THE EFFECT OF NITROGEN, PHOSPHORUS AND BORON FERTILISER IN CONJUNCTION WITH WEED CONTROL ON THE GROWTH AND NUTRITION OF A POLE STAGE STAND OF RADIATA PINE FROM AGE 7 TO 17 YEARS IN MAMAKU FOREST, CENTRAL NORTH ISLAND.

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ABSTRACT

On P deficient Mangowera/Otanewainuku soils of the Mamaku Ranges, radiata pine responded dramatically to both weed control and the application of phosphate fertiliser as North Carolina Reactive Rock at 50 kg P/ha. After 9 years radiata pine productivity was improved by 38% with both weed control and P fertiliser. N and B were determined to be not limiting for growth. Improvements in the foliar levels of B were achieved with mineral B, but the effect was maintained only for the first 5 years.

INTRODUCTION

On the Mamaku Plateau radiata pine was introduced as a commercial production crop in the early 1970's. The then accepted practice of site preparation by V-blading removed considerable quantities of top-soil which in itself was phosphorous (P) deficient, exposing sub-soil of even lower fertility. The low P fertility of the top-soil can be ascribed to podzolization under the previous native podocarp forest.

MATERIALS AND METHODS

The site

The native vegetation is Podocarp broadleaf forest scrub and the average rainfall is about 2000 mm/year. In the late 1970's and early 1980's the majority of sites were prepared for radiata pine by burning and blading off the debris into windrows. This blading operation removed considerable amounts of topsoil into the windrows. However at the trial site, there was no blading and the site would have been subjected to a low intensity burn.

The soils

The soils are classified as primary podzolic soils in the Kaharoa suite (NZ Soil Bureau, 1954). The two dominating soil types in the area held by Fletcher Challenge Forests are Mangowera sand, derived from Kaharoa ash, and Otanewainuku sand and sandy silt, derived from rhyolite and rhyolitic ash. Total P reserves are low for the Mangowera soil: in the top 8 cm the reserves are 0.007%; and between 9 and 11 cm total P is 0.003%. For the Otanewainuku soils, total P reserves are marginally higher at 0.011% to a depth of 17 cm.

The current radiata pine crop

Foliage samples taken in 1989 from the neighbouring Galaxy Rd and Otanewainuku area (trees 7 years old) showed the following nutrient concentrations:

	Major nutrients in %; minor nutrients in ppm								
	N	P	K	Ca	Mg	Zn	Mn	B	Cu
Site A	1.28	.0.07-.09	0.73	0.13	.09	37-41	233-284	7-9	25-27
Site B	ND	0.01	ND	ND	ND	ND	ND	ND	ND

ND = not determined

These analyses show that P is acutely deficient and that nitrogen (N) is marginal for growth (Will, 1985). The boron (B) levels between 7 and 9 ppm are cause for concern and the magnesium (Mg) levels although marginal should not present a problem (yellowing) in the absence of pruning.

The crop will certainly respond to the addition of P, and additional gains are likely with added N. Boron should be added to raise foliar B levels to greater than 11 - 12 ppm.

Experimental design

The basic trial examines N, P, B, and weed control as a 2^4 factorial. The treatment schedule is: N (2 levels at 0 and 200 kg N/ha) by P (2 levels at 0 and 100 kg P/ha) by B (2 levels at 0 and 8 kg B/ha) by weed control (yes/no). The trial was replicated twice.

With this design it was thought extremely unlikely that the third order interaction (N*P*B*WC) would be of significance. It was therefore decided to amend the complete factorial design. Each replicate was divided into two blocks to reduce site variability, with the removal of the third order interaction term (N*P*B*WC). The loss of this interaction term was more than compensated for by the increased precision. The ANOVA for this field layout is shown below in **Table 1**.

Table 1. ANOVA for field experiment (modified)

Source of variation	Degrees of freedom
Total	31
Blocks	3
N	1
P	1
B	1
WC	1
N*P	1
N*B	1
N*WC	1
P*B	1
P*WC	1
N*P*B	1
N*P*WC	1
N*B*WC	1
P*B*WC	1
error	14

Layout of the experimental plots

Each of the two replications was divided into two incomplete blocks of 16 plots each. The measurement plots are 12 m x 18 m, with a 4 m similarly treated surround (0.035 ha total plot area).

