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THE EFECT OF MAGNESIUM AND BORON FERTILISERS ON FOLIAR NUTRIENT CHEMISTRY FIVE AND A HALF YEARS AFTER APPLICATION TO A 1 YEAR OLD P. RADIATA STAND, TAUHARA FOREST

By

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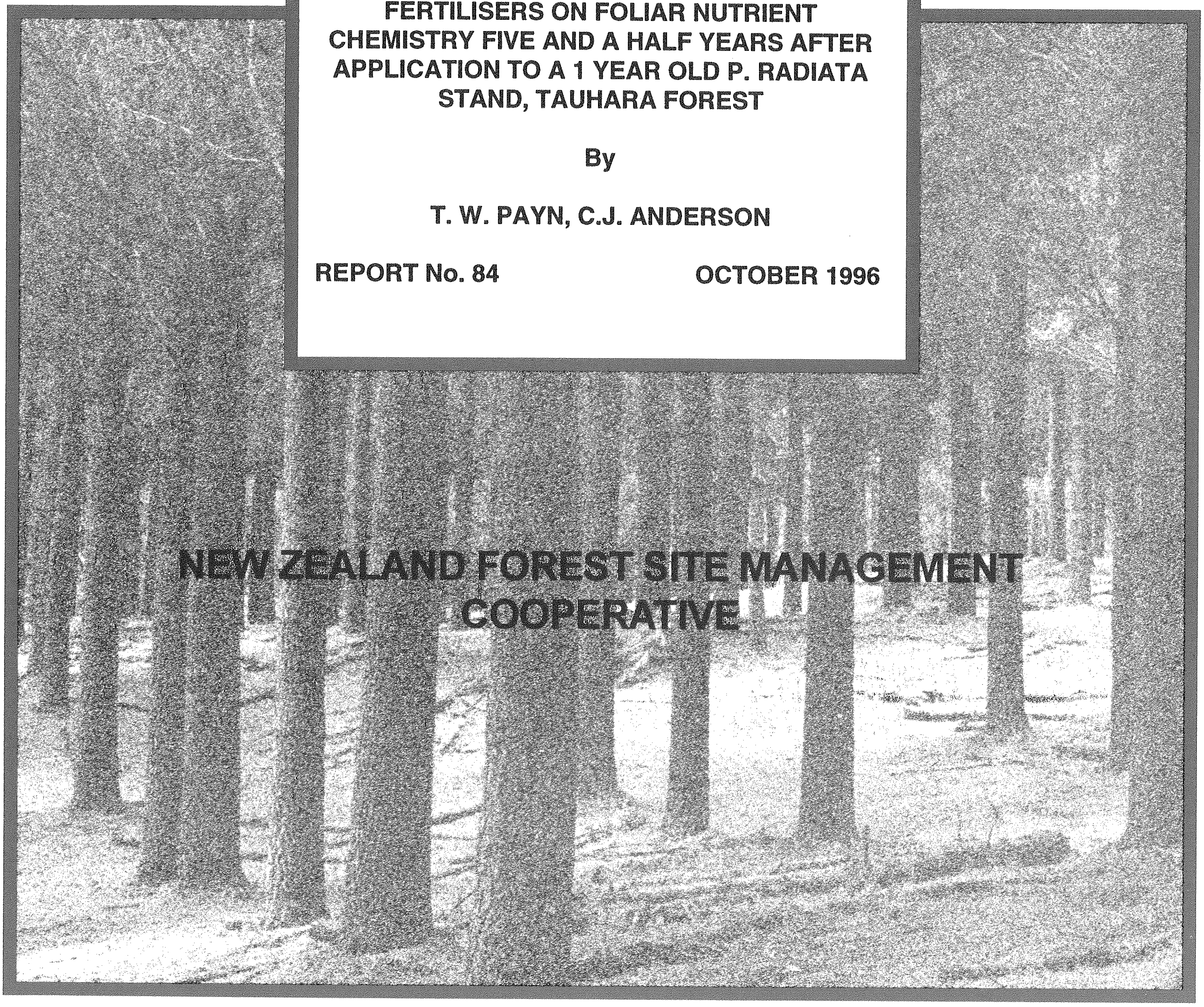

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LIMITED

The effect of magnesium and boron fertilisers on foliar nutrient chemistry five and a half years after application to a 1 year old *P. radiata* stand, Tauhara Forest

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Abstract

The magnesium/grass/boron trial established in Halls Block, Tauhara forest as part of Tim Payn's Ph.D programme was resampled in March 1995. The objective was to determine if magnesium and boron fertiliser and grass control treatments applied shortly after planting were still affecting foliar nutrient concentrations five and a half years later.

