Project Record No. 2200

OMAHUTA: AK961.

A NUTRIENT SUBTRACTIVE TRIAL

by

I.R. Hunter, J.D. Graham
and J.M. Prince

Report No 36 May 1989

FRI/INDUSTRY RESEARCH CO_OPERATIVES

EXECUTIVE SUMMARY

ABSTRACT

A trial was established in Omahuta Forest on a strongly podzolised soil to study the effects of varied nutrition on the growth of radiata pine from age 0 to age 6. Various fertilisers were applied in a pure form to the trees on an annual basis so that the effect of omitting one or more elements from the mix could be studied. The main conclusions are:-

1. The site was very strongly P deficient. Applying fertiliser minus P caused poor, sick trees to result.
2. The site became deficient in K. Trees fertilised with all elements excluding K produced only 50% as much growth to age 6 as those thoroughly fertilised with all elements. This is one of our few quantifiable K responses to date.
3. The site became slightly N deficient. Trees fertilised with all elements except N produced 80% as much growth as the All On treatment.
4. The trees proved to be susceptible to the balance of nutrients applied and repeated fertilising with some proprietary fertilisers badly upset their health.
5. At age three half the trial was clearfelled and replanted. The new trees proved to be just as deficient in P, but more deficient in N and K than they were the first time round.

OMAHUTA: AK961
A NUTRIENT SUBTRACTIVE TRIAL

Introduction

In the late 1970's it became increasingly clear that:-

1. in many situations, nutrient deficiencies in radiata pine were complex, involving more than one element.
2. the sources of fertiliser that had been used were no longer necessarily the most cost effective. In particular, single superphosphate was being rapidly replaced as the main source of phosphate. Single superphosphate included substantial amounts of calcium and sulphur and substantial amounts of several micronutrients such as zinc.
3. the balance between nutrients appeared in some circumstances to be critical yet we had no knowledge of desirable ratios.
4. there was evidence that nutrient deficiencies experienced would change and perhaps become more severe in the second and subsequent rotations.

We decided therefore to establish a trial in which the effect of each of many individual nutrient applications could be studied. We decided also to accelerate the nutrient impact on the site by a deliberately accelerated form of nutrient removal: the trees would be whole tree harvested repeatedly.

Methods

A site was selected in Omahuta Forest in 1982. The soil type was a Waikare clay/Wharekohe silt loam with pan complex. As such it was representative of the poorer to poorest soil types established in North Auckland.

Thirty plots of 20*20m size, with 5m surrounds were established in spring 1982. The site had been ripped and roughly bedded and planted with radiata pine in 1982 at normal management spacing. Approximately 1300 s/ha survived in most plots. To these plots a combination of fertilisers was applied as laid out in table 1. There were two replications of the most important treatments. Four replications of the All On treatment were applied in case it became necessary to apply extra treatments. In the event boron concentrations reduced rapidly and in 1984 boron was added to the list of treatments. Two All on plots became minus B plots. The fertilisers applied to these main treatments were of high grade experimental or food quality, in order to ensure that other nutrients were not inadvertently applied with the main treatment. The micro nutrients of copper and zinc were applied partly as a sulphate salt and partly as chelates.

Treatments used at Omahuta

Treatment	Number of Reps
All On (i.e + N,P,K,Ca,Mg,S,Zn,Cu)	4 to 1984 2 from 1984
-P (but plus all others)	2
-N	1
-K	2
-Ca	2
-Cu	2
-Mg	2
-Zn	2
Control (minus everything)	1
Single Super only	1
DAP only	1
Triple Super Only	1
Ammophos only	1
-NP,-NK	2 of former 1 of latter
-S	2
Combinations of nutrients	3
-B	2 from 1984

1 Table 1: Treatments used at Omahuta Nutrient Subtractive Trial

It is very important to note that if a treatment is described as -N (for example) that means that it contains ALL OTHER ELEMENTS NOT EXPRESSLY EXCLUDED i.e. P,K,Ca,Mg,B,etc.

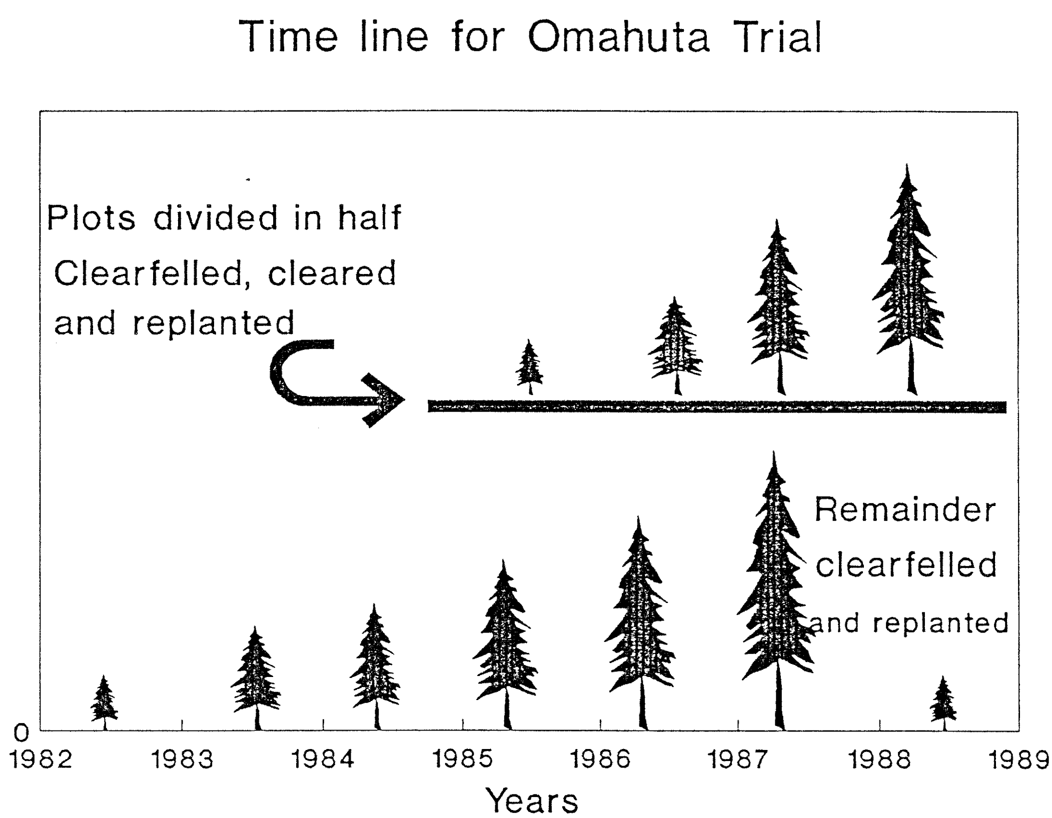
Fertilisers were applied annually in spring. Foliage samples were collected annually in the following autumn. We had, initially, almost no idea of how much fertiliser to apply. Ideas on fertiliser efficiency were not as well developed then. The initial rate was calculated from the above ground biomass content of 4 year old trees. The results of the foliage analysis was used to adjust the amount of fertiliser applied in the following spring. We knew that the uptake rate would be exponential and made multiplicative adjustments.

There was only one plot each of several proprietary fertilisers. Fertilisers used included single superphosphate, triple superphosphate, Ammophos and Di-ammonium phosphate. These fertilisers were applied annually in amounts as closely similar to those in the main treatments as possible, although with the compound fertilisers some compromises were inevitable. We had some information as to what nutrients were missing from the proprietary fertilisers and established plots adjacent with what we believed were complementary treatments, but in pure fertilisers.

One plot was left completely free of all fertiliser.

The cumulative amount of fertiliser applied to the older trees is given in table 2.

Accelerated harvesting began in 1985 when half of each plot was clearfelled, the trees were pulled off the plots into waste areas around the trial and the plots were then replanted. The fertiliser treatment was then divided with the younger trees receiving lesser amounts of fertiliser and the larger trees an adjusted but generally greater amount. A second clearfelling and clearing took place in 1988 when the 6 year old trees were removed and the plots replanted. Currently , in 1989, half of each plot is occupied by 4 year old trees and the other half by 1 year old trees.



2 History of plot development

Table 2: Amount of Fertiliser applied over time at Omahuta Ak961 (Kg/ha elemental)

	Year						Total
Element	1982	1983	1984	1985	1986	1987	
Nitrogen	83	83	124	248	338	338	1213
Phosphorus	10	10	20	40	50	50	180
Potassium	27	27	41	81	82	82	642
Calcium	6	6	6	6	7	7	40
Magnesium	12	12	12	23	25	25	108
Copper	1	1	2	2	4	4	14
Zinc	1	1	2	2	4	4	14

Results

This trial has yielded a fascinating series of foliar nutrient analyses and growth patterns. The influence it has had on our thinking about pine nutrition, on the type of wider scale research that is needed, and on practical fertiliser strategies will become very apparent.

We will present the results in the following manner:-

1. The pattern of foliar nutrient concentrations in the main elements.
2. The pattern of foliar nutrient concentrations in the proprietary fertiliser plots
3. What happened to key elements when the plots were clearfelled and replanted.
4. The pattern of growth response.