Testing a lower rate of P

Additional plots (2 per replicate) to test for a half rate of P (50 kg P/ha) were set up (with and without weed control) in the presence of N and B. These plots were placed adjacent to their counterparts at the full rate of P.

Trial establishment

The trial was established over the winter and spring of 1989 in a seven year-old stand of radiata pine in Compartment 3469/1.

The following fertiliser prescriptions were used:

- Nitrogen as urea at 435 kg /ha to yield 200 kg N/ha;
- Phosphorus as North Carolina phosphate rock to yield 100 kg P/ha;
- Boron as ulexite at 60 kg/ha to yield 8 kg B/ha.

The required number of plot trees (approximately 13) to provide 600 - 625 sph were selected and pruned to 2.5 m, and the remaining stems (about 1000 sph) were thinned to waste.

Within the weed control plots the understorey of hardwood shrubs, bush lawyer, ghania and native toetoe were cleared with a chainsaw. Vegetation regrowth was sprayed when required with "Roundup".

Measurements

The trees were measured at time of fertilising, and annually thereafter. All diameters at breast height (DBH), and total heights were processed through the ***Forest Research*** Permanent Sample Plot System (PSP). Standard foliage samples were collected from every plot during late summer, and annually thereafter. Statistical analyses of the growth and nutrition data were made using SAS. The initial growth measurements were used as the covariate.

RESULTS

Tree growth

The ANOVA result (**Table 2**) shows that weed control and P fertiliser were the main factors significantly (p<0.05) affecting growth. There was no evidence of a growth improvement with B fertiliser. However, there was some indication of an interaction between N and P from age 9 years, and with N and weed control from age 11 years. For these reasons the results are presented in the figures showing the effect of weed control, P fertiliser (at 100 and 50 kg p/ha rates) and N.

Table 2. ANOVA for the treatment effects on growth

		Probability of Significant Treatment Effects on growth									
Year	**Age**	**N**	**P**	**B**	**Weed**	**N*P**	**N*B**	**N*W**	**P*B**	**P*W**	**B*W**
1990	8	0.8097	**0.0022**	0.1600	**0.0216**	0.9218	0.4208	0.7774	0.3212	0.7542	0.3091
1991	9	0.5884	**<.0001**	0.1718	**<.0001**	0.0990	0.0785	0.9763	0.3596	0.4830	0.4726
1992	10	0.1071	**<.0001**	0.0873	**<.0001**	0.0649	**0.0123**	0.2002	0.2376	0.1637	0.9387
1993	11	0.5289	**<.0001**	0.2192	**0.0002**	0.0796	**0.0444**	0.0652	0.9332	0.2237	0.7236
1994	12	0.5629	**<.0001**	0.4774	**0.0004**	0.1190	**0.0164**	**0.0413**	0.4877	0.2911	0.6537

Figure 1 shows BA growth from age 8 to 12 where the N and P fertiliser treatments have been imposed in the absence of weed control and **Figure 2** where the same treatments were imposed where weeds were controlled.

