Project Record No. 2201

RESPONSE OF RADIATA PINE TO VARYING RATES OF NITROGEN AND PHOSPHORUS FERTILISER AT FIVE SITES IN NEW ZEALAND

by

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Report No 37 May 1989

FRI/INDUSTRY RESEARCH CO_OPERATIVES

EXECUTIVE SUMMARY

ABSTRACT

In 1983 a series of 5 trials was established at sites throughout New Zealand. The trials were located at Parengarenga in the Far North, Pipiwai in the mid-north, Southern Kaingaroa, Nelson and the West Coast of the South Island. The trees were approximately 5 years old and were kept unthinned and mostly unpruned during the first four years of the trial series.

The trials used a revolutionary design called a "central composite" to test a wide range of rates of N and P fertiliser. The lowest tested rates 80kg/ha of N and 40 kg/ha of P were some of the lowest used in forestry in NZ. In addition extra elements such as potassium and magnesium were tested. This report deals with the years 1983 to 1987. It therefore covers the early, short-term response period only.

Conclusions to date are as follows:

1. Four of the five sites responded to fertiliser. The site in Southern Kaingaroa was the one that did not.
2. Good responses were achieved to the new low rates, indicating that fertiliser rates could be further reduced. However foliar concentrations in the lower rates were lower at the end of the period suggesting that responses to lower rates might not be as long lived.
3. Two of the sites (Parengarenga and Nemona) gave better responses when potassium and copper were included in the fertiliser mix.
4. The trial series results should have a direct impact on fertiliser recommendations because generally the results indicated multi-element applications at lower rates of any one element were preferable to single element applications at the same or often a very much higher rate.
5. We cannot currently predict what will happen to the concentration of other elements when one element is applied. We probably have enough stored data to begin this exercise.

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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 around New Zealand.

1. AK976/1 — on a podzolised sand in Northern Pulp's Parengarenga Block, Northland. (Planted 1979, remains unpruned)
2. AK976/2 — on a leached to podzolised clay soil in New Zealand Forest Products' Maromaku (Pipiwai) Block, North Auckland. (Planted 1979, some variable lift pruning has occurred)
3. RO1889 — on a shallow flow tephra from the Taupo orogenic centre in Waimihia Forest(Southern Kaingaroa), where an earlier experiment had shown a negative response to nitrogen but positive to nitrogen and phosphorus + other elements. (Planted 1978, remains unpruned)
4. NN518 — on a low fertility granite soil in Motueka Forest, Nelson. (Planted 1978, remains unpruned)
5. WD399 — on a pakihi site in Nemona Forest, West Coast of the South Island. (Planted 1978, remains unpruned)

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

METHODS

Design & Treatments

The trials were established using a modified central composite design. Such a design enables the experimenter to test a large number of rates of things like fertilisers in a pseudo factorial arrangement. The alternative design to achieve the same objective would be a full factorial, but this design would lead to a much larger trial. For example one replication of a full factorial testing 5 rates of N and 5 rates of P would have 25 plots per block. With two or more replications the number of plots would reach at least 50 per trial.

The central composite design is smaller because not all treatment combinations are used and replication is minimal. On the other hand, however, the central composite trial design has a number of crucial assumptions which are not easy to satisfy in forestry. The main assumption is that the experimenter can pick the optimal rate with accuracy, because the design has the highest degree of precision at that point. The design is ideally suited to a laboratory experimenter who can repeat his experiments almost daily while zeroing in on the optimal rate. It is not so well suited to long term forestry field trials where the consequences of a poor choice of optimum could haunt the experimenter for years.

In the simplest, unmodified, form of the central composite the pivotal (or optimal) treatment is replicated four or five times. The other treatments are not replicated at all. The assumption is that variability is constant across the site and between different rates. That may not be true in forestry trials. Moreover not all potential treatment combinations are present in the trial. Treatments are arranged around the pivotal treatment in a "star" shape. The easiest way to explain it is to refer the reader to the diagram below where the treatments used in these trials are shown.

Numbers of Plots in a Simple Central Composite Design

		Rates of one element				
		0	1	2	3	4
Rates of	0			1		
other	1		1		1	
element	2	1		4		1
	3		1		1	
	4			1		

This absence of all treatment combinations can be a drawback in forestry. Foresters often want to test different combinations or to extend results to different situations. There is no need for example for a control in the central composite design as laid out in table 1 . However everyone wants to know the magnitude of the fertiliser response.

The trials as laid out were modified from the central composite design in the following way:

1. A control was included (treatment 10)

2. The trials were replicated on each site so that for each treatment there were two plots at a minimum.

3. 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 have not really been tested in previous field experiments.

4. Extra treatments were included to test the effect of nutrients that might be marginal at each specific site. This was done to ensure a response from each site should N&P provoke other deficiencies. (Treatments 11-14).

The full list of treatments for each site is given below:-

The treatments are:

TREATMENT No.	NITROGEN (kg/ha)	PHOSPHORUS (kg/ha)	OTHERS
1.	80	40	
2.	80	120	
3.	240	40	
4.	240	120	
5.	0	75	
6.	400	75	
7.	150	0	
8.	150	200	
9.	150	75 (Pivotal or optimal)	
10.	0	0	
11.	150	75	(a) Cu 10 kg/ha and K 80 kg/ha for AK976/1 and Ak976/2 and WD399 OR (b) Mg 100 kg/ha for RO1889 OR (c) minus Boron (base dressing of 8 kg/ha to all other plots) at NN518
12.	80	40	Cu 10 kg/ha and K 80 kg/ha for AK976/1 and WD399
13.	80	40	Cu 5 kg/ha and K 40 kg/ha for AK976/1 and WD399
14.	150	75	Cu 5 kg/ha and K 40 kg/ha for AK976/1 and WD399

At each site there are two replications of treatments 1 to 8, eight of treatment 9, and four of treatment 10 and 11. Treatments 12 to 14 are replicated twice at the sites where they were present.

Materials

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 like superphosphate . The normal sources of nitrogen (urea), potassium (potassium chloride [muriate of potash]), copper (copper sulphate), boron (sodium borate) and magnesium (dolomite) were used.

Data Presented

All plots in the trial series were measured at establishment (in 1983) and again in 1984, 85, 86 and 87. Diameters of all trees were measured and also heights on a sample of stems.

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

total stem volume 1983(covariate) & 87;
mean height 1983(covariate) & 87;
basal area from 1983 to 87.

Foliage samples were collected from all plots in late summer of 1984 and 87. The samples were analysed for a wide range of nutrients. Statistical analyses were carried out on a subset of analyses as detailed in the following table:

Elements analysed statistically

	Year of foliage collection	
Trial	1984	1987
AK976/1	N,P,K,Cu	N,P,K,Cu
AK976/2	N,P,K,Cu	N,P,K,Cu
RO1889	N,P,Mg	N,P,Mg
NN518	N,P,B	N,P,B
WD399	N,P,K,Cu	N,P,K,Cu

Statistical Analyses

Central composite design trials can be analyzed using response surfaces. In the past, subsets of data from these trials have been presented that way. For the purposes of this report however the trial was analyzed as a collection of treatments with unequal replication. This approach enables a more detailed study of the trials.

RESULTS

The results will be presented in two parts. Part 1 will deal with each trial site individually. In part 2 the sites will be grouped and considered as a series.

PART 1: Each trial considered individually

Site 1: Ak976/1 Parengarenga.

The trial at Parengarenga was established on an almost flat rather poorly drained strongly podzolised soil, representative of the Te Kopuru/Ohia sand type. This site had the lowest soil N and the lowest soil P of the five sites (table 11).

Tree growth on the site was rather variable. There was thick undergrowth of manuka.

Shortly after the trial was established a small part was accidentally topdressed with N and P fertiliser. It was the least "accurate" of the 5 trials. That is to say it had the highest error mean square as a percentage. This high error was probably due to both the site variability and the accidental transgression.

Tree growth

Table 1 shows the standing volume in 1987 at age 8. In table 2 the four year volume response is shown. Periodic current annual increment in the unfertilised plots was 10.6 m^3/ha/yr. Additions of small amounts of N and P caused a 20 - 30% increase in PCAI but additions of larger amounts of fertiliser reduced the response markedly. It is very noticeable that the treatments including potassium and copper increased growth much more than the comparable treatments without those elements.

Height growth was affected by treatment. It was reduced slightly below the control by large amounts of N. It was increased 20% by the extra treatments containing copper and potassium.

Foliar Nutrient Concentrations

In figure 1 the N,P, K foliar concentrations are shown.