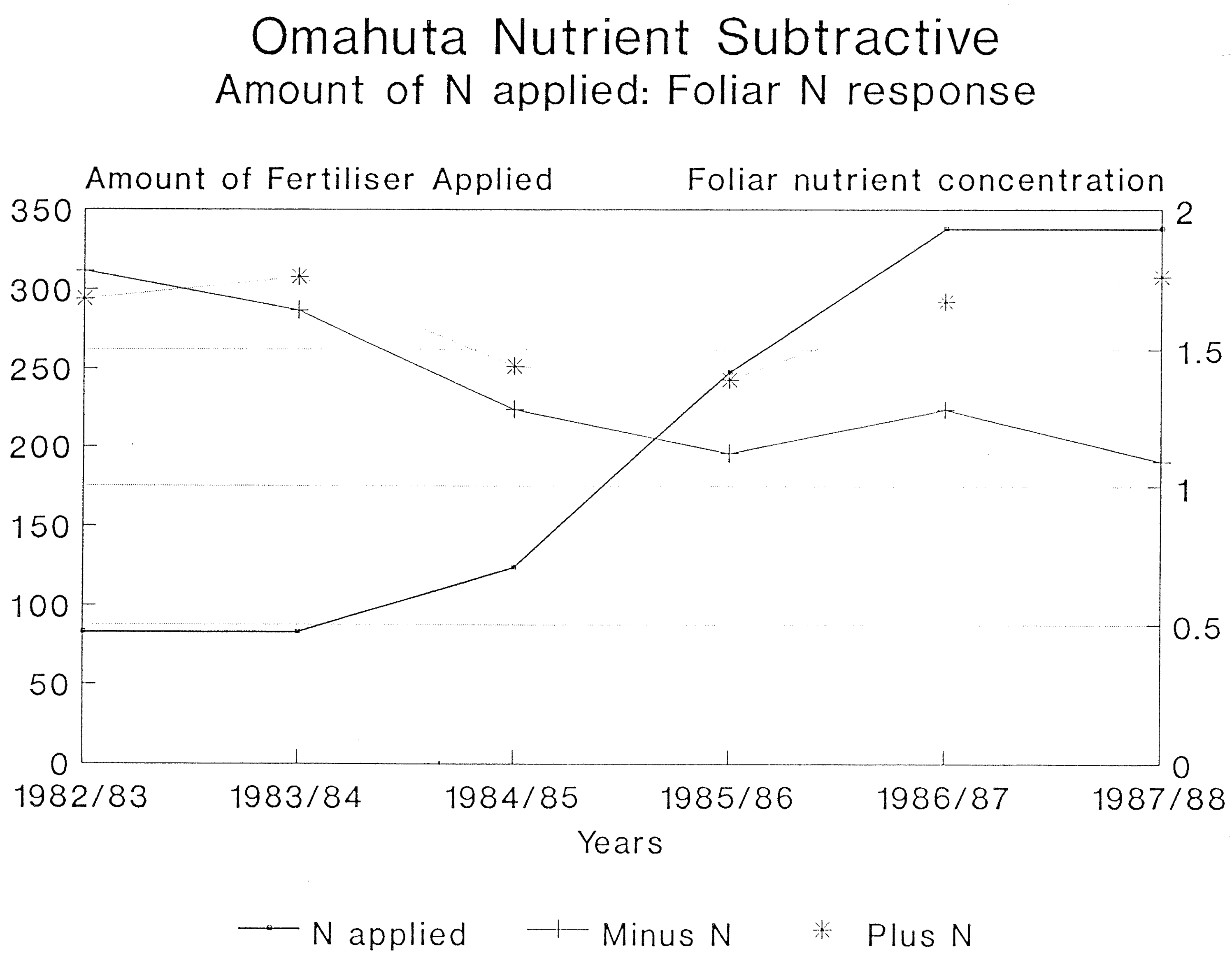
1. Foliar nutrient concentrations

Foliar Nitrogen.

These soils tend to be low in available nitrogen. Figure 1 shows what happened to foliar nitrogen following planting. Initially foliar N concentrations were very adequate (1.6 to 1.7%) and remained at that level for two years. Elevated N concentrations in the first couple of years are normal on most soil types. The reasons for the adequacy of N early on are probably to be found in the site preparation treatments which bring about an increase in aeration in the soil, and an increase in mineralisation. The effect is however short lived. Nevertheless it's prevalence helps explain why N responses analogous to those experienced with P fertilisers are rarely experienced at time of planting. Then the trees began to enter the exponential phase of growth and foliar N concentrations declined rapidly in the -N plot. Since the trees were 3 years old foliar N concentrations in this plot have never exceeded 1.25%. The surge of growth in the +N plots was so sudden that our fertiliser increments were not adequate to compensate for it, and foliar N concentrations fell just below 1.5% for two years when the trees were 3 and 4. Subsequently the increased amounts of applied fertiliser have been sufficient to raise and hold foliar N above 1.5%. Cumulatively 1213kg/ha of N have been applied to the plots. We would expect the fertilised trees to contain approximately 200 kg/ha[1]. The non-fertilised trees were smaller and had a lower N concentration. They would therefore have contained an appreciable amount of N, probably in excess of 100 kg/ha. An uptake efficiency of considerably less than 15% is indicated.

---

[1] Madgwick, H.A.I , Jackson, D.S. and Knight P.J 1977; dry Matter and Nutrient Data on **Pinus radiata** Trees and Stands. New Zealand Forest Service Forest Research Institute Soils and Site Productivity Report no 94. Unpublished



Omahuta Nutrient Subtractive
Amount of N applied: Foliar N response
Amount of Fertiliser Applied
Foliar nutrient concentration
350
300
250
200
150
100
50
0
2
1.5
1
0.5
0
1982/83
1983/84
1984/85
1985/86
1986/87
1987/88
Years
N applied
Minus N
Plus N

Fig 1.

Foliar Phosphorus.

The soil is very low in available P. So low in fact that the unfertilised trees never had a P concentration greater than 0.07%. After two years that concentration fell to between 0.05 and 0.06%. The initial amounts of fertiliser applied were adequate to raise foliar P to over 0.15% (Figure 2) but despite repeated and increasing amounts of fertiliser foliar P fell to 0.093% at age 3 before the higher amounts of fertilisers applied in later years brought it back up again to 0.13%. The fertiliser used, monocalcium phosphate, is the pure form of the phosphorus fertiliser contained in both triple and single superphosphate. (In single superphosphate the rock P is reacted with sulphuric acid so the fertiliser consists of a mixture of MCP and Calcium Sulphate, but in triple superphosphate the rock is reacted with phosphoric acid so the fertiliser contains twice as much MCP). MCP is very highly soluble. Forty kilograms of P were applied before the third foliage sample was taken. Normal applications of P fertiliser at time of planting apply approximately 20 - 25 kg ,once, in a concentrated dose adjacent to each tree.

Trees in Kaingaroa had accumulated 40 kg/ha of P in their above ground parts by age 6 [1]. The fertilised trees would have had approximately the same amount, while the unfertilised trees were extremely small and would have had very little P in them. We had applied 180 kg of P as fertiliser indicating a much higher utilisation efficiency than for N, approaching 20%.

Foliar Potassium

In recent years the plantings on the podzol soils of North Auckland have proved to be marginal or deficient in potassium. Foliar potassium concentrations in the minus K plots at this site were very adequate in the first of year (figure 3), at 1.0%K. However from the second foliage collection onwards they declined into a strong and persistent deficiency. Although concentrations as low as 0.3% were reached visual symptoms (yellow tipped needles) were not present at all seasons, being strongly visible only in the winter. An early availability of K which is rapidly exhausted seems to be characteristic of many sites. Again it helps to explain why soluble fertilisers applied at time of planting rarely give a growth response, even in stands that are later responsive to K. Potassium fertilised plots declined in concentrations in the third year to approximately 0.6%. A slightly higher concentration might have been preferable. Half as much K has been applied cumulatively as N. Trees in Kaingaroa had 184 kg/ha of K at age 6. As with N, the unfertilised trees were smaller and had a lower K concentration. They would nevertheless have contained appreciable amounts of K (probably 100 kg/ha) which suggests a fertiliser efficiency of approximately 10 -15%.

Foliar Magnesium.

Some of the clay soils and some of the podzols, particularly away from sea influence, have given Mg concentrations below 0.10% and at times as low as 0.08%. For that reason Mg was included as a treatment in this trial. Cumulatively 108 kg/ha of magnesium have been applied as pure calcium carbonate. Trees in Kaingaroa contained 33 kg/ha of Mg at age 6. The minus Mg plots had adequate concentrations for the first two years and then declined to marginal (approximately 0.08%) from age 3 onwards. The fertilised plots behaved in the way we have all