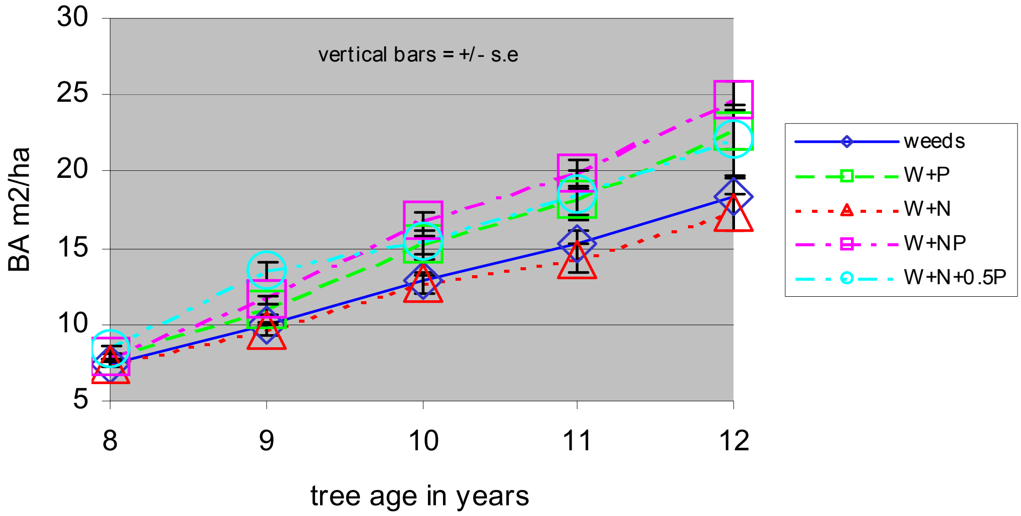

Figure 1. Basal area growth of pines in the presence of weeds

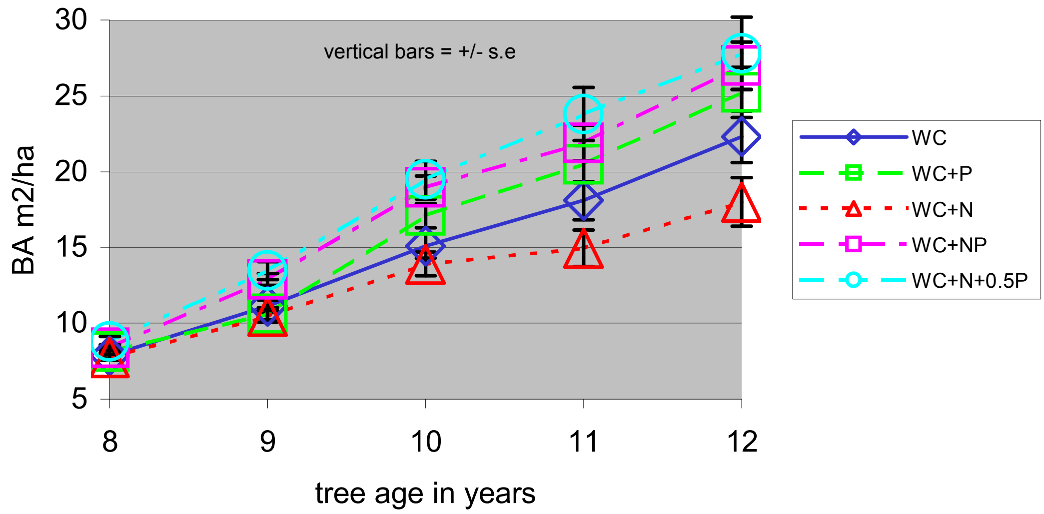

Figure 2. Basal area growth of pines in the absence of weeds

In the presence of competing weeds, nitrogen fertiliser (W+N) had no effect on growth (**Figure 1**). Where the weeds had been removed, the addition of N (WC+N) reduced growth from age 10 (**Figure 2**). The reason(s) for the delay in the growth restriction when N was applied to trees free of weeds is not clear. It is well known is that where soil available P is low, the addition of N can further depress P uptake (***Forest Research*** unpubl. data).

The addition of P in the presence of weeds (W+P) shows improvement in BA performance relatively soon after the application of P fertiliser. Where weeds were controlled BA improvements with P (WC+P) has been delayed by 3 years, presumably due to the rotting vegetation providing sufficient inorganic P to meet tree needs. Evidence to support this proposition is shown later under "Nutrition".

Adding P at 50 kg P/ha overall was as satisfactory as applying P at 100 kg/ha particularly in the plots where the weeds had been controlled. There is some evidence, however, that where N fertilising was combined with P fertilising at the lower rate, and weeds were present, the BA response was lessened (presumably due to competition from the weeds for nutrients).

By the end of the growth measurements (age 12 years) weed control alone had significantly improved growth from 18 to a little over 22 m^2/ha. Applying P alone improved growth to 22.5 m^2/ha (weeds present) and 25 m^2/ha (weeds controlled). In the presence of N and P growth improved to 25 m^2/ha (weeds present) and about 27 m^2/ha (weeds controlled).