Nitrogen was increased to 2% in 1984 by high amounts of N fertiliser but in common with just about every other N trial, had reduced back to the level of the control by 1987. In the control and in the lowest N treatment N concentrations were marginal to deficient. The control was at 1.46% in 1984 and 1.37% in 1987. Potassium concentrations were adequate in K fertilised treatments but in other treatments were just above deficient in 1984 and had decreased to deficient by 1987. Phosphorus concentrations were marginal to satisfactory in all treatments, averaging 0.126% in 1984 and 0.132% in 1987, although high rates of N alone did reduce the concentration to barely satisfactory (0.11%).

Copper concentrations averaged 2.2 ppm over all plots in 1984. The control was at 3.6 ppm but plots fertilised with high levels of N were at only 1 ppm (below the critical level of 2-3 ppm). As a result there was a high degree of branch and stem twisting in these plots. By 1987 a rather disquieting trend emerged. The average Cu had decreased to 1.7 ppm. The control was down to 1.4 ppm and only the Cu fertilised plots were adequate at 2.8 ppm.

Zinc concentrations were tested in 1987 and revealed the somewhat surprising result that they were low to marginal. The lowest concentration was 6 ppm and the highest only 15 ppm.

Boron, calcium and magnesium concentrations were adequate. (There has to be some good news!)

Table 1: STANDING VOLUME AT PARENGARENGA in 1987 m3/ha

Nitrogen Rates

Phosphorus	0	80	150	240	400
0	45.0		56.8		
40		54.6		55.1	
75	58.7		57.1		52.7
120		52.7		44.0	
200			52.6		

Table 2: FOUR YEAR VOLUME RESPONSE AT PARENGARENGA m3/ha

Nitrogen Rates

Phosphorus	0	80	150	240	400
0	0.0		11.8		
40		9.6		10.1	
75	13.7		12.1		7.7
120		7.7		-1.0	
200			7.6		

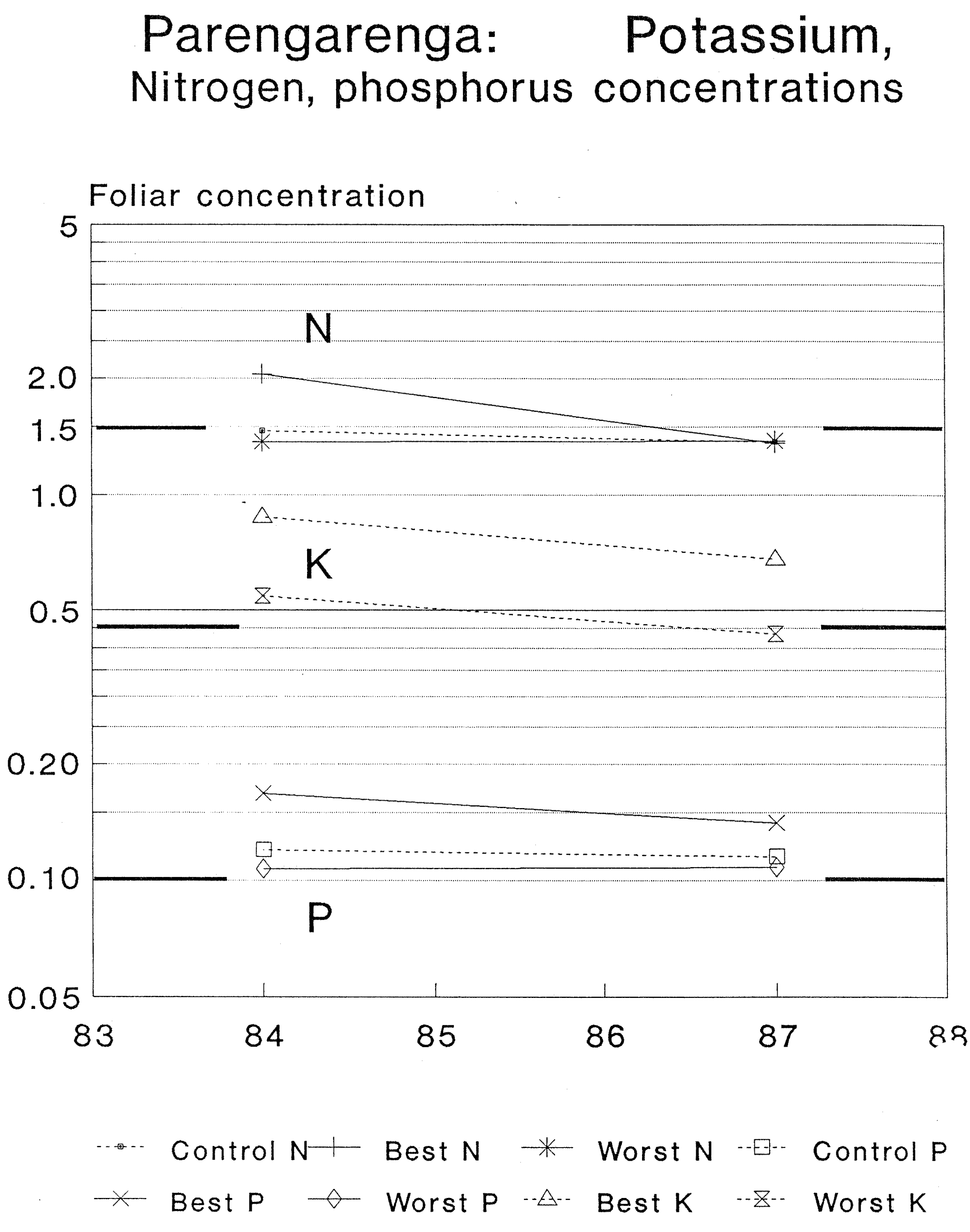
EXTRA TREATMENTS	
150N 75P 80K 10Cu	17.2
150N 75P 40K 10Cu	25.5
80N 40P 80K 10Cu	23.1
80N 40P 40K 10Cu	19.9

PERCENTAGE INCREASE IN PCAI

PCAI= 10.6325 m3/ha/yr

	0	80	150	240	400
0	0.00%		127.75%		
40		122.57%		123.75%	
75	132.21%		128.45%		118.10%
120		118.10%		97.65%	
200			117.87%		

EXTRA TREATMENTS	
150N 75P 80K 10Cu	140.44%
150N 75P 40K 10Cu	159.96%
80N 40P 80K 10Cu	154.31%
80N 40P 40K 10Cu	146.79%



Parengarenga: Potassium,
Nitrogen, phosphorus concentrations
Foliar concentration
5
2.0
1.5
1.0
0.5
0.20
0.10
0.05
N
K
P
83
84
85
86
87
88
Control N
Best N
Worst N
Control P
Best P
Worst P
Best K
Worst K

Figure 1

Tree growth and nutrition in the extra treatments

There were 4 extra treatments in this trial, treatments containing a high and low amount of potassium and copper interacted with treatments containing a high and low amount of N&P.

N&P	KCu (kg elemental per ha)	
150:75	80:10	40:5
80:40	80:10	40:5

The key results are:-

	N&P only	+80:10 KCu	+40:5KCu	
Foliar Potassium 1984	0.525%	0.787	0.683	***
Foliar Potassium 1987	0.525	0.653	0.563	*
Foliar Copper 1984	1.56 ppm	2.65	2.58	***
Foliar Copper 1987	1.38	2.85	2.15	****
Volume in 1987	57 m^3/ha	71	74	*/NS
Height in 1987	9.8	10.2	10.2	NS

	150N 75P(+KCu)	80N 40P(+KCu)	
Foliar N in 1987	1.335%	1.405	*
Foliar Cu in 1984	3.48 ppm	1.56	***
Volume in 1987	70 m^3/ha	75	NS
Volume at same NP rates but without KCu	57	55	NS

Conclusions:

It is possible to grow good trees on these sites. PCAI for fertilised plots is as good as Southern Kaingaroa at a higher stocking. However the way to do it is with light fertiliser dressings of mixed fertilisers containing at least N,P,K. Frequent monitoring through foliage sampling seems to be essential. Additions of micronutrients may be necessary. This strategy is not necessarily expensive. The soil does not "lock up" nutrients so frequent applications of low rates are possible. Moreover a higher rate of P alone or of DAP which achieves very little in additional growth may be cheap in acquisition but is expensive in lost opportunity.