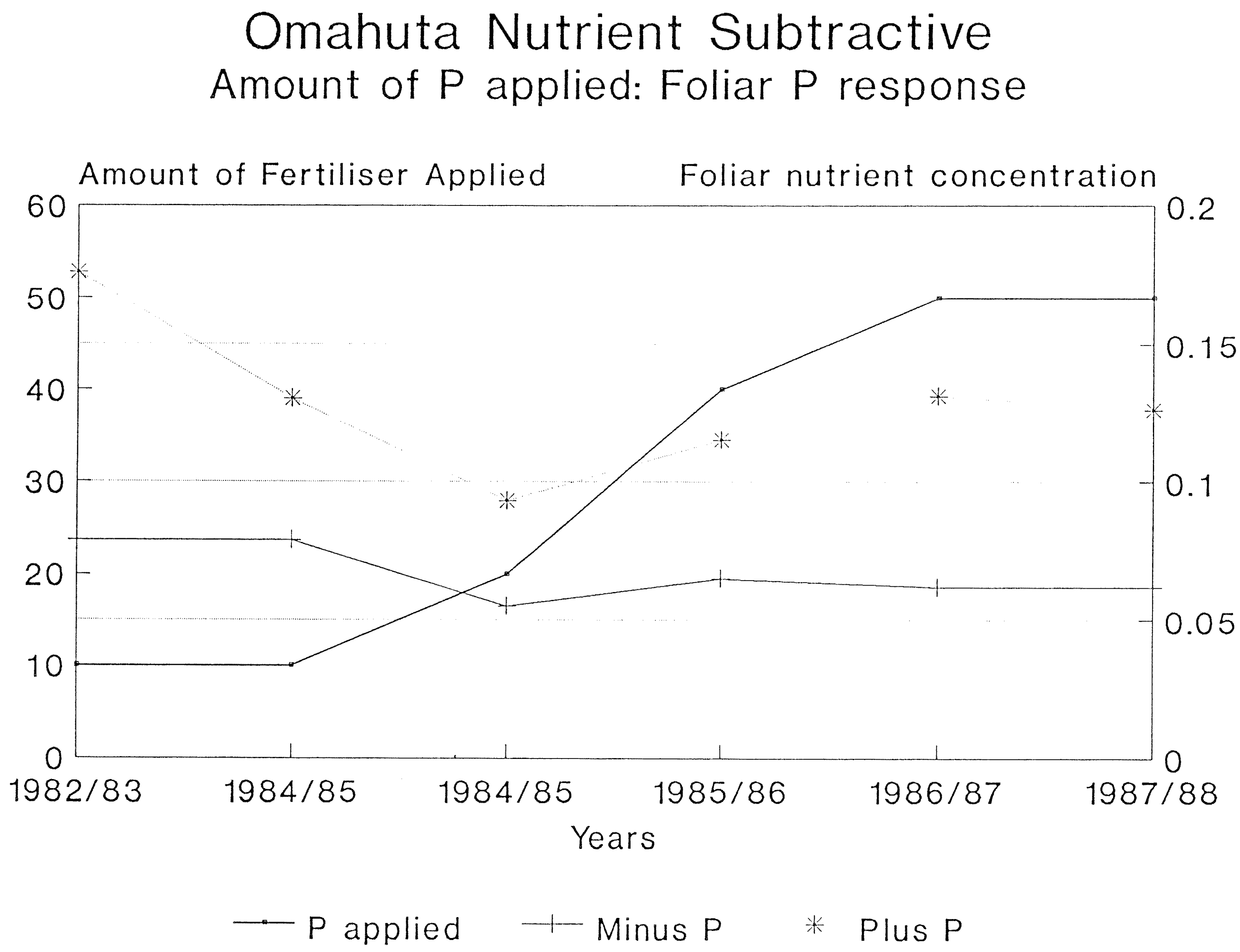

Omahuta Nutrient Subtractive
Amount of P applied: Foliar P response
Amount of Fertiliser Applied
Foliar nutrient concentration
60
50
40
30
20
10
0
0.2
0.15
0.1
0.05
0
1982/83
1984/85
1984/85
1985/86
1986/87
1987/88
Years
P applied
Minus P
Plus P

Fig 2.

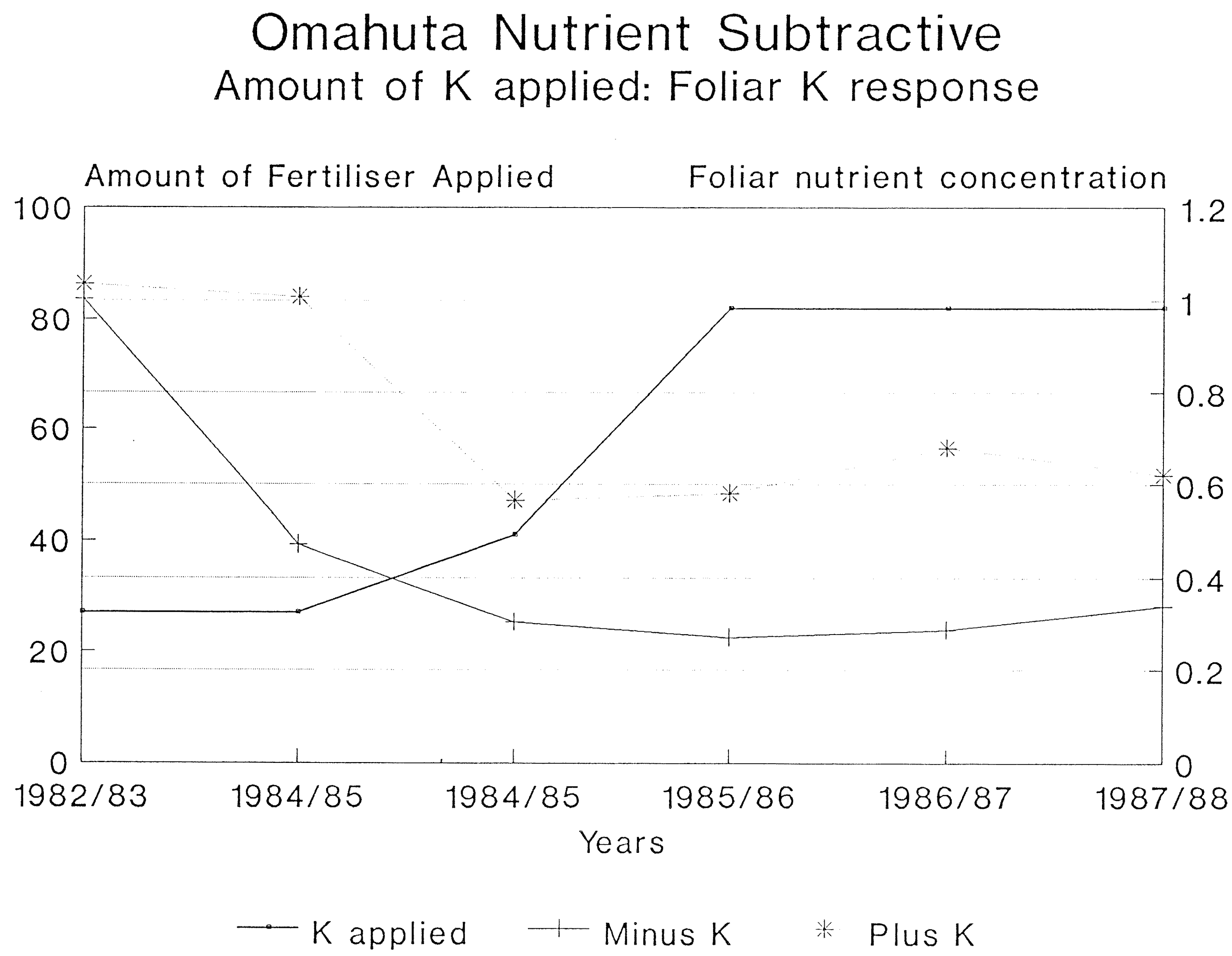

Omahuta Nutrient Subtractive
Amount of K applied: Foliar K response
Amount of Fertiliser Applied
Foliar nutrient concentration
100
80
60
40
20
0
1.2
1
0.8
0.6
0.4
0.2
0
1982/83
1984/85
1984/85
1985/86
1986/87
1987/88
Years
K applied
Minus K
Plus K

Fig 3.

