MAGNESIUM FERTILISER EFFECTS ON FOREST SOILS UNDER *Pinus radiata*

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ABSTRACT

Magnesium deficiency is of concern in a number of forest regions in New Zealand and has been linked in recent years to a condition in *Pinus radiata* called upper mid crown yellowing (UMCY). Magnesium deficiency is also acknowledged as a common nutrient disorder linked to 'new type forest decline' in Europe and the USA. With increases in the number of rotations and increased growth rates through tree breeding, the incidence of Mg deficiency and UMCY is expected to increase. This study investigated the Mg fertility of a range of forest soils, their responses to the application of Mg fertilisers and Mg uptake by *P. radiata*.

New Zealand Forest Research (Institute Ltd) has established a series of Mg fertiliser trials (FR190 series) in a range of forest soils. Five of these trial sites, located in the North Island of New Zealand, where calcined magnesite (calmag) was applied at 150 kg Mg ha^{-1}, were sampled to investigate the effectiveness of calmag in increasing plant available Mg and to determine the fate of the fertiliser. At all of the sites, within two and three years following calmag application, both soil exchangeable Mg and solution Mg concentrations were increased in the top 5 cm. However, the increases were significant only at three of the sites, where the initial soil exchangeable Mg was low. The other two soils had medium to high concentrations of soil exchangeable Mg prior to Mg fertiliser application. Between 70-90% of the applied fertiliser Mg had dissolved and estimated losses due to leaching ranged from 0-20%. Foliar concentrations of Mg were generally improved in the fertilised trees, but the increases were not significant.

Symptoms of Mg deficiency and UMCY are worse in trees that have high foliar K:Mg ratios. High foliar K:Mg ratios reflect changes in the pools of soil exchangeable Mg and K. Therefore, the effects of Mg fertiliser application on soil K:Mg molar ratios at the FR190 series trials were examined. In the trials where Mg fertiliser application significantly increased soil exchangeable Mg the soil K:Mg molar ratio was significantly reduced. This could see a reversal of the trend of the soil K:Mg ratios increasing with time and a reduction in the severity of Mg and UMCY symptoms. In

the trials that had medium to high concentrations of Mg, the K:Mg molar ratio was not affected by increases in exchangeable Mg from Mg fertiliser application.

As there are several Mg fertilisers with varied solubilities available to foresters a study was conducted to determine the rates of dissolution of a range of Mg fertilisers applied at 200 kg Mg ha^{-1} to a pumice soil under *P. radiata* in Kaingaroa Forest near Rotorua. Twenty seven months after fertiliser application the mean percentage of Mg dissolved were 100% for Epsom salts, 92% for calcined magnesite 1-2 mm, 91% for Granmag 20 (granulated product from 20% acidulation of calcined magnesite, 2-4 mm), 83% for calcined magnesite 2-4 mm and 70% for forestry grade dolomite. The specific dissolution rate constants (μg fertiliser cm^{-2} day^{-1}) for the slowly soluble Mg fertilisers were 279 for calcined magnesite 1-2 mm, 220 for calcined magnesite 2-4 mm, 212 for Granmag 20 and 13 for forestry grade dolomite. A computer program based on an elemental sulfur (S^o) oxidation model, where the rate of S^o oxidation depends on surface area of the particles, explained the rate of dissolution of Mg fertilisers within a narrow fertiliser particle size range.

Application of Mg fertiliser has been shown to increase plant-available Mg. However, there has been no significant increase in foliar Mg concentrations in the fertilised trees. It was thought that though the bulk soil had sufficient plant-available Mg, some factors in the rhizosphere might be inhibiting Mg uptake by *P. radiata*. Therefore, trials were conducted to increase the understanding of Mg availability in the soil immediately surrounding the tree roots. Two glasshouse experiments were conducted investigating the tree-induced changes in Mg availability in the rhizosphere of *P. radiata* seedlings. The first used pumice topsoil fertilised with various forms of Mg fertilisers. The second used pumice sub-soil that had lower exchangeable Mg concentrations and pH buffering capacity. The subsoil was fertilised with different rates of Mg and K fertilisers.

There was a significant accumulation of exchangeable Mg in the soil layers near the rhizosplane, compared to the bulk soil for the Epsom salts and granmag fertiliser treatments in the first experiment. A similar accumulation occurred for treatments where Mg fertiliser was applied in the second experiment. Magnesium accumulation at the root surface is probably due to a higher rate of Mg movement by mass-flow

compared to Mg uptake by the seedlings. The higher rate of Mg movement was probably caused by high seedling transpiration rates. Magnesium accumulation in the rhizosphere could have also been influenced by ectomycorrhizal fungi growth.

Soil pH in the rhizosphere soil of the first experiment was generally unaffected by nutrient uptake of the seedling compared to the bulk soil, probably due to the high buffering capacity of this soil. Whereas, in the second experiment the soil pH, because of the low pH buffering capacity of the soil, was significantly reduced in the rhizosphere compared to the bulk in all treatments. Cation-anion balance without considering N uptake, showed that the seedlings took up an excess of cations compared to anions. Because the ionic form of N taken up by the seedlings was not determined, it was not possible to explain the rhizosphere acidification from the cation-anion balance in the seedlings. Magnesium concentrations in the fertilised seedling in the first experiment increased for all fertiliser types used, but only the increases in root Mg concentrations were significant. In the second experiment Mg fertiliser application significantly increased Mg concentrations in both the shoots and roots.

Recently, Forest Research installed a fertiliser trial that manipulated the soil K:Mg ratio through the application of Mg and K fertiliser. This trial was used to study the losses of Mg due to leaching under *P. radiata* after the application of Mg and K fertiliser. Suction cup lysimeters were installed at 2 depths (10 cm and 45 cm) to monitor changes in soil solution Mg concentrations in the top-soil where the active roots are and the leaching losses of Mg down below 45 cm over an 18 month period after fertiliser application. Magnesium and K fertiliser application resulted in significant increases in soil solution Mg and K concentrations in the 0-10 cm soil layer soon after fertiliser application. However, by 90 to 180 days after application concentrations have returned to levels not significantly different from those of the control treatment.

The soil solution K:Mg molar ratio in the 0-10 cm soil layer was significantly increased by both K fertiliser treatments at all sampling times. Magnesium fertiliser application generally decreased the soil solution K:Mg molar ratio, although none of the decreases were significant. Magnesium fertiliser application significantly decreased the soil

exchangeable K:Mg molar ratio and K fertiliser application significantly increased the soil exchangeable K:Mg molar ratio.

Between 180 to 240 days following application, concentrations of Mg and K in the sub soil lysimeters peaked. Concentrations of solution Mg in the sub soil lysimeters of the fertilised and unfertilised plots were generally greater than solution K concentrations. Estimated leaching losses of Mg were 39.4 kg Mg ha^{-1} in the Mg fertilised plots and 11.2 to 26.9 kg Mg ha^{-1} in the K fertilised plots. Estimated leaching losses of K were 8.9 kg K ha^{-1} for the 200 kg K ha^{-1} treated plots and 17.4 kg K ha^{-1} for the 400 kg K ha^{-1} treated plots. Magnesium fertiliser application did not cause any increase in the leaching losses of K.

This thesis has increased the knowledge base of the Mg fertility of a range of forest soils and their response to application of Mg fertiliser. More research is required to determine the reasons for the slow tree response to increases in soil Mg from Mg fertiliser application and the role of ectomycorrhizal in the Mg uptake by *P. radiata*.

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