Site 2: AK976/2 Maromaku/Pipiwai

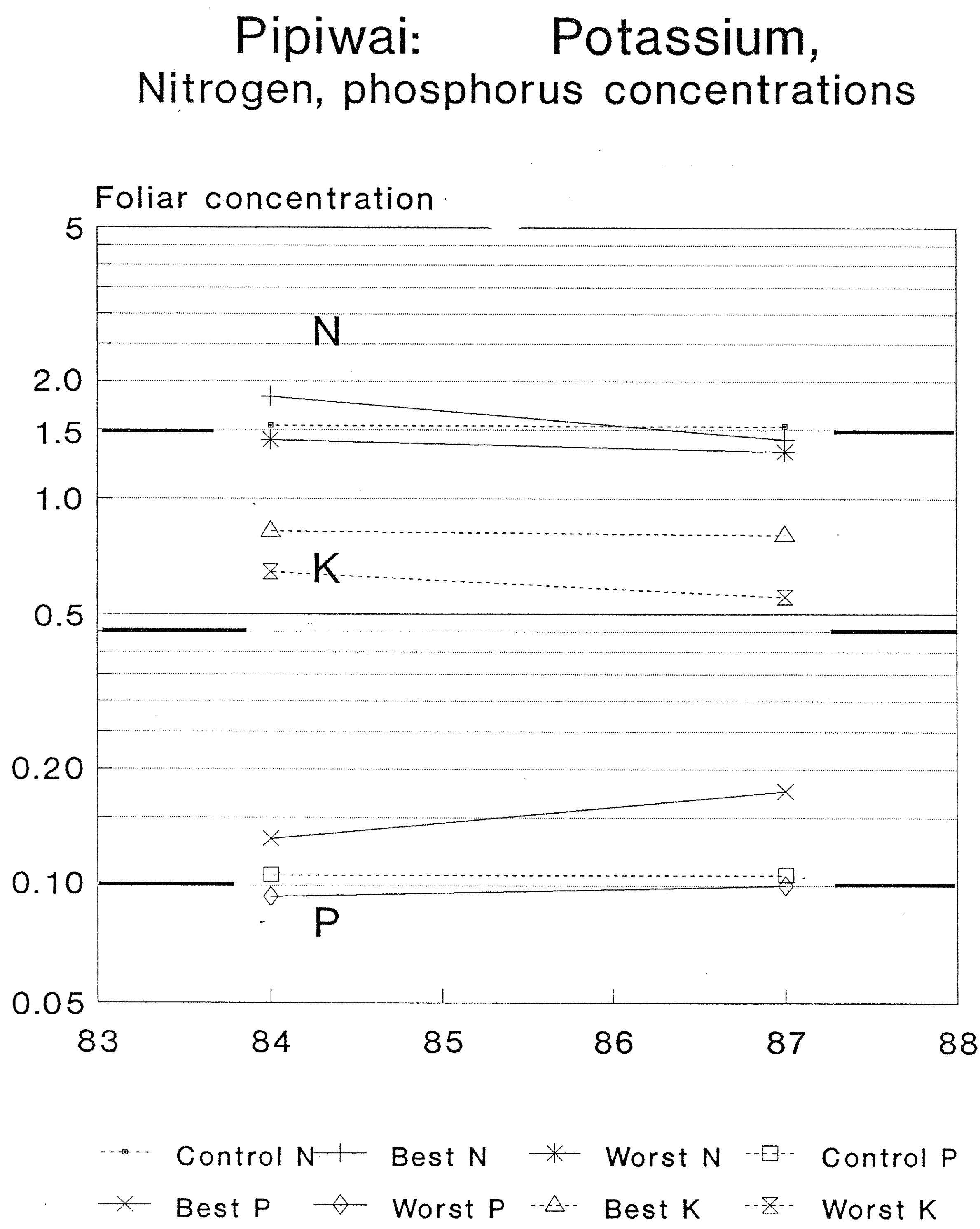
The site at Maromaku was established on old farmland still carrying moderately good pasture. This site had one of the higher soil N values and a moderate soil P. It had the highest sum of available cations although the C.E.C was dominated by Ca.

Tree growth

This site had the highest standing volume of all the sites in 1987 (Table 3). It had a PCAI of 33.7 m^3/ha/yr which was nearly twice that of any other site. Despite this high base growth rate there was a further gain of 10 - 20 % from applications of N and P together (table 4). N by itself or P by itself were not beneficial. The extra treatment containing potassium and copper produced a small (8%) gain over the equivalent N&P treatment.

Foliar nutrient concentrations

Foliar N averaged 1.54% in the controls in 1984 and in 1987. High rates of N fertiliser increased foliar N in 1984, high rates of P decreased it. Foliar P was at 0.106% in both 1984 and 1987 in the control. Applying N alone reduced it to 0.09% in 1984 from which level it recovered to 0.1 in 1987. It was increased to 0.15% by P fertilising in 1984 and continued to increase, reaching 0.175% in some treatments by 1987 (figure 2). Foliar potassium averaged 0.69% in both 1984 and 1985. The lowest value was 0.32% after fertilising with high amounts of N&P. Five of the 32 plots had K values below 0.5%. K fertiliser increased the concentration to 0.82% in 1984 and 0.81% in 1987. Copper concentrations averaged 4.2 ppm in both 1984 and 1987. High levels of N&P fertiliser reduced copper to 3.3 ppm which should have been adequate. Despite this slight branch and stem twisting occurred in these treatments immediately after fertilising.



Pipiwai: Potassium,
Nitrogen, phosphorus concentrations
Foliar concentration
5
2.0
1.5
1.0
0.5
0.20
0.10
0.05
N
K
P
83
84
85
86
87
88
Control N
Best N
Worst N
Control P
Best P
Worst P
Best K
Worst K

Figure 2

Table 3: STANDING VOLUME AT PIPIWAI/MAROMAKU in 1987 m3/ha

Nitrogen Rates

Phosphorus	0	80	150	240	400
0	159.1		149.2		
40		171.8		187.1	
75	151.6		175.7		186.6
120		187.6		176.9	
200			181.8		

Table 4: FOUR YEAR VOLUME RESPONSE AT PIPIWAI/MAROMAKU m3/ha

Nitrogen Rates

Phosphorus	0	80	150	240	400
0	0.0		-9.9		
40		12.7		28.0	
75	-7.5		16.6		27.5
120		28.5		17.8	
200			22.7		

EXTRA TREATMENTS	
150N 75P 80K 10Cu	27

PERCENTAGE INCREASE IN PCAI

PCAI= 33.7 m3/ha/yr

	0	80	150	240	400
	0.00%		92.66%		
40		109.42%		120.77%	
75	94.44%		112.31%		120.40%
120		121.14%		113.20%	
200			116.84%		

EXTRA TREATMENTS	
150N 75P KCu	120.03%

Calcium magnesium and zinc concentrations were adequate. Boron concentrations varied between 8 ppm (4 plots in 1987) and 14 ppm. Boron concentrations were close to marginal. Distance from the sea seems to be very important. The same soil type will have trees with a higher foliar B if close to the sea.

Conclusions

Remarkably good growth overall was achieved on this ex-pasture site. Despite the high level of growth, gains of between 10 and 20% of PCAI were achieved by fertilising with moderate amounts of N and P fertiliser. Twenty percent of Pipiwai is the same as 60% at Parengarenga -- a gain of 6 m^3/ha/yr.

Site 3: RO1889 Waimahia (Southern Kaingaroa)

The site in Southern Kaingaroa was established at over 650 m above sealevel on a weakly weathered but strongly leached rubbly pumice. Tree establishment had been successful in the trial area but within 300 m was a shallow basin where despite modern weed control treatment tree establishment had repeatedly failed due to frost. Five year old, 3 metre tall trees were killed by a February frost in that basin a couple of years ago. The site was bare of weeds having only a sparse cover of small grasses underfoot.

Tree growth

Standing volume in 1987 averaged 81 m^3/ha (table 5). There was no Volume response to fertiliser (table 6). PCAI in the control averaged 18.8m^3/ha/yr so the controls at this site came second in the suite of 5 trials to Pipiwai. However fertilised treatments in all other sites except Parengarenga produced greater PCAI's than this.