The effect of Epsom salts applied at 400 kg Mg ha^{-1} was still apparent 5.5 years after application with foliar Mg concentrations remaining significantly higher than in unfertilised plots, and foliar K:Mg ratios lower. Medium grade (2-5 mm chip) calcined magnesite applied at the same rate appeared to be starting to improve foliar Mg concentrations after this time. Magnesium fertiliser had the effect of depressing both foliar B and Cu concentrations, though not below critical levels. Foliar boron concentrations in the 4 kg B ha^{-1} treatment remained significantly higher than the control. The effects of grass competition on foliar nutrients recorded in earlier sampling exercises were no longer apparent, probably due to the trees attaining canopy closure and suppressing understorey grass growth.

It is suggested that this trial is resampled in 1997 and 1999 to further track the longevity of improvement in foliar Mg and B concentrations and effectiveness of the calcined magnesite source and trends in K:Mg ratio. Soil sampling is recommended at these sample times also. Due to the small plot size collection of mensuration data will not be possible.

General Introduction

A field trial was established on Hall's block, Tauhara Forest in August 1989, in order to determine the effects of magnesium fertilisers on *Pinus radiata* planted on pumice soils (Payn, 1991). The site had been under pasture for approximately 20 years, and was planted with *P. radiata* in April 1988. The trial was designed to investigate the effect of magnesium, grass and boron treatments, in factorial combination, on tree growth and magnesium uptake. A sub-experiment, of randomised complete block design, was included to assess the effect of types of magnesium fertiliser and other nutrients on tree growth and nutrition of the trees. As part of the NZ Forest Site Management Cooperative Research Programme the trial is being monitored for long term effects of the different types of Magnesium fertiliser. It is also hoped to gain more understanding of the nutrient deficiencies and K:Mg relationship that may be used as early indicators of Upper Mid-Crown Yellowing (UMCY) susceptibility.

Four replicates of the following treatments were used on the factorial experiment:

- 0 and 400 kg Mg ha^{-1}, as $MgSO_4.7H_2O$ (Epsom salts).
- Presence and absence of perennial Rye grass.
- 0 and 4 kg B ha^{-1} , as Boric acid.

In the sub-experiment four replicates of the following treatments were used:

- 0 kg Mg ha^{-1}
- 400 kg Mg ha^{-1}, as $MgSO_4.7H_2O$.
- 400 kg Mg ha^{-1} , as 2-5 mm chip calcined magnesite (MgO).
- A Total Fertiliser (Nitrophoska Blue) @ 50 kg P ha^{-1}, with additional Epsom salts to raise the Mg application rate to 400 kg Mg ha^{-1}.

All these treatments were ungrassed.

The treatments were applied, to plots of 20m by 7m, in September 1989. Measurements were taken September 1989, March 1990, September 1990, and March 1991. These measurements included height and collar diameter and chemical analysis of foliage. Tree biomass and components thereof were measured and analysed in March 1991 only. The trial was pruned in 1994 and foliar samples taken in March 1995 for analysis. Soil chemical analysis was carried out in 1990 and 1991 on an adjacent small plot experiment.

Summary of Results to 1991

Factorial Experiment - Magnesium/Grass/Boron

The application of $MgSO_4$ raised foliar Mg levels above the control levels but no overall growth responses were noted, suggesting a luxury uptake. The concentrations remained high throughout the 1990-1991 period. The biomass was found to increase overall with the removal of grass competition, although foliar Mg concentration did not increase except in line with increase in biomass. This suggests that the Mg supply was not limiting. The application of magnesium fertiliser plus grass control doubled the Mg content in the biomass but no growth responses were found, again suggesting luxury uptake. This luxury uptake may be beneficial in future years for increased growth and reducing pruning shock. The magnesium fertiliser with no grass control showed no growth responses and also no additional uptake of Mg. The magnesium concentration in grass increased when fertiliser was added but the grass biomass did not increase. Boron was suspected of being limiting, but it was found that although foliar concentration more than doubled in the fertilised trees no growth response was found.