Tree nutrition

The ANOVA in **Table 3** shows the pattern of significance for the various treatment effects from age 8 to age 16 years. The salient points are:

- Nitrogen fertiliser had a significant effect on foliar N for the first year only after application
- Weed control also significantly affected foliar N for the first 3 years
- Foliar P was significantly affected by P fertiliser over the duration of the measurements
- Foliar B was significantly affected by B fertiliser for the first 5 years

Table 3 ANOVA for the treatment effects on nutrition

	Part 1. Probability of Significant Treatment Effects on foliar nitrogen									
Year	**N**	**P**	**B**	**Weed**	**N*P**	**N*B**	**N*W**	**P*B**	**P*W**	**B*W**
1990	**0.0015**	0.6708	0.5874	**0.0034**	0.6840	0.1160	0.829	0.1582	0.3874	0.9272
1991	0.8328	**0.0107**	0.3574	**<.0001**	0.1866	0.2080	0.8962	**0.0483**	0.5622	0.0532
1992	0.9112	0.2367	0.5701	**0.0671**	0.2503	0.5942	0.5920	0.2710	0.3254	0.7924
1993	0.5690	**0.0323**	0.6961	0.1230	0.7636	0.9760	0.6961	0.5103	0.4376	0.6100
1994	0.6706	0.5714	0.5023	0.3612	0.7764	0.4590	0.8313	0.9151	0.5248	0.5023
1996	0.5876	0.7916	0.7916	0.1284	0.2521	0.4679	0.7916	0.4495	0.2401	0.4495
1998	0.5446	0.0804	0.7869	0.2327	0.9461	**0.0361**	0.8924	0.4211	0.9861	0.9461

	Part 2. Probability of Significant Treatment Effects on foliar phosphorus									
Year	**N**	**P**	**B**	**Weed**	**N*P**	**N*B**	**N*W**	**P*B**	**P*W**	**B*W**
1990	0.1617	**<.0001**	0.9627	0.9254	0.0549	0.4171	0.8884	0.4041	0.7260	0.9907
1991	**0.0141**	**<.0001**	0.6824	0.2231	**0.0249**	0.1195	0.6144	0.2213	0.2281	0.8413
1992	0.6888	**<.0001**	0.7026	0.2990	0.6752	0.5584	0.2596	0.9034	0.5102	0.8740
1993	0.1305	**<.0001**	0.9802	**0.0311**	0.7289	0.9013	0.5702	0.7289	0.6211	0.1093
1994	0.9681	**<.0001**	0.9468	0.3114	0.9681	0.9894	0.3365	0.7593	0.9045	0.9894
1996	0.4584	**<.0001**	0.1563	0.9716	0.7671	0.6616	0.9338	0.0598	0.4584	0.8218
1998	0.4341	**<.0001**	0.4770	0.4341	0.7435	0.7990	0.8556	0.3558	0.4069	0.4919

	Part 3. Probability of Significant Treatment Effects on foliar boron									
Year	**N**	**P**	**B**	**Weed**	**N*P**	**N*B**	**N*W**	**P*B**	**P*W**	**B*W**
1990	0.3319	0.8980	**<.0001**	0.6392	0.4706	0.8308	0.9659	0.4209	0.1081	**0.0478**
1991	0.6669	0.2884	**<.0001**	0.5199	0.1430	0.8293	0.1430	0.0971	0.2057	0.6669
1992	0.4896	0.4154	**0.0099**	0.9496	0.0376	0.2901	0.4154	0.0794	0.0485	0.9496
1993	0.3763	0.5049	**0.0140**	0.0019	0.1904	0.2717	0.2717	0.0863	0.1904	0.8232
1994	0.9036	0.0821	**0.0112**	0.1936	0.7169	0.9036	0.5470	0.5470	0.0315	0.4014
1996	0.4567	0.8027	0.2210	0.3239	0.4567	0.0928	1.000	0.8027	**0.0070**	0.6182
1998	0.3816	0.9120	0.6592	0.2333	0.7405	0.8251	0.9120	0.5820	0.1952	0.1099

Weed control and nitrogen fertilising

Weed control alone treatment significantly improved crop growth (**Figure 3**).