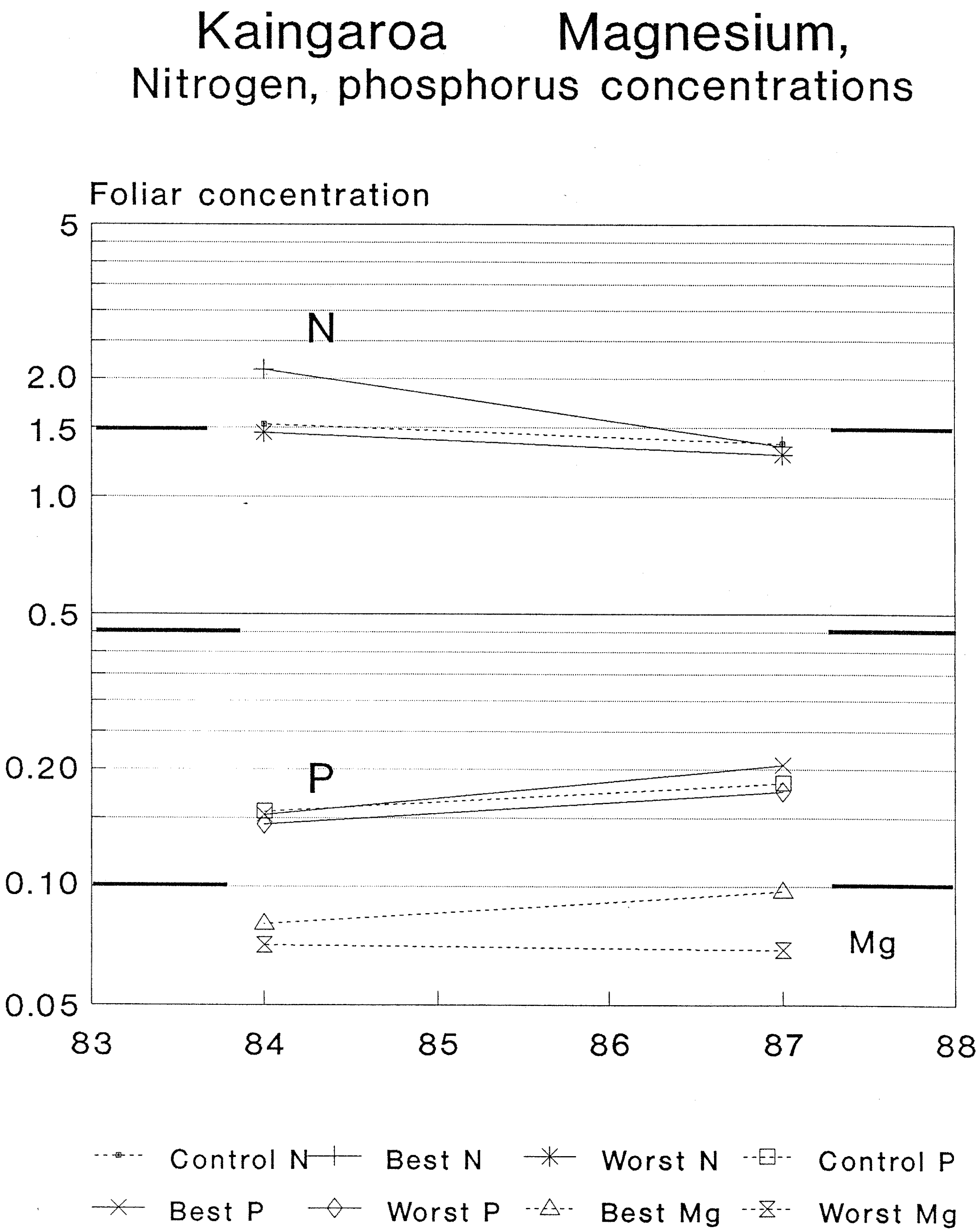
Foliar nutrient concentrations

Foliar N decreased from 1.53% in the controls in 1984 to 1.35% in 1987. It was increased to a peak of 2.11% by N fertilising and reduced a little by P fertilising. P concentrations increased in the controls from 0.16% to 0.18% from 1984 to 1987 . P fertilising increased the P concentrations to over 0.20% by 1987. N fertilising decreased P a little. Magnesium concentrations averaged 0.078% in both years. Mg concentration was relatively unaffected by other treatments. Mg fertilising in the extra treatment had no effect in 1984 but did increase Mg concentration in 1987 to 0.97% (sounds familiar!).

Potassium and calcium concentrations were very adequate. However boron concentrations ranged in 1987 from 6 ppm (4 of the 32 plots) to 12 ppm, with all bar 1 plot being at 10 ppm or below.

Conclusions

It is not N or P that is limiting growth in Southern Kaingaroa. Magnesium and boron concentrations are low enough to cause concern however.



Kaingaroa Magnesium,
Nitrogen, phosphorus concentrations
Foliar concentration
5
2.0
1.5
1.0
0.5
0.20
0.10
0.05
N
P
Mg
83
84
85
86
87
88
Control N
Best N
Worst N
Control P
Best P
Worst P
Best Mg
Worst Mg

Figure 3

Table 5: STANDING VOLUME AT WAIMAHIA/ SOUTHERN KAINGAROA in 1987

Nitrogen Rates

Phosphorus	0	80	150	240	400
0	83.4		77.1		
40		75.2		86.4	
75	76.3		81.3		78.7
120		80.0		82.1	
200			84.5		

Table 6: FOUR YEAR VOLUME RESPONSE AT SOUTHERN KAINGAROA/WAIMAHIA m3/ha

Nitrogen Rates

Phosphorus	0	80	150	240	400
0	0.0		-6.3		
40		-8.2		3.0	
75	-7.1		-2.1		-4.7
120		-3.4		-1.3	
200			1.1		

EXTRA TREATMENTS

150N 75P 100Mg	-4.8

PERCENTAGE INCREASE IN PCAI

PCAI= 18.8 m3/ha

	0	80	150	240	400
	0.00%		91.63%		
40		89.11%		103.99%	
75	90.57%		97.21%		93.76%
120		95.48%		98.27%	
200			101.46%		

EXTRA TREATMENTS

150N 75P Mg	93.62%

Site 4: NN518 Nelson - Motueka

This trial was established on a ridge in steeply dissected granite country. The site was dominated by 1m deep gorse growth.

Tree growth

Strong volume responses to fertiliser were experienced (table 7). Nitrogen fertiliser alone depressed growth (table 8) but P fertiliser alone at a higher rate or in conjunction with N at a lower rate increased growth markedly, increasing the PCAI of 17m^3/ha/yr in the control by 50%. Height growth was significantly improved by treatments containing P but reduced by treatments containing N alone.

There were two extra treatments at this site. In one, which was fertilised with 150kg N and 75 kg P,the basal dressing of B which was applied to all other plots, was omitted. This treatment had a lower volume response (78%) and a poorer height growth (87%) than the comparable treatment fertilised with N,P,B. It is important to be aware however that these differences are not statistically significant. The probabilities are 0.28 and 0.50 respectively.

The other extra treatment involved removal of the rampant gorse understorey. The results show that the volume response in the weed free plots (which were fertilised at 150N and 75P) is identical to that in the comparably fertilised weedy plots. This result is however probably misleading. The trees were using the gorse for support and when it was removed they fell over! Thus the growth measurements from these plots are almost certainly affected and biased downwards.

Foliar nutrient concentrations

Foliar N averaged between 1.38 and 1.4% in the controls. Fertilising with N increased it to a maximum of 1.95% in 1984. In 1987 foliar N concentrations had dropped in fertilised plots to a level slightly below the control (as low as 1.17%). Foliar P concentrations were at 0.09% in the control , strongly deficient. P fertiliser increased foliar P to 0.16% in 1984 and 0.145% in 1987. Foliar B concentrations were increased in 1984 to 25 - 30 ppm by B fertilising, reducing to 13 - 16 ppm by 1987. In the minus B treatments however boron concentrations were 8.3ppm in 1984 and 9.5 ppm in 1987.

Potassium and calcium concentrations were satisfactory, however magnesium concentrations were not good. Seven plots had Mg concentrations below 0.07% .

Conclusions

Fertilising with P or with P and N together produced excellent growth responses.

Table 7: STANDING VOLUME AT NELSON/MOTUEKA in 1987 m3/ha

Nitrogen Rates

Phosphorus	0	80	150	240	400
0	79.8		70.1		
40		114.0		100.4	
75	116.7		107.9		78.7
120		102.4		118.8	
200			110.3		

Table 8: FOUR YEAR VOLUME RESPONSE AT NELSON/MOTUEKA m3/ha

Nitrogen Rates

Phosphorus	0	80	150	240	400
0	0.0		-9.7		
40		34.2		20.6	
75	36.9		28.1		41.7
120		22.6		39.0	
200			30.5		

EXTRA TREATMENTS	
Minus B	21.9
Weed Free	28.1

PERCENTAGE INCREASE IN PCAI

PCAI= 17.0 m3/ha/yr

	0	80	150	240	400
	0.00%		85.77%		
40		150.18%		130.23%	
75	154.15%		141.23%		161.19%
120		133.16%		157.23%	
200			144.75%		