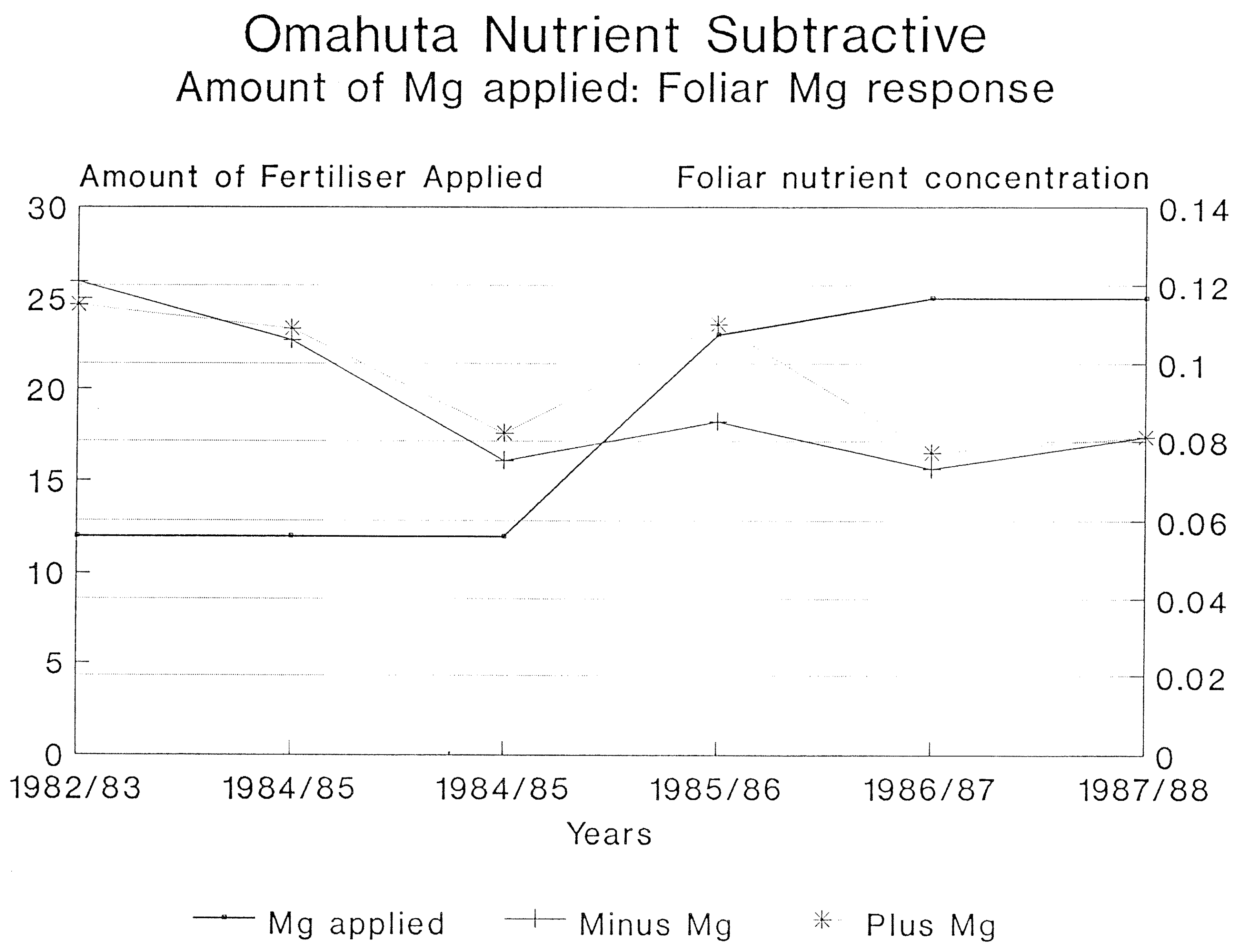

Omahuta Nutrient Subtractive
Amount of Mg applied: Foliar Mg response
Amount of Fertiliser Applied
Foliar nutrient concentration
30
25
20
15
10
5
0
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1982/83
1984/85
1984/85
1985/86
1986/87
1987/88
Years
Mg applied
Minus Mg
Plus Mg

Fig 4.

come to recognise and cherish! Magnesium concentrations were barely affected by the applied fertiliser. The fertiliser source used here was also used in the Mg*Ca trial in Southern Kaingaroa where it proved to be adequately soluble over the time period spanned by this trial. There was no size difference between fertilised and unfertilised plots and a minimal foliar concentration difference. A very low uptake percentage is indicated.

Foliar Zinc.

Zinc concentrations were deficient in trials both at Cape Karikari and at Utakura on a similar soil type. For this reason a minus Zn treatment was included in this trial. Zinc concentrations decreased from 30 ppm in the minus Zn plots in the early years to just over 20 ppm in the latter years. Where Zn was applied foliar Zn concentrations remained above 30 ppm. We do not know yet exactly what concentration of zinc to expect in the foliage at the boundary between a marginal and deficient situation. We know that a concentration much under 10 ppm is associated with die-back of the leader and is corrected by Zn fertiliser. We do not know whether 10,15 or even 20 ppm is marginal. Certainly in this trial there have been no overt symptoms as yet while in AK976/1 at Parengarenga, where zinc concentrations fell to between 10 and 15 ppm there were some signs of Zn deficiency.

Trees in Kaingaroa contained 1.15 kg/ha of Zn at age 6. Average foliar Zn concentrations were much higher in Kaingaroa (averaging approximately 50 ppm), so we would expect a lower content overall at Omahuta. We have applied 14 kg/ha of Zn as fertiliser. There was no size difference between fertilised and unfertilised plots so the difference due to fertilising would be encompassed by the 50% rise in foliar Zn and probably in associated tissue. This means that fertiliser uptake must have been in the region of 0.5 kg or under 5% of that applied.

Foliar Copper.

Foliar copper was adequate regardless of treatment for the first 2 years. In the third year Minus Cu treatments fell to below 3ppm and down to 2 ppm in the 4th and 5th year. The level of twisting in the plots was fairly low and difficult to distinguish from the lingering effects of toppling. It seems from this and other trials that the level at which the branch twisting symptoms onset is probably below 2ppm.

Foliar Calcium.

The symptoms of leader die-back associated with extreme phosphorus deficiency have been ascribed to calcium deficiency. We have one other trial in Riverhead that also studies Ca*P interactions. Calcium, like magnesium, is a difficult element to experiment with because radiata pine is reluctant to take it up. The minus Ca plots had very similar concentrations to those in the All On plots (taking into account the high year to year variability).

Foliar Boron.

The first foliage collection revealed an unexpectedly low average boron concentration in the foliage. It was decided to apply B to half of the original 4 All On plots and to most of the other plots. The exceptions were the plots that had proprietary fertilisers and those that

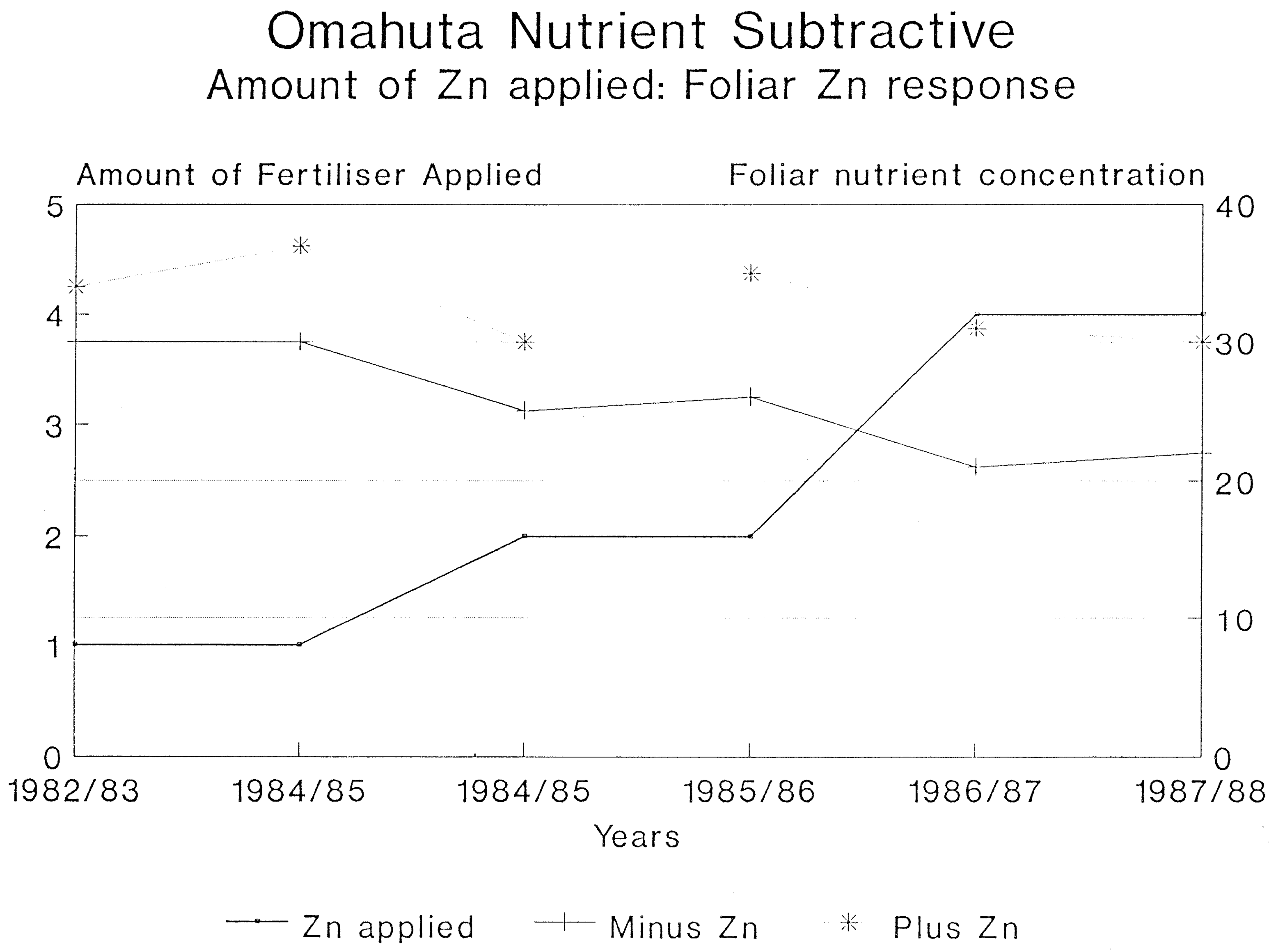

Omahuta Nutrient Subtractive
Amount of Zn applied: Foliar Zn response
Amount of Fertiliser Applied
Foliar nutrient concentration
5
4
3
2
1
0
40
30
20
10
0
1982/83
1984/85
1984/85
1985/86
1986/87
1987/88
Years
Zn applied
Minus Zn
Plus Zn

Fig 5.