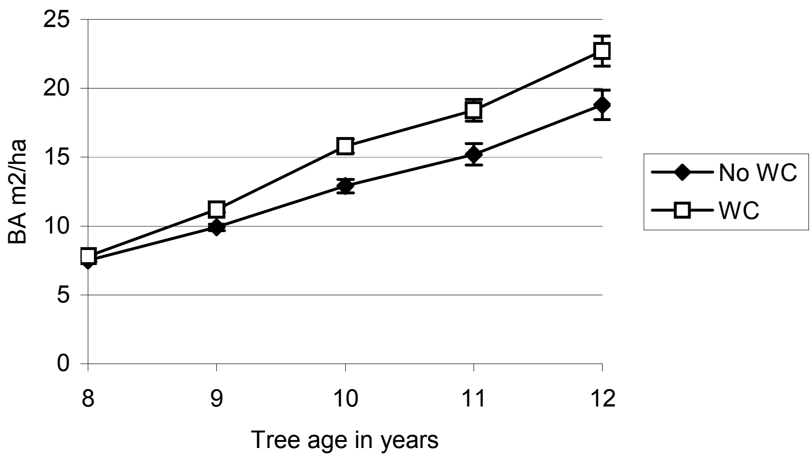

Figure 3. The effect of weed control (WC) on basal area growth of pines

Weed control improved foliar N from 1.45% to 1.6% with a large proportion of that difference remaining through to age 16 (**Figure 4**).

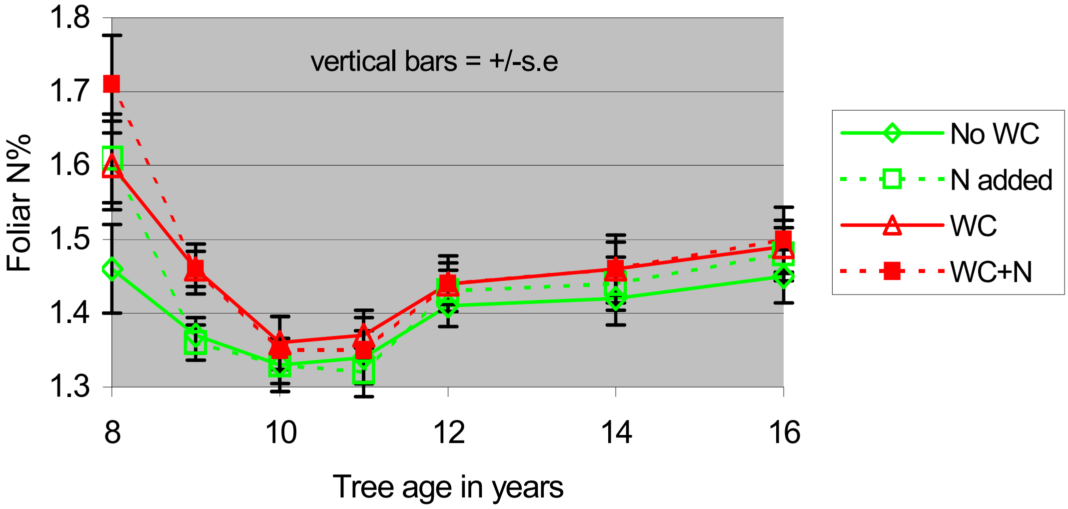

Figure 4. The effect of weed control (WC) and nitrogen on foliar N performance.

Presumably the additional N for the crop was through greater availability of soil mineral N in the absence of competing vegetation. N from the decomposing weed slash would have been unlikely to have been available in such a short time. In contrast the N fertiliser effect (with and without weeds) was short lived at 1 year's duration, although the N concentrations in the weeded and weeded + N plots remained somewhat higher throughout the duration of the measurement period to age 16.

Phosphorus fertilising

The high rate of P fertilising (100 kg P/ha) raised and maintained foliar P concentrations for the first 5 years at 0.17%-0.18%, well in excess of the intervention level of 0.11% (**Figure 5**).