EXTRA TREATMENTS	
Minus B	132.13%
Weed Free	141.23%

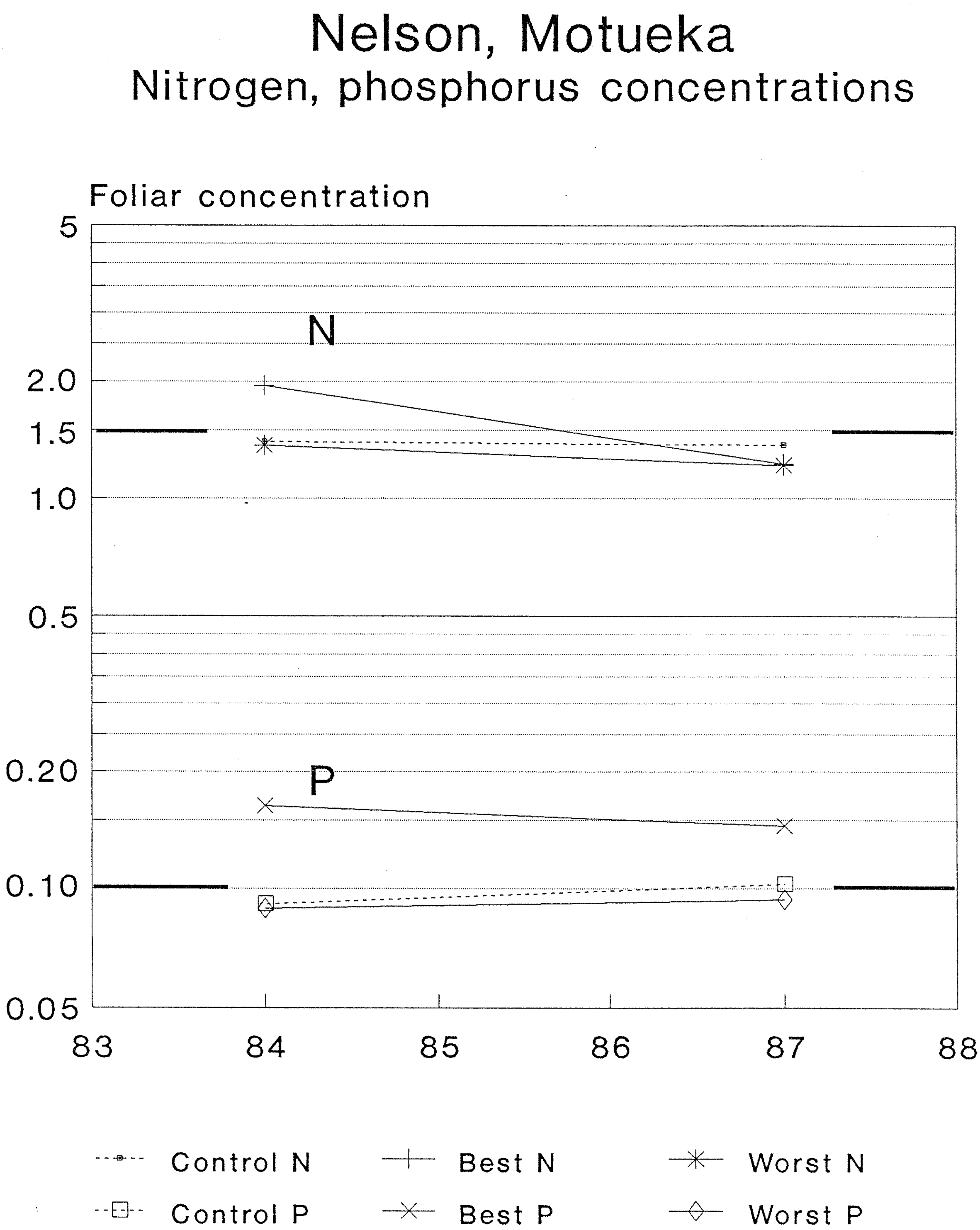

Nelson, Motueka
Nitrogen, phosphorus concentrations
Foliar concentration
5
2.0
1.5
1.0
0.5
0.20
0.10
0.05
N
P
83
84
85
86
87
88
Control N
Best N
Worst N
Control P
Best P
Worst P

Figure 4

Site 5: WD399 Nemona

This trial was established on a pakahi site in Nemona forest on the West Coast of the South Island. The soil consisted of 0.5 to 1 metre of raw organic matter over compact glacial till. Site preparation at planting had consisted of V blading the site, pushing the organic matter into ridges on which the trees were planted, leaving deep drains bottomed by glacial till.

Tree growth

There were strong volume responses to P fertiliser and the combinations of N & P above a background PCAI of $15.29 m^3/ha/yr$. Applications of N alone did not improve growth. There were useful extra gains from the additional treatments of potassium and copper. This site was unusual in the set of five in that responses continued to increase with increasing inputs of N and P.

Foliar concentrations

The unfertilised plots at this site were remarkably low in N , averaging 0.98%. Fertilising with N put concentrations up to 2.7% in 1984 but by 1987 all treatments had N concentrations back at 0.93 - 1.06%. P concentrations were at 0.116% in the controls in 1984 and had decreased to 0.077% by 1987. High rates of P fertiliser increased P concentrations to 0.2% in 1984 and kept them at 0.16% by 1987. However lower rates of P (75 kg or less) allowed P concentrations to fall to 0.11% or below by 1987. Potassium concentrations in the controls averaged 0.68 in 1984 and 0.56 in 1987. Fertilising with N & P reduced K concentrations to below 0.5% in 10 of the 38 plots.

Foliar concentrations of both Ca and Mg were very variable, with some plots being adequate and others having low concentrations of both elements. The lowest Ca was 0.47% and the lowest Mg 0.59%. Boron concentrations were also low with 12 of the 38 plots having concentrations of 7ppm or lower.

Table 9: STANDING VOLUME AT NEMONA in 1987 m3/ha

Nitrogen Rates

Phosphorus	0	80	150	240	400
0	69.1		82.8		
40		87.1		89.9	
75	76.3		82.8		78.7
120		85.0		110.2	
200			98.7		

Table 10: FOUR YEAR VOLUME RESPONSE AT NEMONA m3/ha

Nitrogen Rates

Phosphorus	0	80	150	240	400
0	0.0		1.1		
40		18.0		20.8	
75	10.5		13.7		20.0
120		15.9		41.1	
200			29.5		

EXTRA TREATMENTS	
150N 75P 80K10Cu	20
150N 75P 40 K 5Cu	25.2
80 N 40 P 80K10Cu	12.3
80 N 40P 40K 5Cu	21.1

PERCENTAGE INCREASE IN PCAI

PCAI= 15.29 m3/ha/yr

	0	80	150	240	400
	0.00%		101.80%		
40		129.43%		134.01%	
75	117.17%		122.40%		132.70%
120		126.00%		167.20%	
200			148.23%		