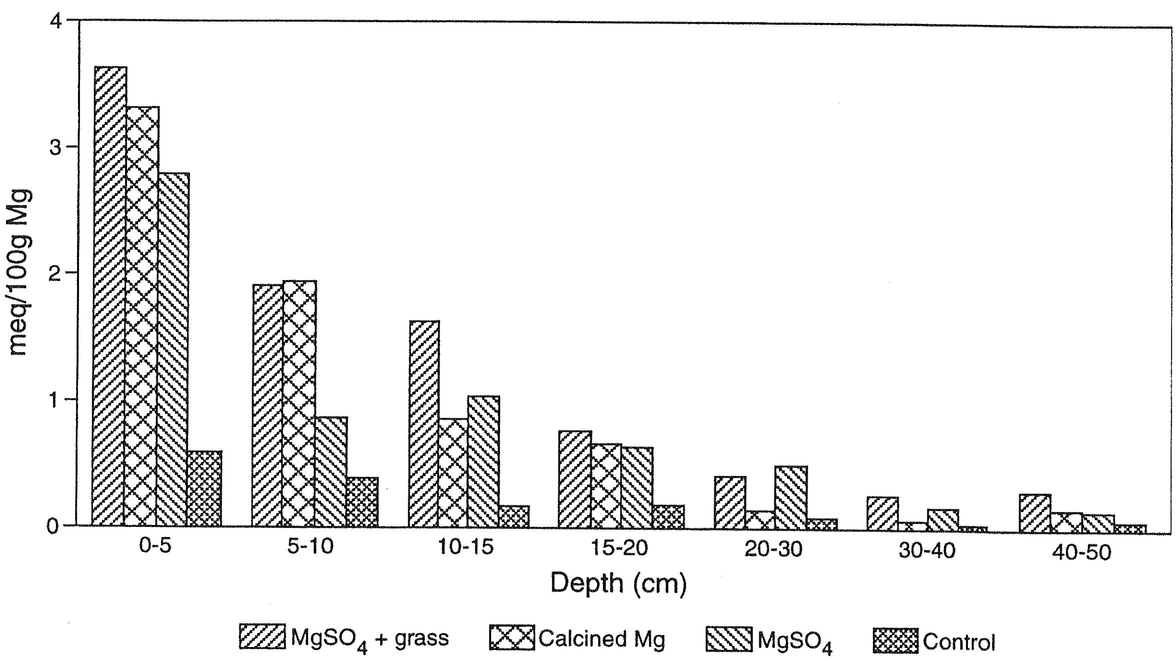
Sub- experiment - Randomised Complete Block

The application of Total fertiliser did not increase growth rates suggesting that the site was not deficient in any other elements. The low solubility 2-5 mm chip calcined magnesium (MgO) had no effect on foliar magnesium concentrations by 1991, though needle mass was slightly increased, and no stem growth responses were found. The $MgSO_4$ fertiliser increased foliar Mg concentrations but no growth response found, as in the factorial experiment. Calcined magnesite was therefore found to be less effective than $MgSO_4$ in increasing foliar Mg concentration.

Soil Chemical Analysis

Soil solution and solid phase chemistry indicated that the two sources of magnesium fertiliser were behaving very differently in the soil. The $MgSO_4$ fertiliser caused a very rapid peak in soil solution Mg concentration and a rapid increase in exchangeable Mg concentrations, whereas calcined magnesite hardly increased soil solution Mg concentrations at all in the first 18 months after application. Calcined magnesite did however improve the exchangeable Mg concentrations, albeit more slowly than $MgSO_4$ and by March 1991 the exchangeable and soil solution concentrations down the soil profile were quite similar for both fertiliser sources (Figure 1).

Figure 1. Treatment effects on exchangeable Mg with soil depth, March 1991, 18 months after treatment application.



The $MgSO_4$ had increased exchangeable levels to a depth of 40 cm, while the lower solubility calcined magnesite had only increased concentrations down to 20 cm. The soil solution phase seems therefore crucial for rapid improvement of foliar Mg concentrations and this is reflected in the different behaviour of the two fertiliser sources.

1995 Foliage Sampling

Objectives

The main objective of this report is:

- To determine what effects on foliar nutrition have occurred with the various treatments, 5.5 years after treatment and one year post pruning.

Methods

Foliage sampling was done in March 1995 using pole pruners. The samples were taken from six trees per plot using the standard FRI procedure. Samples were then analysed for elements N, P, K, Ca, Mg, B, Mn, Zn and Cu using standard methods (Nicholson, 1984).

Statistical Analysis

Foliage data were analysed using ANOVA for both the factorial experiment (Mg/Grass/B) and the randomised complete block (types of fertiliser).

Results for 1995

Factorial Experiment - Magnesium/Grass/Boron

Following ANOVA analysis it was discerned that there were no interactions between Mg*Grass, Grass*Boron and Mg*Grass*Boron. However, the interaction between Mg*Boron was significant at $p=0.0109$ for phosphorus. The mean phosphorus concentrations for the Mg and Boron treatment is 0.152%, compared to 0.145% for Mg with no B, 0.143% for no Mg with B, and 0.156% for no Mg or B (Figure 2).