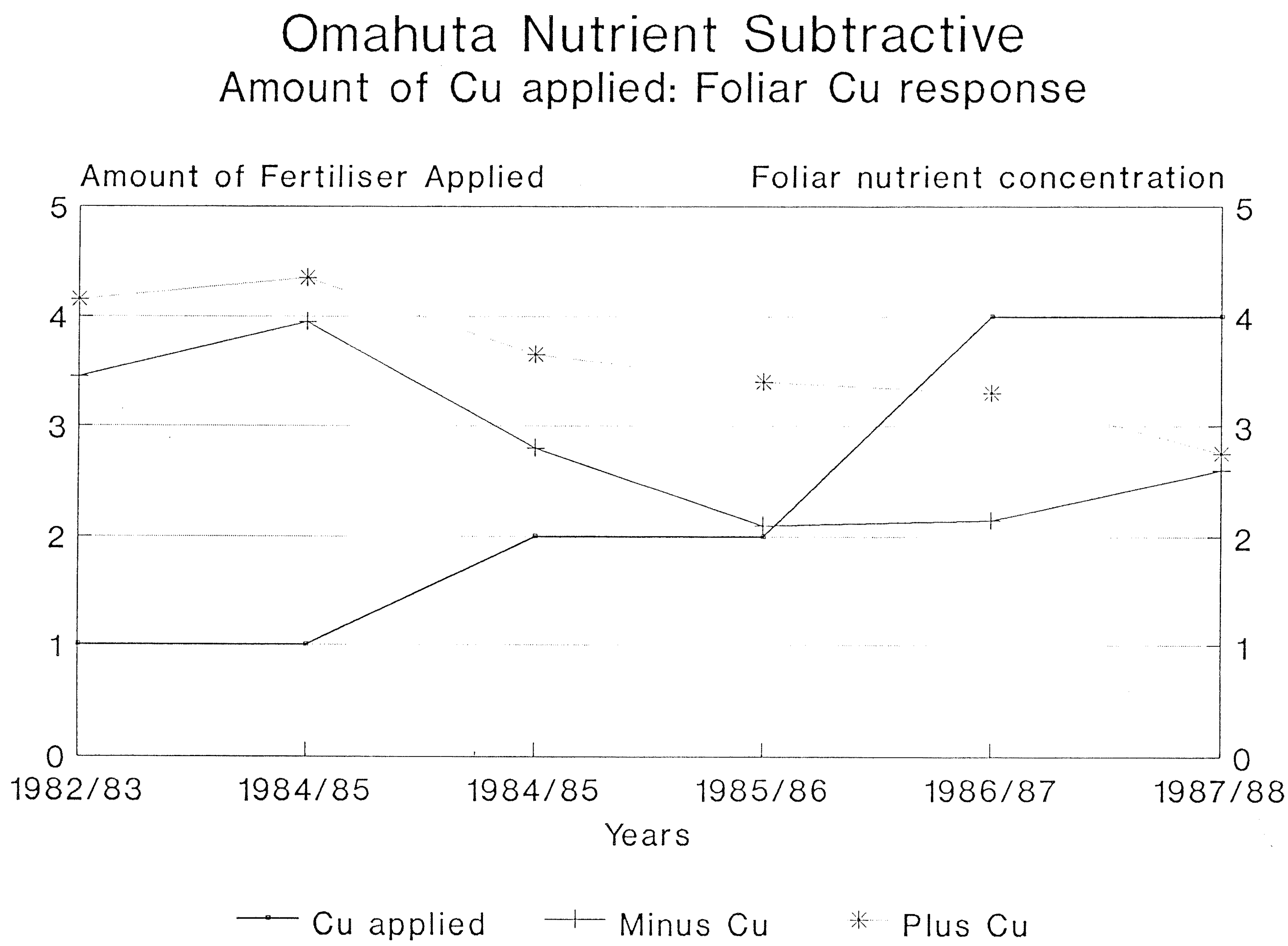

Omahuta Nutrient Subtractive
Amount of Cu applied: Foliar Cu response
Amount of Fertiliser Applied
Foliar nutrient concentration
5
4
3
2
1
0
1982/83
1984/85
1984/85
1985/86
1986/87
1987/88
Years
Cu applied
Minus Cu
Plus Cu

Fig 6.

"mimicked" the proprietary plots. Foliar B in the B fertilised plots has fluctuated between 15 and 30 ppm since, but in the new -B plots dropped to an average of 5.5 ppm in 1985 and has stayed between 5 and 7 ppm since. There has been a low incidence of tip die back. This is a new and unexpected finding.

Boron concentrations in some of the proprietary fertiliser plots also became deficient. For example the Ammophos plot, which otherwise was the best performing of the bag fertilisers, had a boron concentration of only 10, 9 and 8 ppm in 1986-88 respectively. The DAP plot was at 9 ppm in 1988. The Single Super plot was at 10 ppm and the Triple Super at 9 ppm. Interestingly the analogue plots were very similar. The analogue to DAP was at 7 ppm; the analogue to Ammophos at 7 ppm; the analogue to Single Super at 10 ppm and the analogue to Triple Super at 8 ppm.

Foliar Sulphur.

Foliar sulphur concentrations appear to have been slightly increased by sulphur fertilisation from 0.08% in the minus S plots to 0.1% in the All On plots. There is really no evidence that the sulphate in Single Superphosphate has raised foliar S over that in the All On plots, however. Of more interest is the fact that N:S ratios are, at nearly 20:1 over the trial as a whole, rather wide. We have no field evidence of S responses unlike the documented responses in the Pacific North West of America. However if we were to experience S responses this site appears to be one of the most likely.

2. Foliar nutrient concentrations in the proprietary fertiliser plots

The DAP fertilised plot.

Di-ammonium phosphate fertiliser has an 18:20 N:P ratio. The All On plots have been fertilised at a 6.7:1 ratio of N to P. The rate of DAP used had therefore to be a compromise. Figure 7 shows the result of 6 years of fertilising with an N:P fertiliser with a ratio close to 1:1. In this graph and in the following 3 (Figs 8-10) foliar nutrient concentrations are shown as a ratio of those in the All On plots. A value of 1 indicates that concentrations remained similar to those in the All On plots. A rising value indicates that foliar concentrations in the plot rose relative to the All On plot. Thus in this plot foliar P increased relative to the All On plots while foliar N decreased relatively because there was not enough N in the fertiliser to hold foliar N concentrations up. Foliar potassium concentrations and foliar copper concentrations decreased sharply to very low levels. The copper concentrations given in table 5 may not be accurate for 1987 and 1988 because a previously unexperienced black deposit formed in the digested sample and interfered with analytical determination. There is no doubt though that the concentrations were very low. In addition foliar boron concentrations were low.

In tables 2 to 5 the foliar concentrations for the DAP plot, the All On plots and the complete control are given and ratios of nutrients calculated. The All On and complete controls give an indication of the normal ratios to be expected between nutrients. N:P ratios for radiata pine are generally between 10 and 12. In the All On and Control plots they vary between 9.5

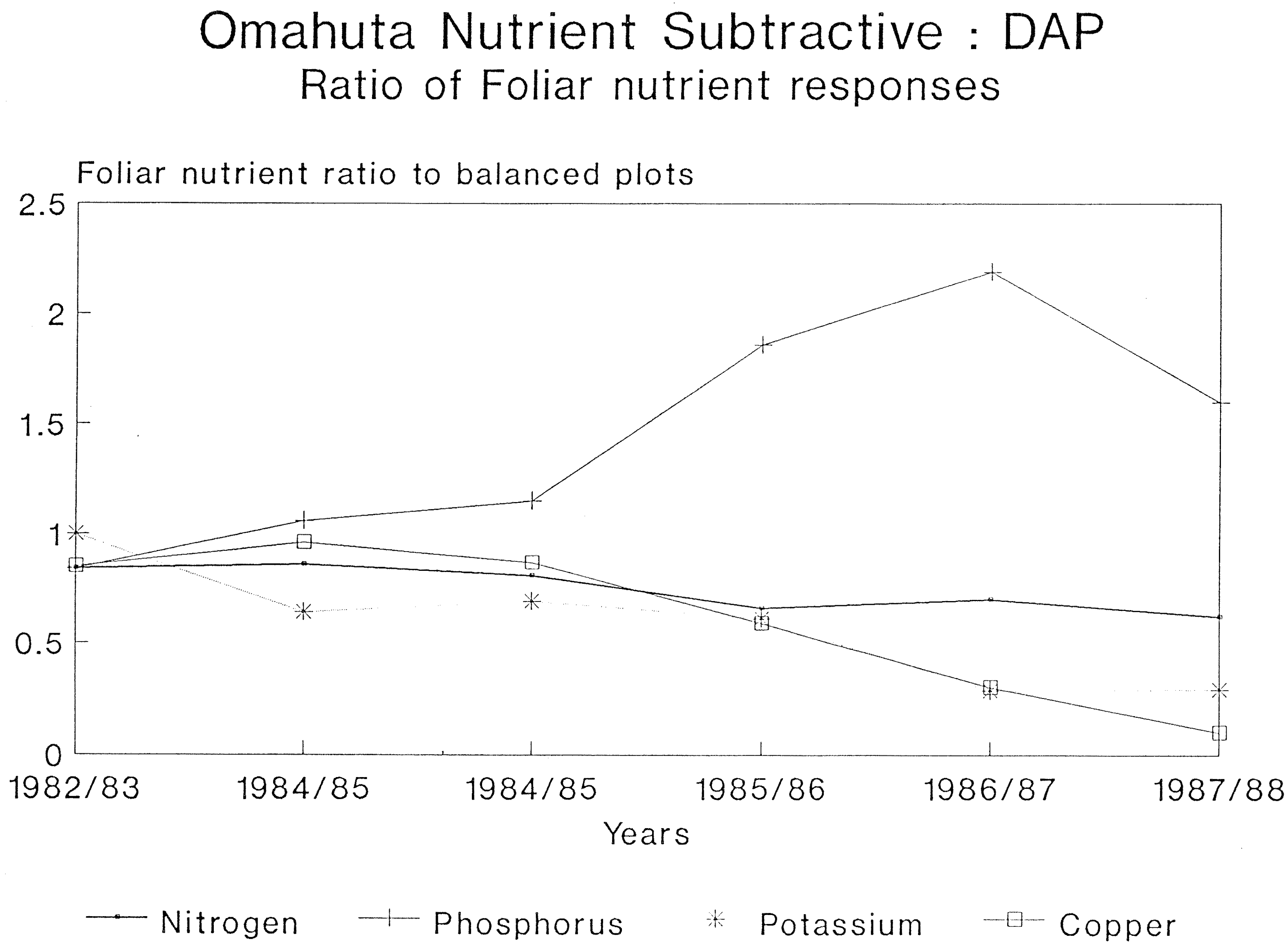

Omahuta Nutrient Subtractive : DAP
Ratio of Foliar nutrient responses
Foliar nutrient ratio to balanced plots
2.5
2
1.5
1
0.5
0
1982/83
1984/85
1984/85
1985/86
1986/87
1987/88
Years
Nitrogen
Phosphorus
Potassium
Copper

Fig 7.

