 - Volume 1983)

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|------|------|-------|-------|-------|
| 0 P | 0 | | -0.4 | | |
| 40 P | | 51.3 | | 47.3 | |
| 75 P | 39.7 | | 46.8 | | 52.2 |
| 120 P | | 51.2 | | 116.0 | |
| 200 P | | | 78.3 | | |

Extra Treatments:-

150N 75P + Cu10 K80 = 56.1

150N 75P + Cu5 K40 = 72.9

80N 40P + Cu10 K80 = 36.1

80N 40P + Cu5 K40 = 63.8

Table 15. Mean height growth (m) (adjusted for covariate) for 1990 plot measurements.

| kg/ha | 0 N | 80 N | 150 N | 240 N | 400 N |
|-------|------|------|-------|-------|-------|
| 0 P | 14.1 | | 14.4 | | |
| 40 P | | 15.5 | | 15.1 | |
| 75 P | 15.0 | | 15.2 | | 15.8 |
| 120 P | | 15.5 | | 17.0 | |
| 200 P | | | 16.5 | | |

Extra Treatments:-

150N 75P + Cu10 K80 = 15.4

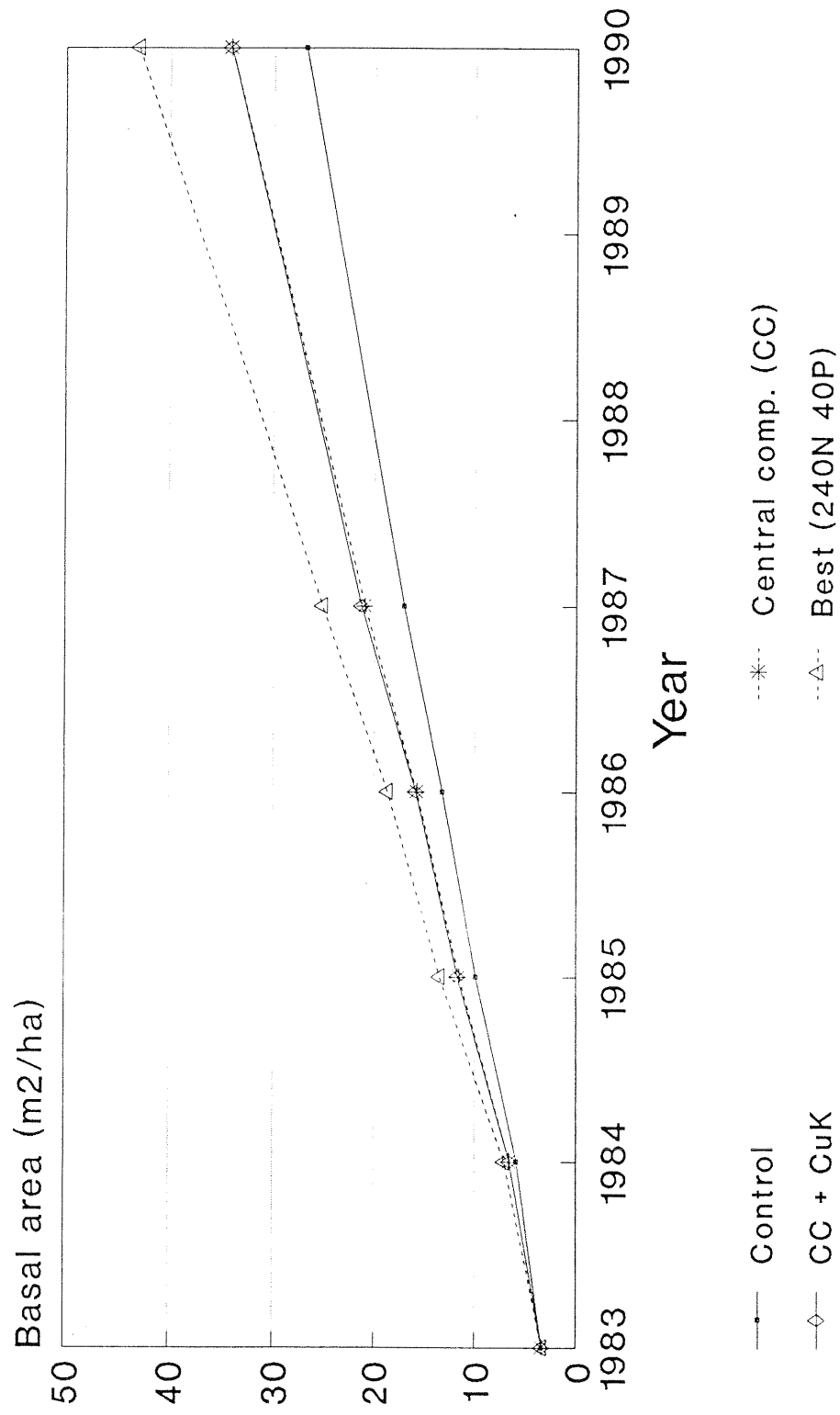
150N 75P + Cu5 K40 = 16.0

80N 40P + Cu10 K80 = 15.3

80N 40P + Cu5 K40 = 15.8

WD 399 Nemona

Basal area (adjusted for covariate)



CONCLUSIONS.

The podzolised sites *i.e.* Nemona and Parengarenga show us that it is possible to increase the yield by fertiliser application. These sites are shown to respond to fertiliser particularly to mixtures of nitrogen, phosphorus and potassium.

The trial at Maromaku showed increased volume response, in comparison to the control, to moderate amounts of nitrogen and phosphorus fertiliser, even though the site was considered to be relatively fertile, being ex-pasture.

The trial at Waimihia showed no response at all to applied fertiliser. This shows that nitrogen and phosphorus are not limiting in Southern Kaingaroa, but previous foliage results had suggested that magnesium and boron levels were low.

Fertilising with phosphorus alone or nitrogen and phosphorus together produced large growth responses at Motueka. Removal of the gorse made little difference, except increasing the susceptibility to wind damage.

All the fertilisers used in these trials were of a soluble source, except the dolomite. Less soluble forms of fertiliser such as phosphate rock should be beneficial in increasing the time over which the nutrients are available to the trees. The 1987 foliage data (presented in Report 37), showed a drop off in foliar concentrations at the lower application rates, suggesting that the responses might not be as long lived.

The trial series results should have a direct impact on fertiliser recommendations because generally the results indicated that multi-element applications at lower rates of any one element, were preferable to a single element application at the same or even at a much higher rate. This is particularly true for marginal sites.

Frequent monitoring by foliage sampling is essential to determine the requirements of microelements such as copper and boron, and probably frequent light applications of fertiliser, although not economic, could produce a better volume response.