Figure 2. Effect of Mg and B fertilisers on foliar P concentrations.

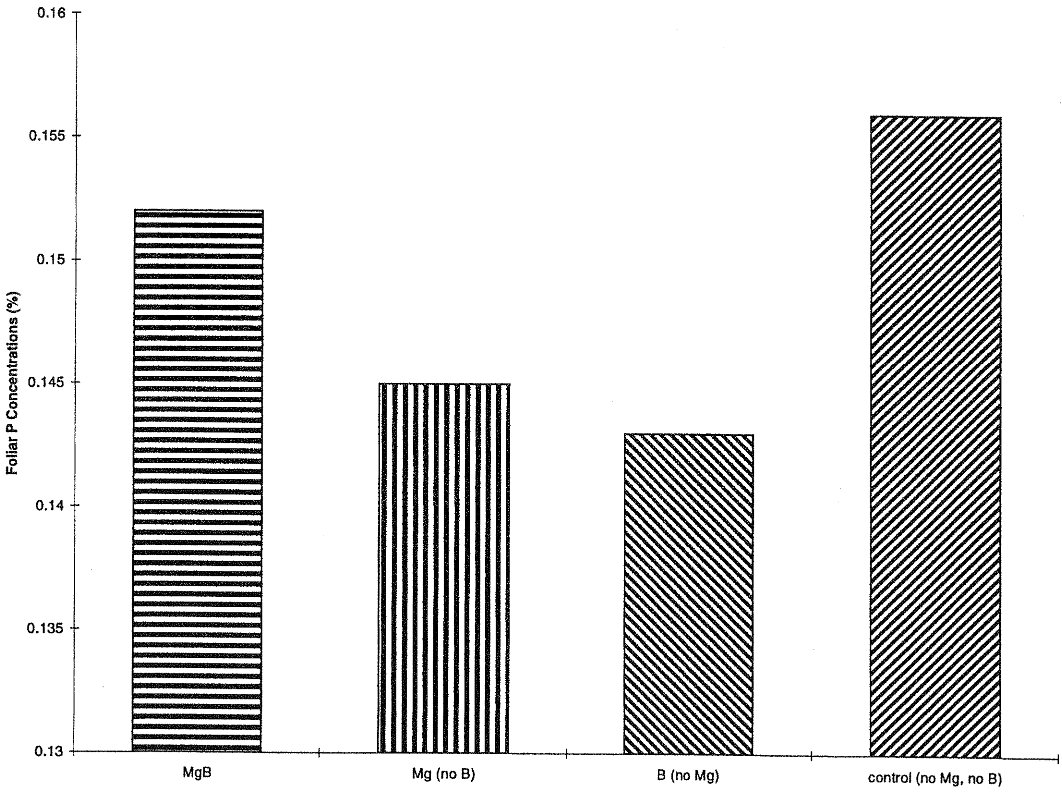


Table 1. Effect of Mg, Grass & Boron Treatments on Foliage Nutrient Concentration March 1995. Main Effect Means.

Treatment		Element concentration									
		%					ratio	ppm			
		N	P	K	Ca	Mg[1]	K:Mg[2]	B	Mn	Zn	Cu
Mg	0	1.31	0.15	0.85	0.20	**0.082**	**10.44**	**17.5**	71.8	33.2	**11.8**
	+	1.29	0.14	0.85	0.20	**0.095**	**9.14**	**16.0**	77.5	34.1	**8.7**
Grass	0	1.31	0.15	0.85	0.20	0.087	9.99	16.5	72.0	33.3	10.4
	+	1.29	0.14	0.85	0.20	0.090	9.60	17.0	77.2	34.0	10.1
Boron	0	1.29	0.15	0.85	0.20	0.090	9.70	**14.6**	74.6	34.0	9.5
	+	1.31	0.14	0.85	0.20	0.087	9.88	**18.8**	74.6	33.3	11.0

Bold type highlights concentrations that are significantly different at $p<0.05$

1 - Critical level for *P. radiata* is 0.07% (Will, 1985)

2 - UMCY symptoms are unlikely to develop in *P. radiata* with K:Mg ratio < 10 (Beets *et al*, 1993)

The main effects of the treatments on the foliar nutrient concentration are shown in Table 1. The treatment to have the most significant effect is the Mg fertiliser. Magnesium foliar levels were significantly higher (p=0.0009) in the magnesium fertilised plots. The mean concentration being 0.095% compared to 0.082% in unfertilised plots. The K:Mg ratio was significantly lower (p=0.0110) in the magnesium fertilised plots. The ratio dropped below the Upper Mid-Crown