EXTRA TREATMENTS	
150N 75P 80K10Cu	132.70%
150N 75P 40 K 5Cu	141.20%
80 N 40 P 80K10Cu	120.11%
80 N 40P 40K 5Cu	134.50%

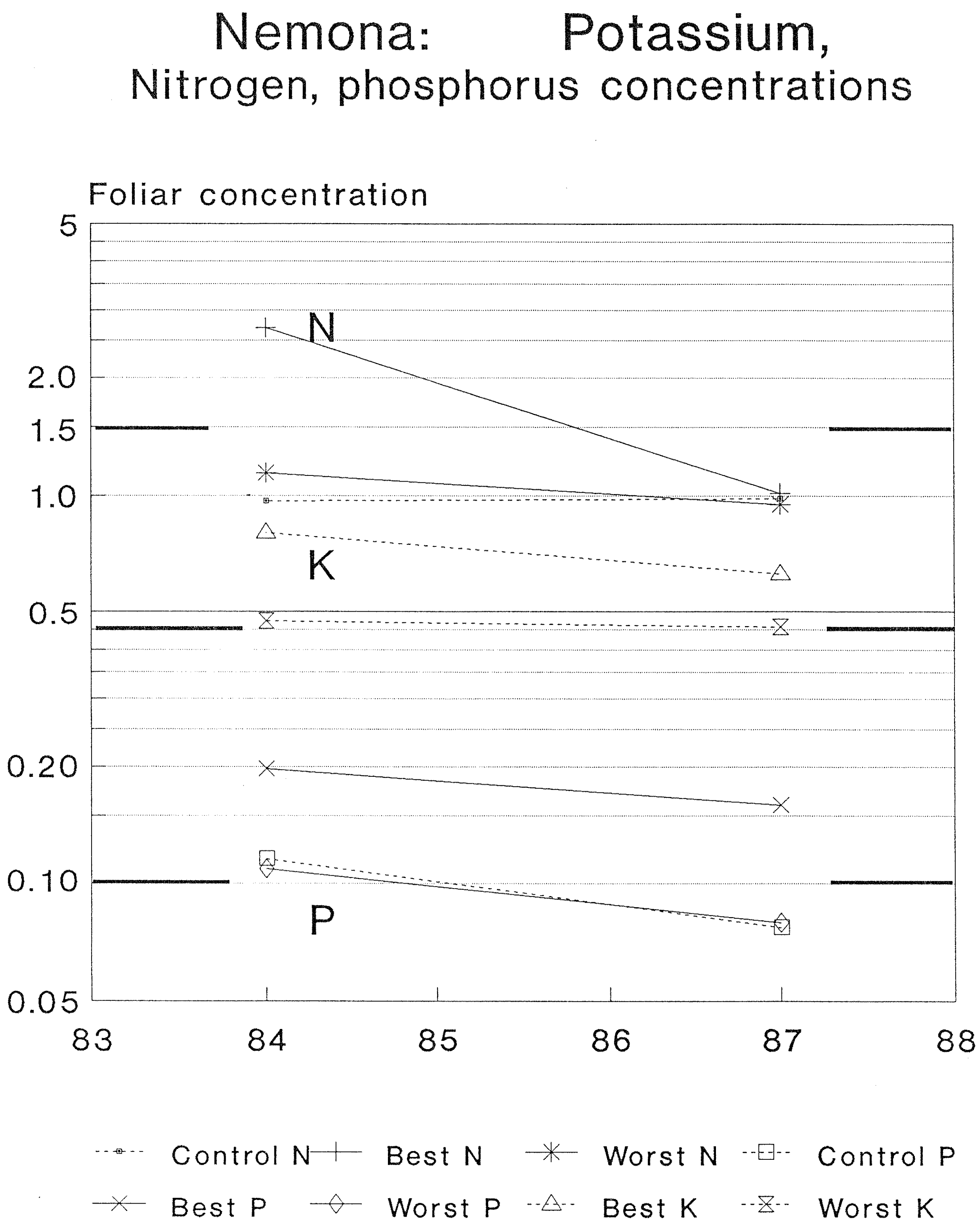

Nemona: Potassium,
Nitrogen, phosphorus concentrations
Foliar concentration
5
2.0
1.5
1.0
0.5
0.20
0.10
0.05
N
K
P
83
84
85
86
87
88
Control N
Best N
Worst N
Control P
Best P
Worst P
Best K
Worst K

Figure 5

Tree growth and nutrition in the extra treatments

There were 4 extra treatments in this trial also, treatments containing a high and low amount of potassium and copper interacted with treatments containing a high and low amount of N&P.

N&P	KCu (kg elemental per ha)	
150:75	80:10	40:5
80:40	80:10	40:5

The key results are:-

	N&P only	+80:10 KCu	+40:5KCu	
Foliar Potassium 1984	0.477%	0.817	0.702	**
Foliar Potassium 1987	0.497%	0.614	0.567	*
Foliar Copper 1984	6.09 ppm	6.90	5.90	
Foliar Copper 1987	3.34	4.02	3.95	*
Volume in 1987	76 m^3/ha	82	89	*/NS
Height in 1987	10.2	10.8	11.0	*

	150N 75P(+KCu)	80N 40P(+KCu)	
Foliar N in 1987	0.968%	0.912	
Volume in 1987	89.1 m^3/ha	94.3	NS
Volume at same NP rates but without KCu	82.8	87.1	NS

Conclusions

These sites are as difficult to manage and rather similar to the podsolised soils of North Auckland. It is clearly possible to grow fairly vigorous trees on these sites (outproducing Southern Kaingaroa for example), however the transient nature of the foliar responses to soluble forms of fertiliser indicates that this is probably not the optimal strategy. It might be better to attack the underlying causes of nutrient availability and to experiment with fertilisers such as rock P (already underway) and dolomite (not tested) to change pH and provide sustainable outputs of P,N, K etc.

Part 2: THE TRIALS CONSIDERED AS A SERIES

FOLIAR NUTRIENT CONCENTRATIONS

Foliar Nitrogen concentrations in 1984 ;

At all sites high rates of nitrogen fertiliser had a big effect on foliar nitrogen concentrations in the autumn immediately following fertilising .

Trial site	Foliar N in 1984		
	In control	in trt 9 150N 75P	in trt 6 400N 75P
AK976/1	1.46	1.45	2.05
AK976/2	1.53	1.58	1.83
RO1889	1.53	1.57	2.11
NN 518	1.40	1.53	1.95
WD 399	0.97	1.72	2.69

Four of the sites behaved fairly similarly in the degree to which foliar N was raised both by treatment 9 and also by treatment 6. One site (Wd 399) was different in that it was much more N deficient to start with and showed larger rises in foliar N to both treatments.

Foliar nitrogen in 1987

In 1987 foliar nitrogen concentrations had reduced in all sites and all treatments to a level similar to that in their respective controls.

Foliar phosphorus

At three of the five sites foliar P was immediately increased by phosphorus fertilising and it remained higher than the control through to 1987 at all sites. RO 1889 and AK976/1 were the exceptions. At these sites foliar P was high in the control and P fertiliser had no effect on foliar P.

Trial Site	Foliar P			
	Trt 9	Trt 5	Trt 7	Control
	150N 75P	ON 75P	150N OP	
AK9761				
1984	0.12	0.12	0.17	0.12
1987	0.12	0.14	0.14	0.12
AK9762				
1984	0.12	0.13	0.09	0.11
1987	0.15	0.18	0.10	0.11
Ro1889				
1984	0.15	0.15	0.14	0.16
1987	0.20	0.21	0.18	0.18
NN518				
1984	0.12	0.11	0.09	0.09
1987	0.13	0.12	0.09	0.10
Wd399				
1984	0.15	0.16	0.11	0.12
1987	0.11	0.10	0.08	0.08

What can we learn for fertiliser recommendations?

In the following table the foliar nutrient concentrations in the control are shown. Beside it is given the action that would be expected to be advised if the sample came to us for fertiliser recommendation. At three of the sites no action would have been recommended because the concentrations were merely marginal.

Trial	Control Foliar nutrient concentrations in 1984			Action	
	N	P	K	Normally recommended	Ideal
AK976/1	1.46	0.12	0.68	Nothing	add NPK
AK976/2	1.54	0.11	0.62	Nothing	add NPK
RO1889	1.53	0.16	-	Nothing	correct
NN518	1.40	0.09	-	Add P alone	Add NP
Wd399	0.97	0.12	0.68	Add N alone or add N&P	Add NPK

Consequences if normal action followed

AK976/1 — Loss of 38% potential volume growth. If just P is applied the volume response is 25% less than the potential.

AK976/2 — Loss of 16% potential growth

Ro1889 — Dead right

NN518 — OK but the same response can be achieved at lower rates of P if some N is added as well and a larger response is achievable where both N and P are applied together.

Wd399 — Disastrous, a complete waste of money and a loss of 29% potential volume increment. The alternative normal strategy of applying N and P together because P is marginal (at a 2:1 ratio of N:P) would have given better results.

Conclusions

1. We need a theory to show how fertilising with one element affects others. Our current approach of fertilising with the most deficient and advising the application of others if they are marginal can lead to lost opportunity and waste of resources.

2. The intervention level for potassium fertilising, currently set at 0.4%, may be too low.

3. The absolute level of copper concentration in the foliage may not be as important as some other nutritional events. At Parengarenga the application of 400 kg of N reduced foliar Cu to a deficient level and caused twisting. However in 1987 all the treatments were Cu deficient but twisting had reduced almost to nothing and even the 400kg N treatment was growing straight. At Pipiwai/Maromaku, slight twisting occurred in the high N treatments even though foliar Cu remained above 3 ppm.

4. Although the differences are not statistically significant absence of boron seemed to reduce growth in NN518. This is a very intriguing result because previously boron deficiency has been judged in terms of malformation only.

Results of soil analysis

Results of soil analysis of topsoil samples are given in table 11. There is a broad general relationship between topsoil total nitrogen and foliar nitrogen in the controls for four of the five sites. The exception is Nemona where despite a high total N, foliar N concentrations were very poor (0.97%) .This is probably due to the very acid (pH 3.8) raw humic matter, which although fairly high in nitrogen does not decompose and release N to the trees.

The soil analyses for P pre-date our new sequential soil test. There is a very broad trend in that the site with the highest Bray-P (Kaingaroa) had the highest foliar P and no response to applied P. Also, if the other four sites are grouped, then they are to some extent all P responsive. However the old standard test does not sort them into order of responsiveness.

There was very little relationship between foliar cations (Ca, Mg,K) and soil cations.

Table 11: SOIL ANALYSIS RESULTS FROM THE FIVE N*P TRIALS

Trial		Soil	Bray P	Bray Cations			P	pH
		Total		Ca	Mg	K	retention	
		N%	ppm		me%		%	
Parengarenga	AK9761	0.10	2.2	0.8	0.6	0.02	3.5	4.3
Pipiwai/Maromaku	AK9762	0.21	6.3	5.5	1.0	0.02	16.5	5.1
Kaingaroa/Waimahia	RO1889	0.26	33.5	2.4	0.4	0.00	52.2	4.7
Nelson/Motueka	NN518	0.11	2.6	1.3	0.5	0.08	32.7	4.5
Nemona	WD399	0.24	8.9	1.4	0.5	0.02	5.4	3.7

Basal area growth in the trial series

Figure 6 shows the basal area growth in the controls in the 5 trials over the 4 years. The trials cluster into 3 groups. The best site, Maromaku, had over twice the standing basal area of the poorest site, Parengarenga. Three trial sites had similar growth, Nelson, Nemona and Kaingaroa.