Table 3: Nutrient concentrations in the control

Element	1983	1984	Year 1985	1986	1987	1988
Nitrogen	1.37	1.83	1.31	1.10	1.24	1.05
Phosphorus	0.09	0.12	0.10	0.09	0.10	0.10
Potassium	1.03	0.61	0.40	0.46	0.45	0.46
Calcium	0.18	0.19	0.16	0.20	0.17	0.11
Magnesium	0.12	0.14	0.10	0.11	0.09	0.10
Boron	17		11	12	10	9
Zinc	29	53	34	46	35	37
Copper	4.2	6.4	3.5	3.2	3.5	3.2
N:P ratio	15.0	14.9	12.6	12.5	12.5	10.6
K:P ratio	11.3	5.0	3.8	5.2	4.5	4.6
N:K ratio	1.3	3.0	3.3	2.4	2.8	2.3
Cu:N ratio	3.1	3.5	2.7	2.9	2.8	3.1
K:(Ca+Mg) ratio	3.4	1.9	1.6	1.5	1.7	2.2

Table 4: Nutrient concentrations in the ALL ON plots

Element	Year 1983	1984	1985	1986	1987	1988
Nitrogen	1.68	1.76	1.44	1.39	1.67	1.76
Phosphorus	0.18	0.13	0.09	0.12	0.13	0.13
Potassium	1.04	1.01	0.57	0.58	0.68	0.62
Calcium	0.18	0.13	0.11	0.15	0.12	0.09
Magnesium	0.11	0.11	0.07	0.11	0.08	0.08
Boron	16		23	17	29	17
Zinc	34	37	30	35	31	30
Copper	4.2	4.4	3.7	3.4	3.3	2.8
N:P ratio	9.5	13.5	15.5	12.1	12.7	14.0
K:P ratio	5.9	7.8	6.1	5.0	5.2	4.9
N:K ratio	1.6	1.7	2.5	2.4	2.5	2.8
Cu:N ratio	2.5	2.5	2.6	2.4	2.0	1.6
K:(Ca+Mg)	3.6	4.2	3.1	2.2	3.4	3.8

Table 5: Nutrient concentrations in the DAP Fertilised plot

	Year					
Element	1983	1984	1985	1986	1987	1988
Nitrogen	1.42	1.52	1.17	0.93	1.17	1.10
Phosphorus	0.15	0.14	0.11	0.22	0.29	0.20
Potassium	1.02	0.65	0.39	0.23	0.19	0.18
Calcium	0.16	0.17	0.15	0.22	0.25	0.21
Magnesium	0.12	0.14	0.11	0.13	0.12	0.20
Boron	15		11	17	10	9
Zinc	33	32	29	23	31	25
Copper	3	4.2	3.2	2	1	0.3
N:P ratio	9.5	11.0	10.9	4.3	4.1	5.4
K:P ratio	6.9	4.7	3.7	1.1	0.7	0.9
N:K ratio	1.4	2.3	3.0	4.0	6.0	6.0
Cu:N ratio	2.1	2.8	2.7	2.2	0.9	0.3
K:(Ca+Mg) ratio	3.6	2.1	1.5	0.7	0.5	0.4

and 15.5. However in the DAP plot they progressively decrease to 5.4. K:P ratios are generally between 5 and 8. In the controls and All On plots, once the initial settling down year is past, they stabilise at between 3.8 and 7.8. However in the DAP plot they decrease to below 1. N:K ratios are generally between 1.5 and 3. The All On and control plots have ratios between 1.7 and 3.3 (once the first year is past). Work done in Australia suggests that the ratio of Cu (as ppm) and N (as %) should be greater than 2. It is greater than 2 in the controls and All On plots (except for 1988 in the All On) . However in the DAP plot it is below 2 from 1987 onwards.

The ratio of potassium to (calcium plus magnesium) is generally between 2 and 5. The All On plot is between these limits but the control, because of low potassium concentrations is low and the DAP plot is very low.

We know that by 1988 the DAP plot looked very sick. It had a very flat branch angle, slow growth, only one years needle retention tufted on the end of the branches. We do not yet know how to really interpret the information we are getting from the foliar nutrient ratios. Many of them are very odd but we cannot yet weight them in order of importance and identify which of them are likely to be critical. This trial is the only one with sufficient control to research and identify these factors.

Single Superphosphate.

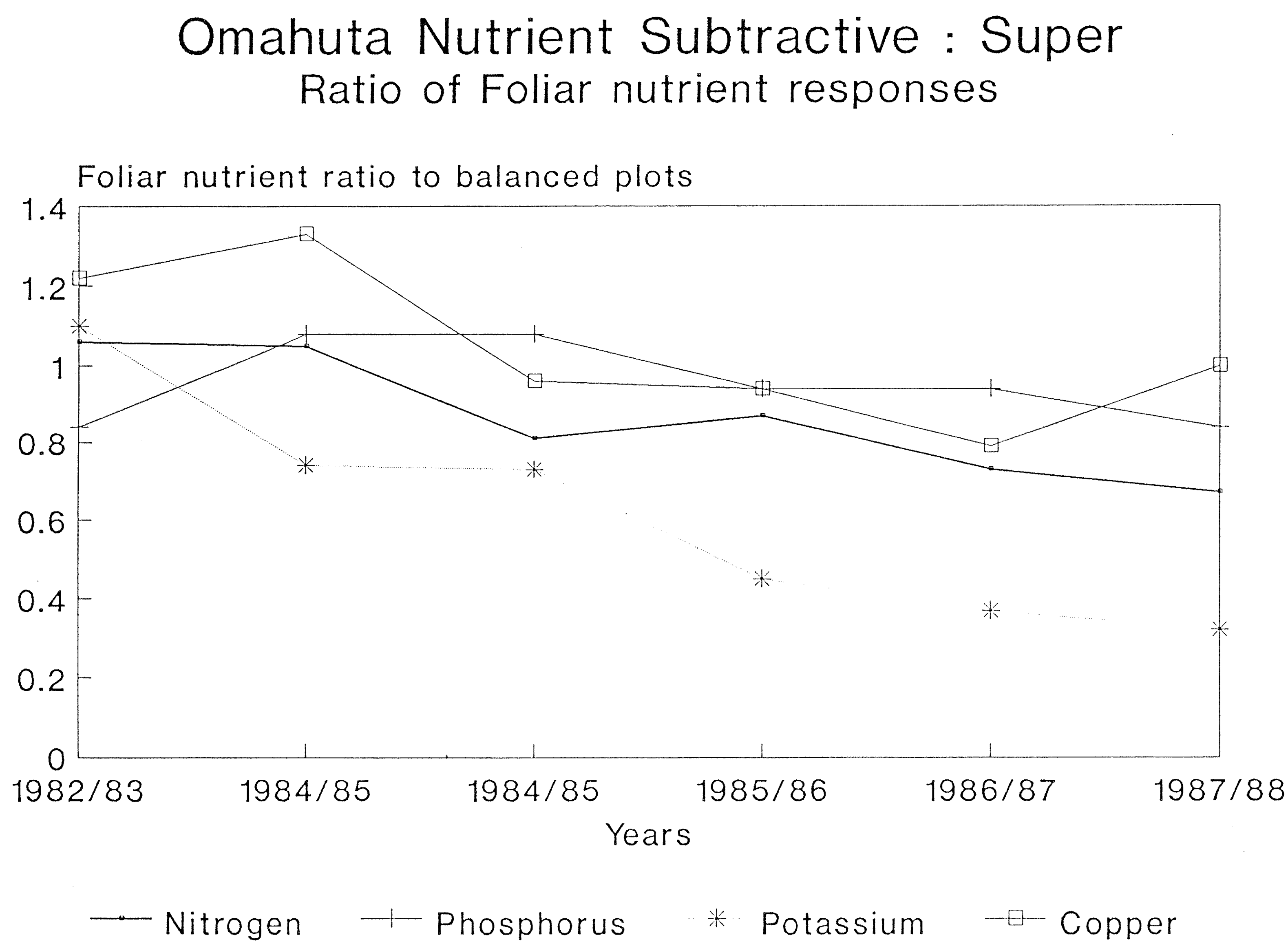
Figure 8 shows the foliar nutrient concentrations in the Single Super plot expressed as a ratio of those in the ALL ON plots. Fertilising with Single Super did not involve the kinds of compromise between multiple elements that occurred with Ammophos and DAP. The P concentrations remained close to those in the ALL ON plots. The N concentrations declined slowly but copper concentrations remained high. Single Super is believed to usually contain useful amounts of Cu. Foliar K concentrations decreased markedly. Just prior to clearfelling these trees looked K deficient, appeared to be slightly N deficient, had high branch angles and restricted diameter growth. They looked like typical Northland trees!