Yellowing (UMCY) threshold of 10, from 10.44 to 9.14, suggesting that the trees should not develop UMCY symptoms as they age. Copper foliar concentrations showed a significant decrease (p=0.0025) in the magnesium fertilised plots. The mean in the unfertilised plots was 11.8 ppm, this dropped to a mean of 8.7 ppm in the Mg fertilised plots, though the levels were still well above the critical level of 2-4 ppm. Both boron and grass treatments had no significant effect on foliar Mg, K:Mg ratio and Cu. However, the boron concentration in the foliage showed a significant decrease (p=0.0172) in the magnesium fertilised plots from 17.5 to 16.0 ppm, although this was still above the critical level of 8-12 ppm. The foliar boron concentration, not surprisingly, showed a significant (p=0.0001) increase to a mean of 18.8 ppm in the Boron fertilised plots.

Sub- experiment - Randomised Complete Block

The effects of types of magnesium and total fertilisers on foliar nutrient concentrations have been summarised in Table 2.

Table 2. Effects of treatments on mean foliar concentrations of elements, March 1995

Sample Date	Element	Treatment				Variation
		Control	C' Mag	$MgSO_4$	Total	$p > F$
March 1995	N[1]	1.29^{a}	1.29^{a}	1.30^{a}	1.30^{a}	0.9738
	P[1]	0.153^{a}	0.155^{a}	0.145^{a}	0.145^{a}	0.6224
	K[1]	0.858^{a}	0.850^{a}	0.819^{a}	0.829^{a}	0.6650
	Ca[1]	0.202^{a}	0.216^{a}	0.199^{a}	0.211^{a}	0.7588
	Mg[1]	**0.079^{b}**	0.091^{ba}	**0.099^{a}**	0.096^{ba}	0.1524
	K:Mg	10.8^{a}	9.46^{a}	8.49^{a}	8.67^{a}	0.1874
	B[2]	14.0^{a}	13.2^{a}	13.7^{a}	14.7^{a}	0.4964
	Mn[2]	61.7^{a}	80.2^{a}	78.0^{a}	69.7^{a}	0.5659
	Zn[2]	33.5^{a}	34.5^{a}	34.0^{a}	33.5^{a}	0.9151
	Cu[2]	10.5^{a}	7.22^{a}	8.32^{a}	10.4^{a}	0.1457

[1] - Values in %
[2] - Values in ppm
The mean values in the same row with the same superscript letter are not significantly different.