In figure 7 the response to the pivotal treatment , 150N:75P, is shown. At Kaingaroa there was no response but at two sites there was a strong response (Nelson and Nemona) while at the other two sites there was a fair but probably not economic response.

In figure 8 the maximum response at each site is shown. At Nelson and Nemona this maximum was 8 m^2/ha over only 4 years. These are very strong responses, not often exceeded in forestry fertiliser trial experience in NZ. Two other sites gave responses of 4 and 6 m^2/ha and only the Kaingaroa site failed to respond. It is interesting that in each case the maximum response came from applications of N and P together.

Can we reduce the rates of fertiliser applied?

Figure 9 shows the response to a rate of N&P similar to that currently advised (150N and 75P) and the response to approximately half that rate (80N and 40P), in relation to growth in the control.

It shows that, at the sites which responded, the lower rate is on average as effective as the higher rate. It would seem therefore that it is possible to further reduce fertiliser application rates.

There are two points which need to be considered however:-

1. Foliar P was lower in 1987 in the lower rate , indicating that the response will not last as long as at the higher rate,

2. Accuracy of distribution becomes critical and may not be achievable routinely.

Trial	Foliar P in 1987		
	control	in 80N:40P	in 150N:75P
Parengarenga	0.115	0.133	0.140
Pipiwai	0.106	0.138	0.148
Kaingaroa	0.185	0.192	0.198
Nelson	0.103	0.107	0.133
Nemona	0.077	0.113	0.109

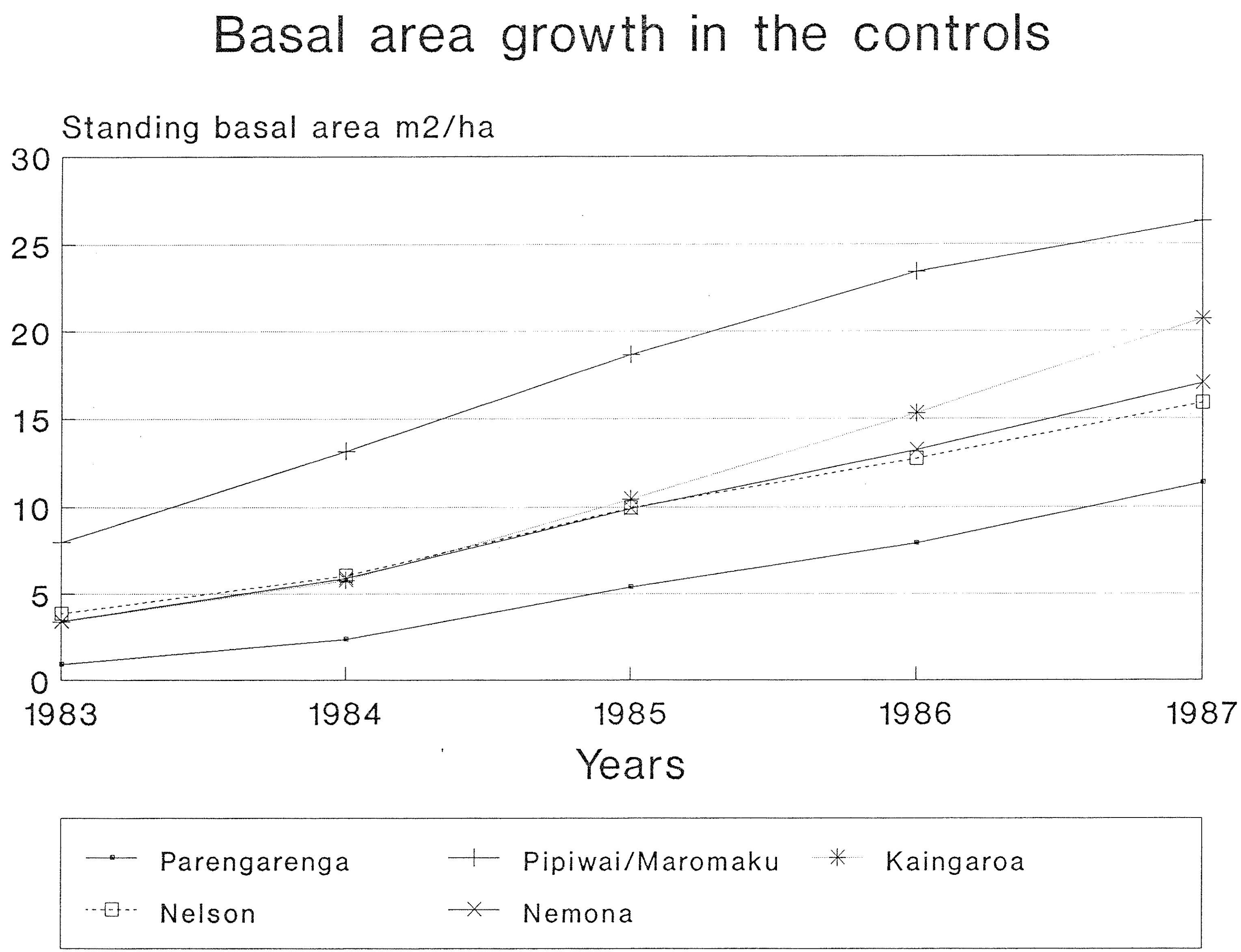
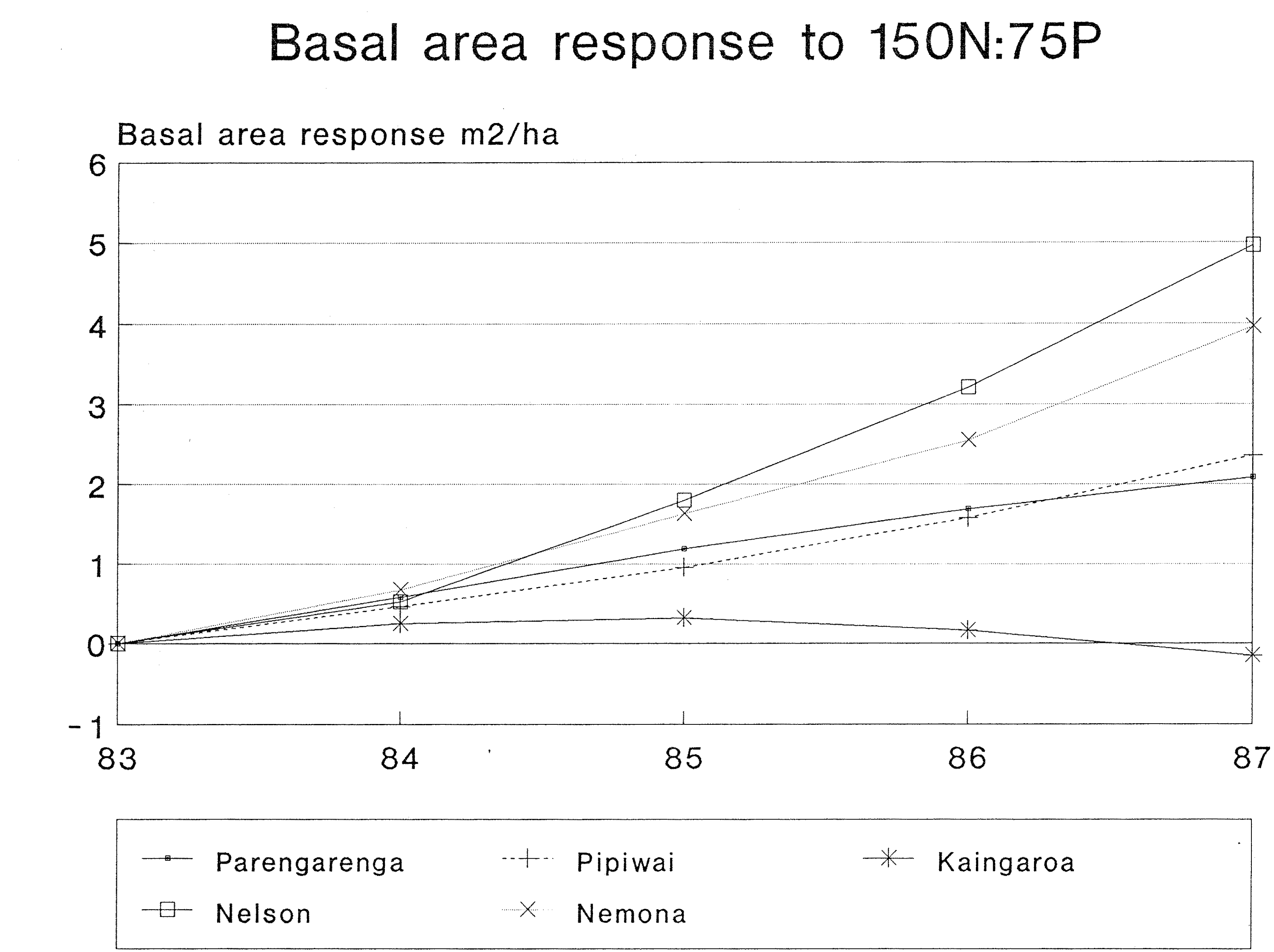