Ammophos.

The Ammophos plot was the best on the site, with large dark-green-foliaged trees. Figure 9 shows that applying fertiliser with an N:P:K ratio of 15:7:5 was nearly optimal. Foliar P concentrations rose a little and foliar N concentrations decreased marginally as did foliar K concentrations. However the nutrient ratios remained more normal than those in the DAP plot. Foliar Cu remained high also. This is difficult to relate to what happened in the DAP plot since both are pure fertilisers low in Cu. Perhaps the low Cu concentration in the DAP plot is the result of disordered nutrition.

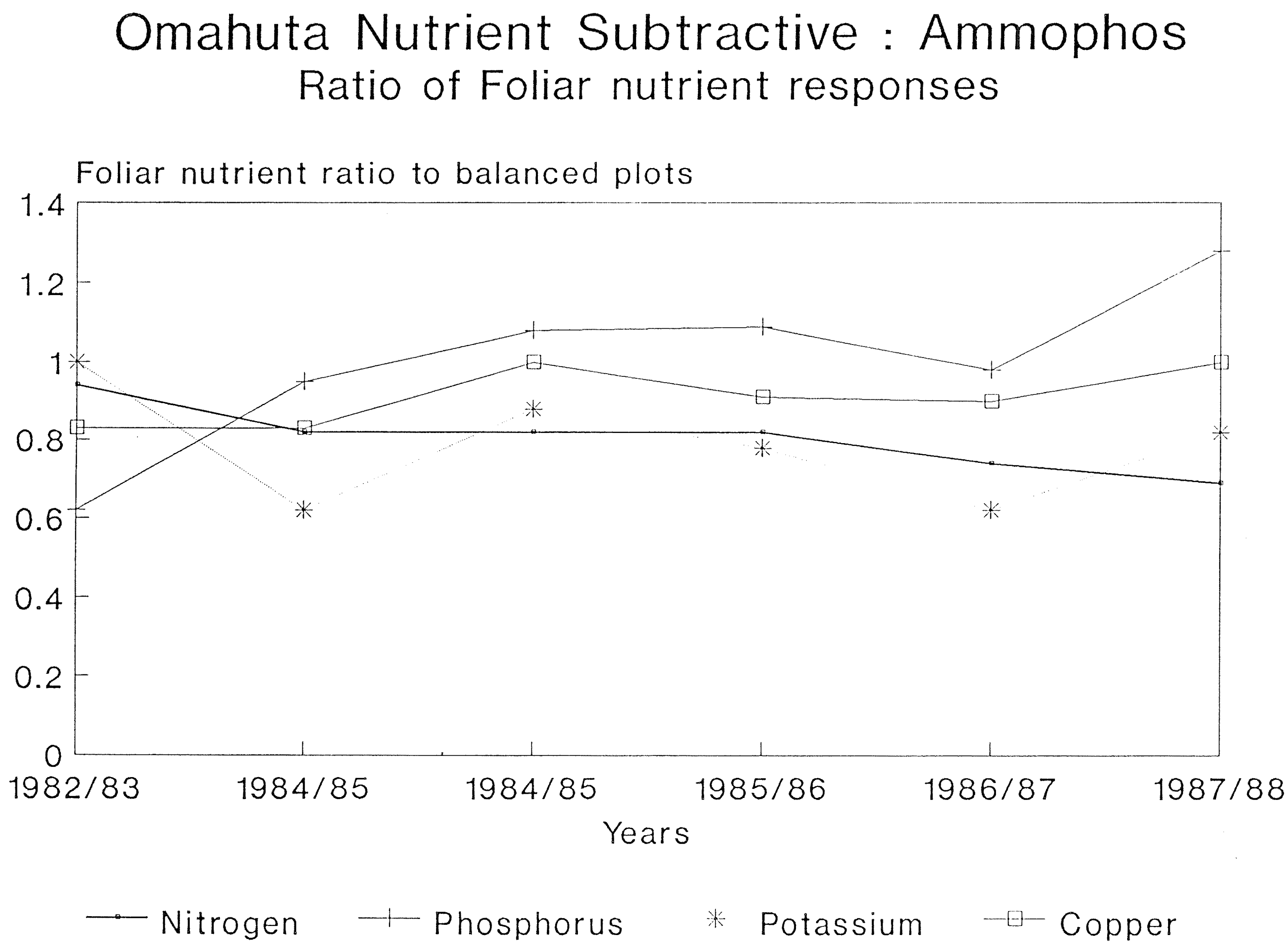
Triple Superphosphate.

The Triple Super plot was very similar in behaviour to the Single Super plot. Foliar p and Cu remained close to those in the ALL ON plots; foliar N decreased slightly and foliar K decreased more markedly.



Omahuta Nutrient Subtractive : Super
Ratio of Foliar nutrient responses
Foliar nutrient ratio to balanced plots
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1982/83
1984/85
1984/85
1985/86
1986/87
1987/88
Years
Nitrogen
Phosphorus
Potassium
Copper

Fig 8.



Omahuta Nutrient Subtractive : Ammophos
Ratio of Foliar nutrient responses
Foliar nutrient ratio to balanced plots
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1982/83
1984/85
1984/85
1985/86
1986/87
1987/88
Years
Nitrogen
Phosphorus
Potassium
Copper

Fig 9.

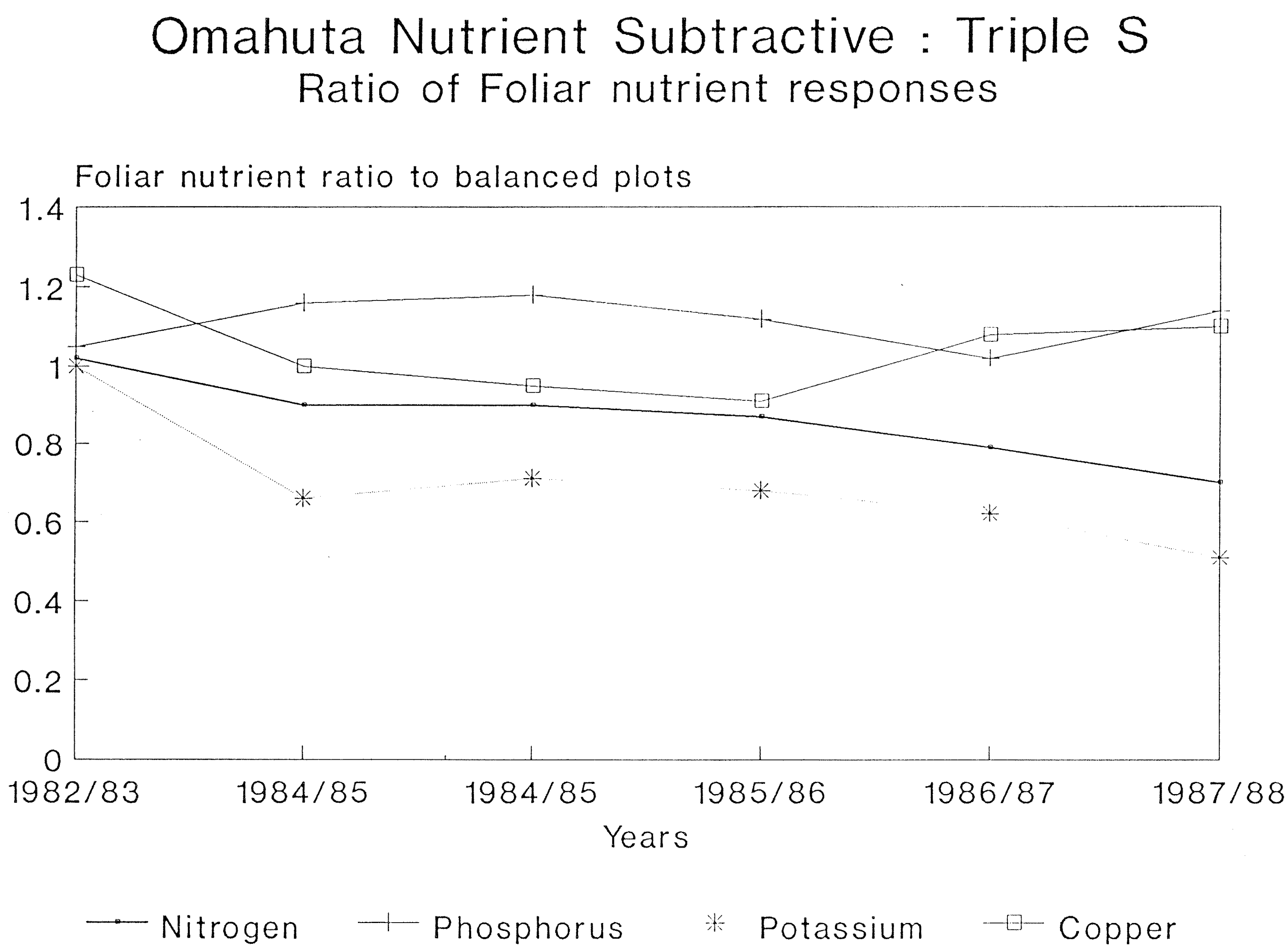

Omahuta Nutrient Subtractive : Triple S
Ratio of Foliar nutrient responses
Foliar nutrient ratio to balanced plots
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1982/83
1984/85
1984/85
1985/86
1986/87
1987/88
Years
Nitrogen
Phosphorus
Potassium
Copper

Fig 10.