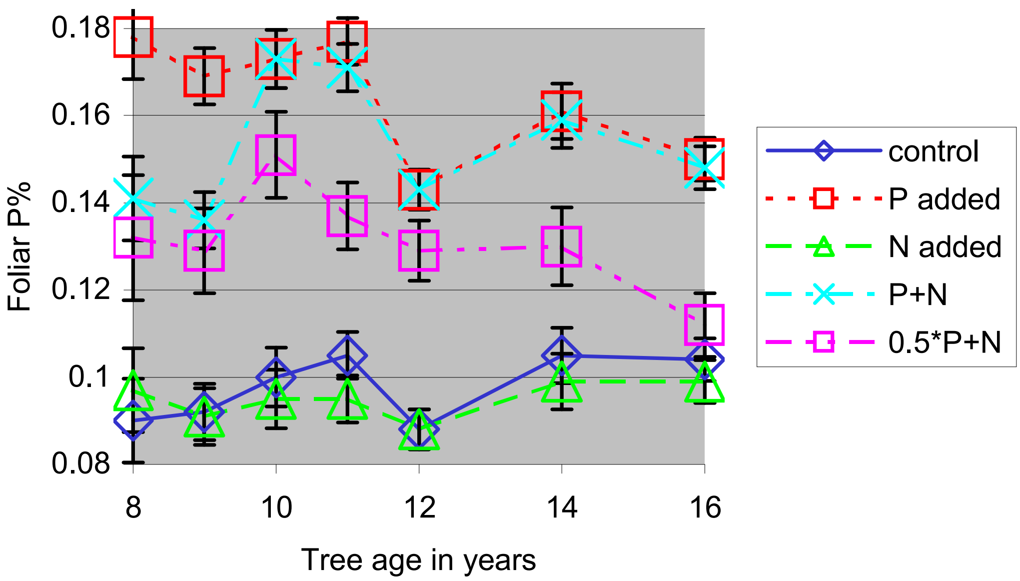

Figure 5. The effect of P fertilising on foliar P performance

Thereafter there was a slow decline to about 0.15%. In contrast the 50 kg P/ha rate maintained foliar P at or above 0.13% for the first six years before a decline to the intervention level. Both P treatments yielded similar growth gains.

Boron fertilising

Boron fertilising had a significant effect on foliar B concentrations for the first 5 years as shown in **Figure 6**. This is an interesting result as elsewhere in NZ the fertilising effect has been longer lasting. The likely reason for this is the reasonably high rainfall at the site.

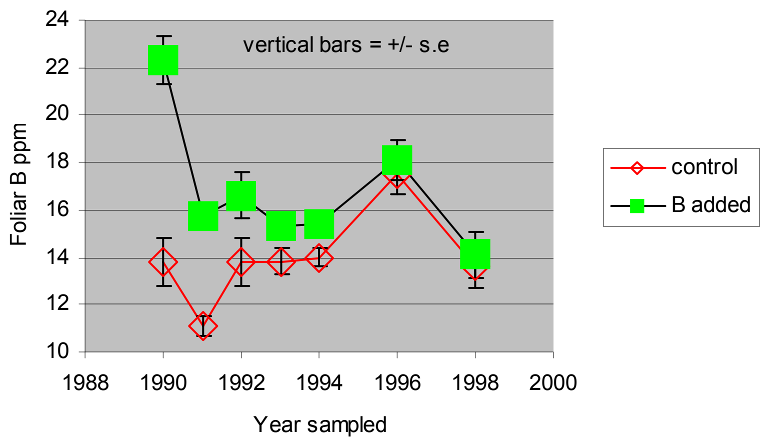

Figure 6. The effect of boron fertilising on foliar B performance

DISCUSSION

The trial raises a number of interesting points:

- the crop's N nutrition at 1.4% was deemed to be marginal (Will, 1985), but there was no response to added N
- the crop's P nutrition was raised to adequacy with the application of 50 kg P/ha
- there were no practical growth gains to combining a N application with the P fertiliser
- boron concentrations were significantly raised, but for a limited period only

The trial was designed to follow growth and nutrition responses for a strictly limited time. P was the primary limiting nutrient at this site and the increased growth did not have a deleterious effect by lowering the existing foliar B concentrations.

CONCLUSIONS

On the very P deficient Mamaku soils, controlling the weeds improved the basal area production of a 7 year-old radiata pine crop over a 5 year period by 22% (from 18 m^2/ha to 22 m^2/ha). Without weed control, application of either 50 kg P/ha or 100 kg P/ha as North Carolina reactive rock achieved an increase of 27% (to 23 m^2/ha); where weed control and P fertilising were combined the gains were 39% (to 25 m^2/ha). There were no significant gains to N fertiliser in combination with P; N fertilising depressed growth when combined with weed control and B fertilising had no effect on growth.

ACKNOWLEDGMENTS

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