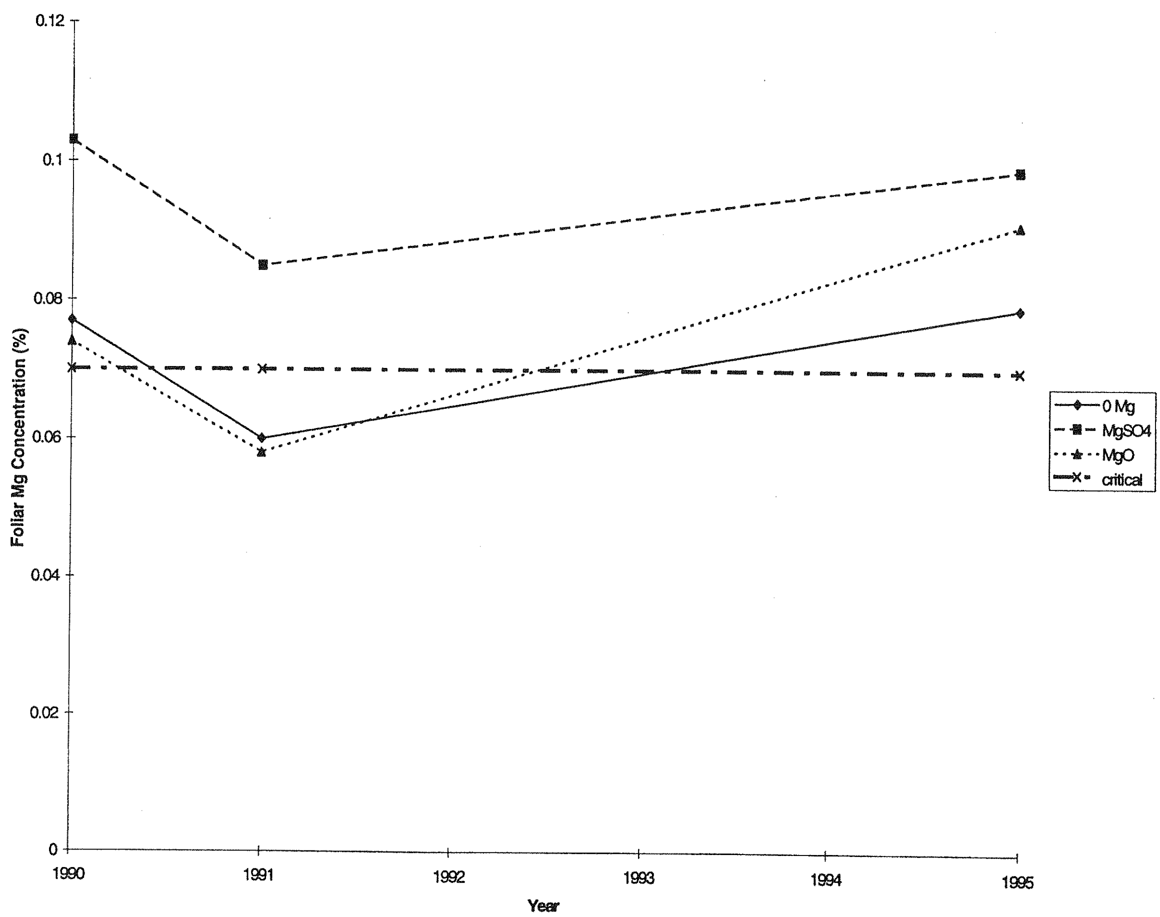
The analysis showed no significant treatment effects between the types of fertiliser. However there was a significant difference in mean magnesium concentrations between the $MgSO_4$ fertiliser (mean foliar Mg concentration = 0.099%) and the unfertilised plots (mean = 0.079%). There was no significant difference between the means of $MgSO_4$, Total (mean = 0.096%) and calcined magnesite (mean = 0.091%). However the difference between the control and the calcined magnesite treatment was larger than for previous years. There was no significant difference between the means of the treatments for any of the other nutrients analysed.

Discussion

Trends in Foliar Magnesium Concentrations Over Time

Magnesium is essential for photosynthesis (as part of the chlorophyll molecule), protein synthesis and activation of enzymes (for transport of carbohydrates). It is important for normal growth to maintain Mg concentration above the critical level. Figure 3 shows that magnesium foliar levels dropped from 1990 to 1991 in both fertilised and unfertilised plots. This drop was most likely caused by climatic differences as a dry season can reduce magnesium uptake considerably. Growth differences can also make a difference as faster growing trees will have a greater demand for magnesium which the site may not be able to provide. Figure 1 shows that although the 1991 unfertilised treatment dropped below the critical concentration level of 0.07% it increased to 0.082% by 1995. The differences between the $MgSO_4$ fertilised and the unfertilised plots did not alter between the 1990 to 1991 period. However the difference was reduced in the 1995 analysis, suggesting that five and a half years after treatment the fertiliser has still improved foliar Mg concentration but the improvement is reducing. By comparison there was an increased difference in foliar Mg concentration between the calcined magnesite treatment and the control (Figure 3). This suggests that the effect of this lower solubility source of Mg may be increasing.

Figure 3. Trends in Foliar Mg Concentration Over Time. Sampled in March.



Grass Effect

In both 1990 and 1991 grass cover had the effect of increasing foliar Mg concentration and we attributed this at the time to a concentrating effect within the lighter needles on those plots. This effect had disappeared in this sampling, suggesting that this effect had reduced over time as the grass became shaded out by canopy closure. There were no differences in foliar concentrations in 1995 across these treatments. These differences might be expected to last longer however on lower stocked stands as shading effects would be lighter.

Effects on Other Nutrients

In the 1990/91 analyses it was found that foliar calcium concentration decreased in the fertilised treatment plots while it increased in the grassed plots. Potassium decreased in the grassed plots in that period. It was found that the 1995 analyses that neither calcium nor potassium was significantly affected by any treatments. Sulphur increased in the 1990 period with the $MgSO_4$ treated plots due to the sulphate component. Aluminium increased in both 1990 and 1991 in the grass treatment plots. Sulphur and Aluminium were not analysed in 1995. Foliar boron concentrate was found to increase from 17 to 45 ppm in 1990 in the boric acid treatment but no growth responses were found indicating luxury uptake. By 1995 however the difference between fertilised and unfertilised plots had decreased to 18.8 and 14.6 ppm. Hunter (1991) showed that foliar boron levels may be reduced on magnesium fertilised sites. This can be seen in the 1995 analyses (Table 1) where foliar boron levels were significantly reduced in the Mg fertilised plots compared to the unfertilised plots, although the levels were not reduced to a critical level. Copper was not previously analysed for. The 1995 analyses showed the foliar copper concentration to be significantly reduced in the magnesium fertilised plots, although the concentration had not dropped to a critical level. Foliar nitrogen concentrations were not determined prior to 1995. In the 1995 results mean N concentrations suggested the stand was marginal for N. However the high growth rates suggest that N supply was not limiting.