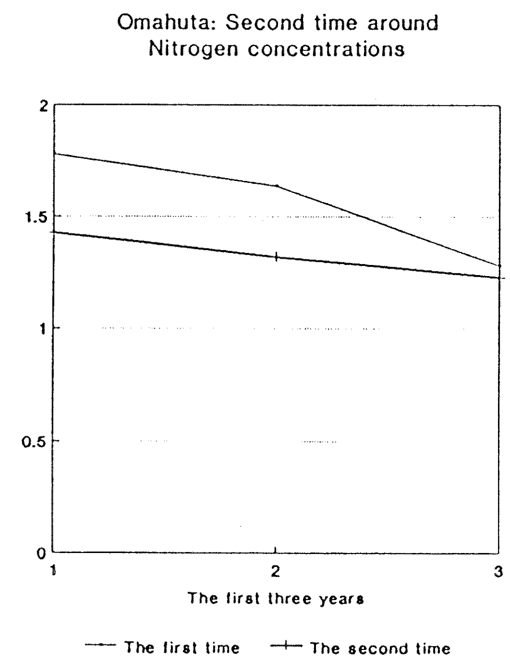


Fig 11

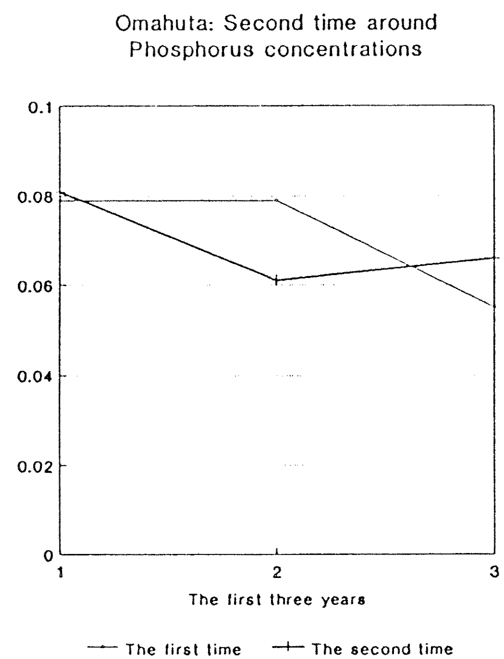


Fig 12

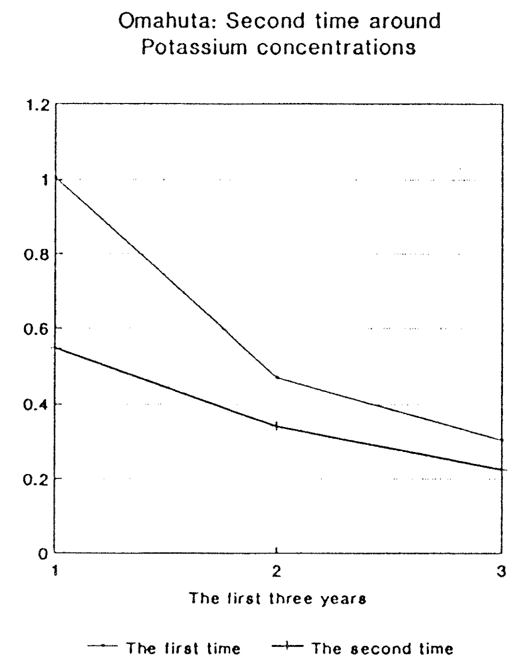


Fig 13

3. What happened to key elements when the plots were clearfelled and replanted?

Figures 11,12 and 13 show what happened to foliar N,P, and K following replanting. These figures show the nutrient concentrations in the minus N, minus P and minus K plots respectively over the first three years of growth. "The first time" encompasses years 1982 to 1985. "The second time" encompasses years 1985 to 1988. The figures show that foliar N and foliar K were markedly lower in the first three years the second time the plots were used. Foliar P was very similar but then it was strongly deficient on both occasions.

We must stress that harvesting and removing three year old trees is not a particularly severe harvesting drain on the site. The trees had not built up to a high nutrient content when they were clearfelled. Thus the reduction in foliar nutrients in the replanted trees is probably partly due to the drain in nutrients and partly due to the absence of the flush of nutrients that accompanies initial site preparation.

The behaviour of the young trees that have been replanted following the clearfelling of the 6 year old trees will be a fairer test of what to expect on second rotation sites.

4. The pattern of Growth Response

All plots were measured for height and diameter in 1985 and a subsample were measured in 1988. In figure 14 and 15 the average height and root collar diameter in 1985 for a selection of treatments is shown. In figure 14 the height and diameter of the main subtractive treatments is given. Poorest growth on the site occurred in the two minus P plots. Growth was poorer in this treatment than in the control. A reduction in growth when N is applied to P deficient plots has been observed before. The All On treatments gave the best growth on the site. The minus Ca, minus Mg, minus Zn, minus Cu and minus S treatments all gave growth that was not significantly better or poorer than this. The minus N and minus K treatments were poorer in diameter but little different in height.

Growth at Omahuta to 1985
Average Height and Diameter

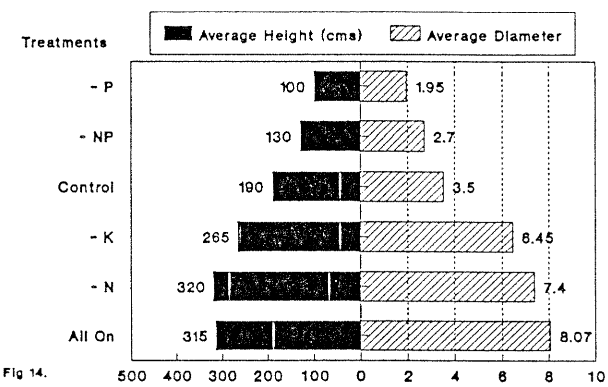


Fig 14.

The performance of the proprietary fertilisers is shown in figure 15. Single superphosphate gave height growth which was very little different from the ALL ON but gave diameter growth which was poorer, reflecting increasing N and K deficiency. Triple superphosphate behaved similarly to Single Super, except that diameter growth was poorer again. Ammophos produced growth which was as good as the ALL ON treatment. DAP was the poorest of the proprietary fertilisers, lagging well behind the ALL ON treatment as early as 1985. It was in fact slightly than the Minus K treatment in the main treatments.

Growth at Omahuta in 1985
Average Height and Diameter

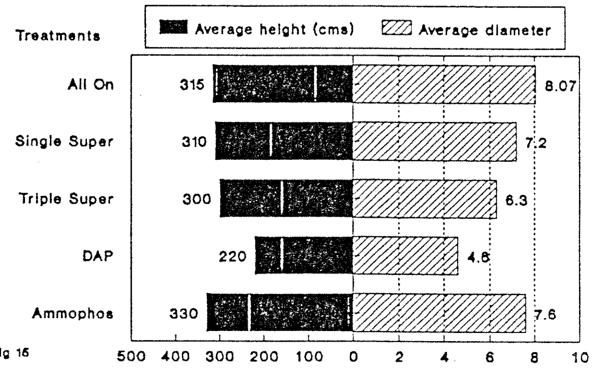


Fig 15

Only a subset of treatments were measured in 1988. Results of this measurement are shown in figure 16. The -P treatment had only grown 0.71 metres in height in 3 years. The ALL ON treatment had grown 5.4 metres in the same time. The differences between the treatments had become more marked. The minus N treatment still had a similar mean height to the ALL ON but its basal area was only 82% of that in the ALL ON . The minus K treatment was at 84% of the ALL ON height at age 3 but had fallen back to 72% by 1988.

Growth at Omahuta to 1988
Average height; plot basal area

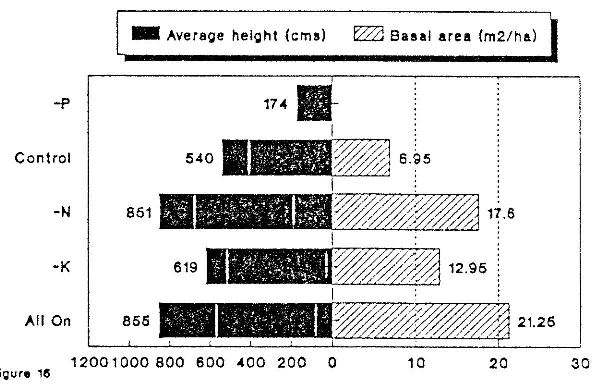


Figure 16

The basal area and height values can be converted into broadly indicative volumes. These show that the minus P had 0.0% of the volume of the ALL ON treatment; the control had 23%; the minus K had 48% and the minus N 82%. These results are very interesting because they contain the first clearly quantifiable K response. Most of our other K responses to date are complicated by the inclusion of other nutrients in the K fertiliser mix. For example in the Nby P trial series the K comparisons also contain copper.