Basal area growth in the controls
Standing basal area m2/ha
30
25
20
15
10
5
0
1983
1984
1985
1986
1987
Years
Parengarenga
Pipiwai/Maromaku
Kaingaroa
Nelson
Nemona

Figure 6



Basal area response to 150N:75P
Basal area response m2/ha
6
5
4
3
2
1
0
-1
83
84
85
86
87
Parengarenga
Pipiwai
Kaingaroa
Nelson
Nemona

Figure 7

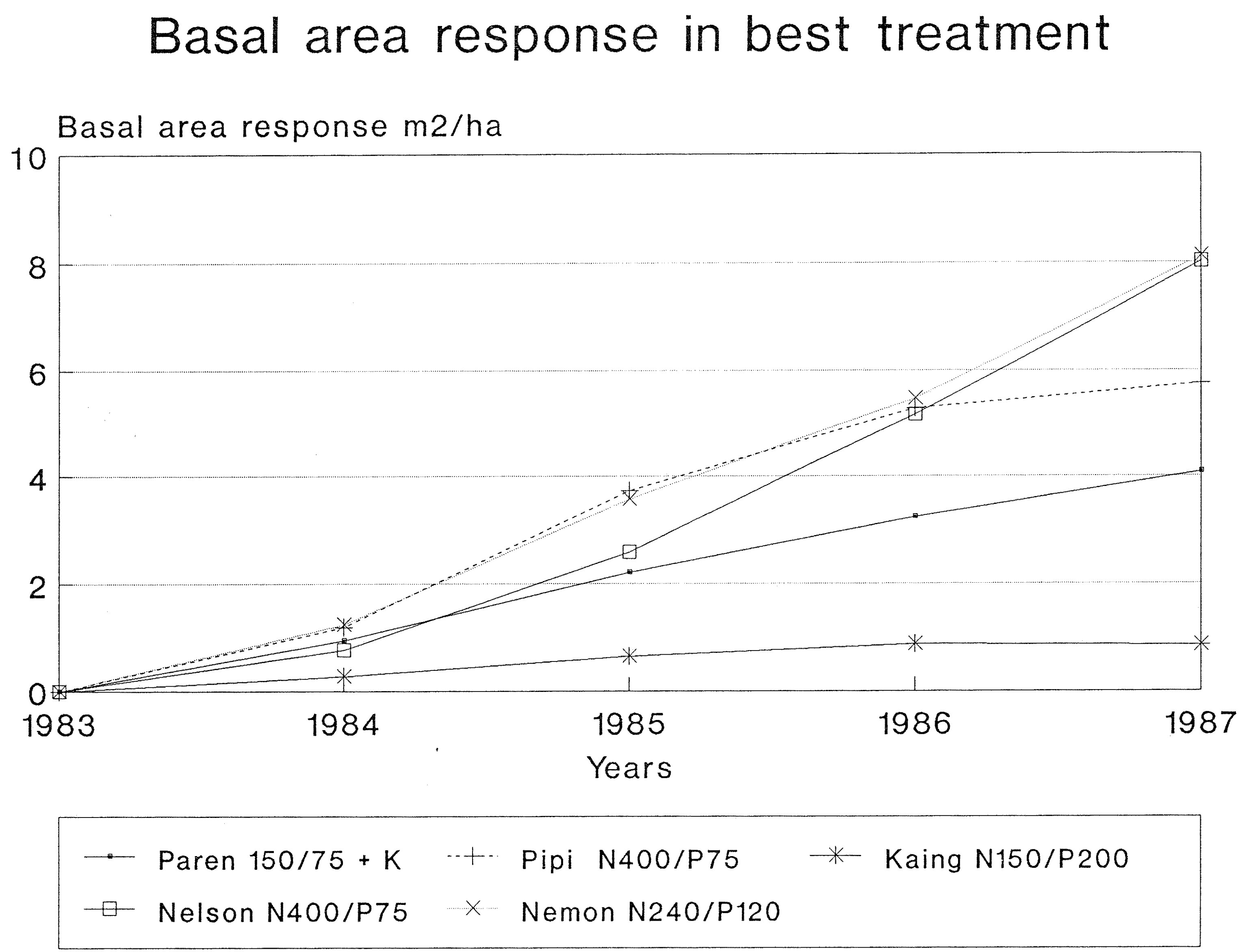
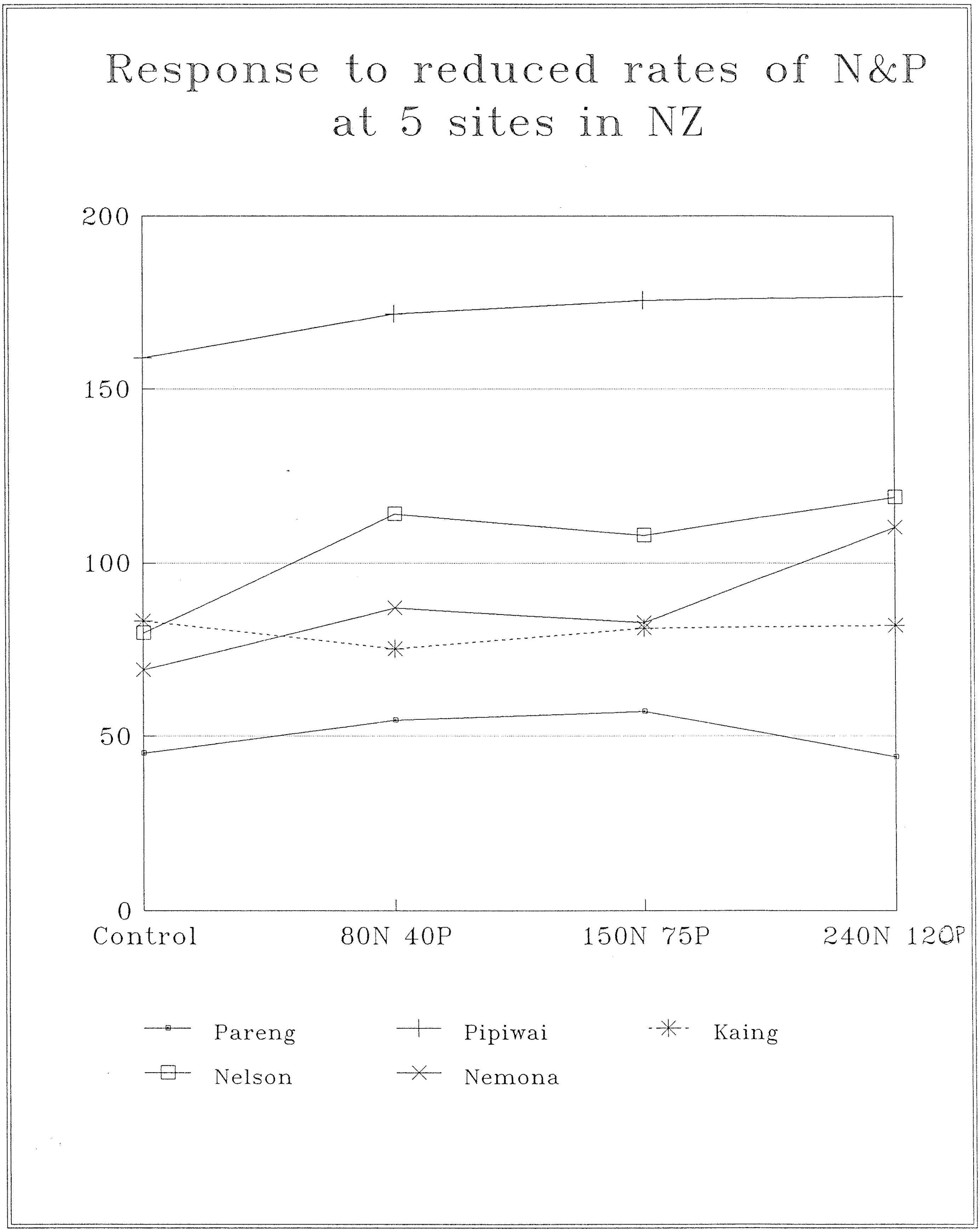

Basal area response in best treatment
Basal area response m2/ha
10
8
6
4
2
0
1983
1984
1985
1986
1987
Years
Paren 150/75 + K
Pipi N400/P75
Kaing N150/P200
Nelson N400/P75
Nemon N240/P120

Figure 8


Response to reduced rates of N&P
at 5 sites in NZ
200
150
100
50
0
Control
80N 40P
150N 75P
240N 120P
Pareng
Pipiwai
Kaing
Nelson
Nemona