K:Mg Ratio

It has been suggested that development of Upper Mid-Crown Yellowing in older trees may be caused not just by Mg deficiency but may be exacerbated by an imbalance between K and Mg within radiata pine (Beets *et al*, 1993). The K:Mg ratio can be used to determine the likelihood of UMCY symptoms developing. It has been previously stated that UMCY is unlikely to develop in *P. radiata* with a K:Mg ratio < 10 (Beets *et al*, 1993). The data from this trial showed the unfertilised trees to have K:Mg ratios of slightly over 10. The ratio was significantly reduced in the magnesium fertilised plots in the factorial experiment, where the ratio was reduced to 9.14 from 10.44 in the unfertilised plots suggesting that UMCY is unlikely to develop in the $MgSO_4$ fertilised plots.

Types of Fertiliser

There was no significant difference overall between the types of fertiliser used (Table 2). The only significant difference in the means of foliar nutrients was for magnesium in the $MgSO_4$ treatment and the unfertilised control plots. It was hypothesised (Payn, 1991) that the slow release calcined magnesite chip would have more of an effect on magnesium availability over time, however it appears that after 5.5 years after fertilisation the $MgSO_4$ still has a greater effect on foliar magnesium than the calcined magnesite. However, the Mg concentration in the calcined magnesite treatment is increasing with time relative to the control, and it appears that the effect of this source may be starting to show more strongly. In the 1990/91 analyses there were early indications that needle mass was increased in the calcined magnesite treatment. Although the concentration of magnesium did not increase, the total content within the needle did suggesting that the calcined magnesite was beginning to have a small effect then.

Pruning

Pruning was done throughout the Halls block trial area on selected trees. Foliage samples were taken randomly and not with respect to the pruned and unpruned trees within the treatments. As such, no analysis can be drawn on the differences between pruned and unpruned trees with the various treatments.

Conclusions

The only elements possibly in short supply in this trial are Mg and N as evidenced by foliar concentrations near the critical level. However, while N concentrations are marginal, growth rates are high, suggesting no limitation. Five and a half years after fertiliser application it was shown that foliar Mg concentrations in those plots fertilised with 400 Kg Mg ha^{-1} as Epsom salts remained above the concentrations of the unfertilised plots and foliar K:Mg ratio was reduced by application of the fertiliser. It appears that the highly soluble Epsom salts have more of a long term effect than expected. The effects of grass competition on foliar Mg levels found earlier in the experiment were not apparent at this stage, probably due to the lessening of competition as trees have shaded the grass out in all plots. The magnesium added as calcined magnesite had not significantly increased foliar Mg concentration over the control, though concentrations appeared to be increasing relative to the controls. As in other Mg trials, foliar boron concentrations had declined in the Mg fertilised plots, though not to a critical level. Copper concentrations were also depressed. The improvement in foliar B concentrations due to B fertiliser application was still apparent five years after application.

This trial was only designed to run for three to five years and has very small plots, however it is recommended that further foliage and soil sampling exercises are done in 1997 and 1999 to further monitor the longevity in improvement in foliar Mg and B concentrations and to follow the long term trends of the calcined magnesite treatment. Due to the small size of the plots collection of further mensurational data will not be possible.

Acknowledgments

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Rules for Incorporation in Decision Support System

If Magnesium fertiliser is applied as Epsom salts @ 400 kg Mg ha^{-1} ***Then*** foliar Mg concentrations will be maintained above the control values for at least 5.5 years

If Magnesium fertiliser is applied as calcined magnesite @ 400 kg Mg ha^{-1} ***Then*** Mg concentrations will not be improved in the first 18 months ***But*** will be starting to improve after 5.5 years

If Magnesium fertiliser is applied as Epsom salts ***Then*** there will be a rapid (within 6 months) improvement in both soil solution and exchangeable Mg concentrations ***But*** this will decline thereafter

If Magnesium fertiliser is applied as 2-5 mm chip calcined magnesite ***Then*** there will be little effect on solution Mg concentrations ***But*** exchangeable levels after 18 months will be similar to those from Epsom salts application

If magnesium fertiliser is applied to *P. radiata* ***Then*** foliar boron and copper concentrations will be depressed

If a site is marginal for boron (and/or copper) and magnesium ***Then*** a base dressing of boron (and/or copper) should be applied with the magnesium

If boron fertiliser is added as soluble boric acid @ 4 kg B ha^{-1} ***Then*** foliar B concentrations will be raised by approximately 30 ppm within six months ***But*** this difference will have declined to approximately 2 ppm above the control 5.5 years after application

If grass competition is removed ***Then*** foliar Mg concentrations can decline due to a dilution effect

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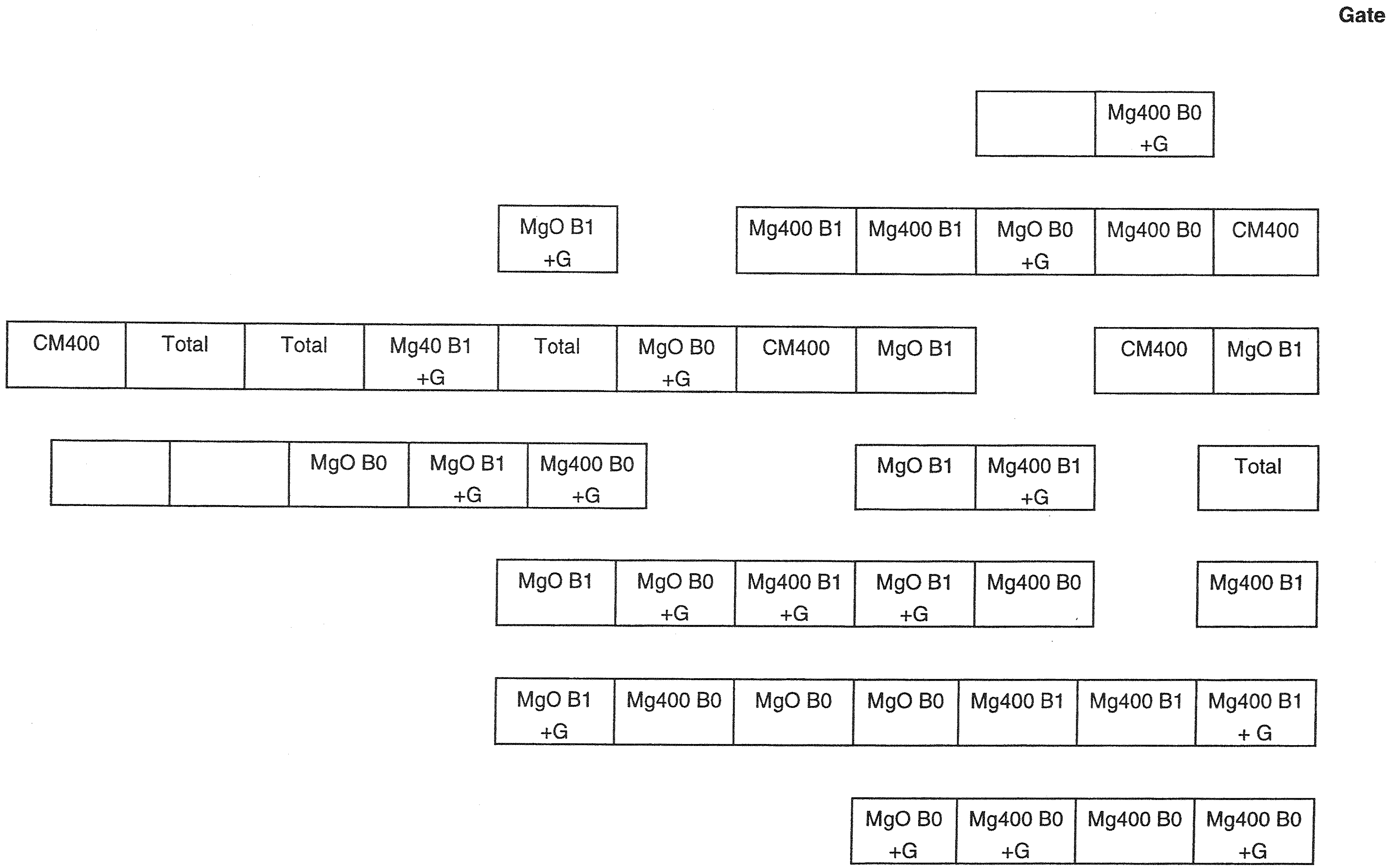
FR 104/3 HALLS BLOCK TAUHARA FOREST



Expt. 134 Tasman (Tim Payn)