CRITICAL SOIL MAGNESIUM LEVELS FOR RADIATA PINE NUTRITION

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ABSTRACT

Soil magnesium (Mg) levels corresponding to the critical foliar Mg level in radiata pine (**Pinus radiata** D. Don) of 0.06-0.08% (600-800 ppm) were investigated in a preliminary study of eight trees on the Ahaura stony fine sandy loam in the Inangahua Depression, South Island. Of the four measures of soil Mg studied, (1) total, (2) HNO_3-soluble and (3) HCl-soluble, but not (4) exchangeable, were found to give significant correlations with foliar Mg levels. HNO_3-soluble and HCl-soluble Mg appear to be potentially the most useful. Critical soil levels corresponding to the critical foliar levels are approximately 300 ppm for HNO_3-soluble Mg and 500-600 ppm for HCl-soluble Mg. Further studies will assess the applicability of these values both to young stands and older stands over a range of soil types.

INTRODUCTION

Foliar analysis and field trials have been commonly used to investigate nutrient problems in radiata pine (*Pinus radiata* D. Don) in New Zealand forests. The potential forest-site fertility of an unplanted area on a particular soil type may be determined from soil analyses providing that the background data exist for relating soil nutrient levels to critical foliar levels of these nutrients. In situations where trees are under nutrient stress, a close correlation between soil nutrient levels and foliar levels seems most likely to occur. In radiata pine in New Zealand, critical soil levels have so far been confidently defined only for phosphorus (Ballard, 1970; Adams, 1970; Ballard *et al.*, 1971).

This paper reports a preliminary study in a 5 ha block of four-year-old radiata pine growing in the Ahaura stony fine sandy loam near Reefton, South Island.

Trees in the block showed visual symptoms of magnesium (Mg) deficiency of varying severity. The study attempted to establish soil Mg levels corresponding to the critical foliar levels of 0.06-0.08% (Will, 1966). Four methods of extraction were evaluated, chosen partly from those used by other workers in similar studies with other pines (Leaf, 1968), and partly from methods currently in use at the New Zealand Soil Bureau to investigate the magnesium status of New Zealand soils.

EXPERIMENTAL

The study area (grid reference S 31 : 338444) is located near Fletcher Creek, 1.8 km SW of Rotokohu on State Highway 69 between Reefton and Inangahua Junction, Westland. The 5 ha block was planted in radiata pine in 1969 following clear-felling of the original beech forest. Present (1973) stocking of the stand is 1140 stems per ha, with a predominant mean height of 4.5 m and a mean diameter breast height of 5 cm (D. J. Evans, pers. comm.).

The soil type is Ahaura stony fine sandy loam which is classified as a hygrous to hydrous southern yellow-brown earth formed from glacial outwash gravels. It is the major soil type on the low glacial outwash terraces in the Inangahua Depression (Mew *et al.,* in press).

Foliar samples were taken from one-year-old foliage on the top whorls of eight trees in April 1972. The sampled trees showed visual Mg deficiency symptoms of varying severity and were classified into three classes (Table 1):

1. with severe symptoms,
2. with moderate symptoms,
3. with no symptoms.

Severely affected trees (class 1) showed yellowing of all one- and two-year-old foliage with yellow colours of 5Y 7/8-8/8 (Munsell Soil Colour Chart). Moderately affected trees (class 2) showed yellowing of needle tips with two-year-old foliage being more affected than one-year-old foliage. Trees in class 3 showed no visual deficiency symptoms.

Foliar samples were dry-ashed following Piper (1942) except that any insoluble silica residue was discarded. Magnesium was measured in the acid extract by atomic absorption spectrophotometry (Techtron AA4) using strontium as a suppressant. Calcium (Ca) and potassium (K) were measured by emission flame photometry.

Soil samples were collected from the immediate vicinity of each tree. Each sample was a composite of eight cores taken randomly around each tree within the area bounded by the tree crown. Cores were collected from 0-15 cm which had previously been found to be the average depth of the A_1 horizon and the depth in which most tree rooting occurred.

Four methods of soil Mg analysis were investigated:

(a) Total Mg—following destruction of organic matter by concentrated HNO_3/HCl, the samples were treated with 42% HF for 3 hours at 90°C, evaporated to dryness, and the residue extracted with 5 M HCl and boric acid.

(b) Exchangeable Mg—as in Blakemore *et al.* (1972).

(c) HNO_3-soluble Mg—as in Leaf (1958).

(d) HCl-soluble Mg—as in Metson (1968) except that exchangeable Mg was included in the HCl-soluble fraction.

The extracted Mg was determined by atomic absorption spectrophotometry as for the foliar samples.

RESULTS AND DISCUSSION

The relationship between visual deficiency symptoms and foliar cation levels is shown in Table 1. Foliar Mg levels are closely related to the visual symptoms. Radiata pine with no visual symptoms have foliar Mg levels within the critical range suggested by Will (1966) for this element. The moderately and severely affected trees have foliar levels well below the critical foliar range.

Foliar K levels in all but one of the affected trees are below the suggested critical level (0.4%, 4000 ppm) of Will (1966). The bright yellow colours characteristic of Mg

TABLE 1—Visual deficiency symptoms and foliar cation levels of sampled radiata pine.

Tree number	Visual deficiency symptoms	Foliar Mg	Foliar K	Foliar Ca	(Ca + Mg + K)
		%	%	%	mol kg^{-1}
1	severe	0.029	0.343	0.123	0.13
2	severe	0.021	0.377	0.086	0.13
3	severe	0.022	0.210	0.187	0.11
4	moderate	0.057	0.494	0.314	0.23
5	moderate	0.059	0.208	0.164	0.12
6	none	0.079	0.769	0.169	0.27
7	none	0.067	0.758	0.232	0.28
8	none	0.083	0.728	0.229	0.28

deficiency are often compounded by the dull, more neutral yellows to bronzes of K deficiency (Leaf, 1968). In the current study the bright yellow needle colours suggest that Mg deficiency was the main cause of the visual symptoms. Potassium deficiency may be contributing to these symptoms. Total cation levels (Ca + Mg + K) in the deficient trees (Table 1) are below the level of 0.25 mol kg^{-1} considered from data on radiata pine at Kaiteriteri, Nelson to be critical for cation deficiencies (Adams, unpublished data).

Fig. 1 shows the correlations between foliar Mg and the four measures of soil Mg which were investigated. It appears that all except exchangeable Mg can adequately differentiate deficient from non-deficient sites on the soil type studied. The very highly significant correlation with total Mg is rather surprising as total element concentrations commonly bear little relationship to nutrient availability. The very highly significant correlation here suggests that the cause of the Mg deficiency in the radiata pine examined may be the very low levels of total Mg in the A_1 horizon rather than a problem of availability. This is supported by chemical analysis of an Ahaura stony fine sandy loam profile under beech 100 m from the study area which shows very low total Mg in the A_1 horizon increasing sharply in lower horizons (Adams, in press). This suggests that the Ahaura soil series may sustain healthy tree growth once the higher subsoil Mg content is utilised.

The lack of correlation between foliar and exchangeable Mg in this study suggests that exchangeable soil Mg levels are likely to be of little practical use in the evaluation of forest-site fertility. Ballard *et al.* (1971) have also found no correlation between foliar Mg and exchangeable soil Mg in a New Zealand-wide survey of radiata pine stands. This lack of correlation may be due to the dependence of exchangeable soil Mg levels on the soil organic matter content which is likely to show considerable variation within soil groups, independent of their total Mg contents. In this study disturbance of the original organic horizons has occurred during clear-felling of beech and replanting in radiata

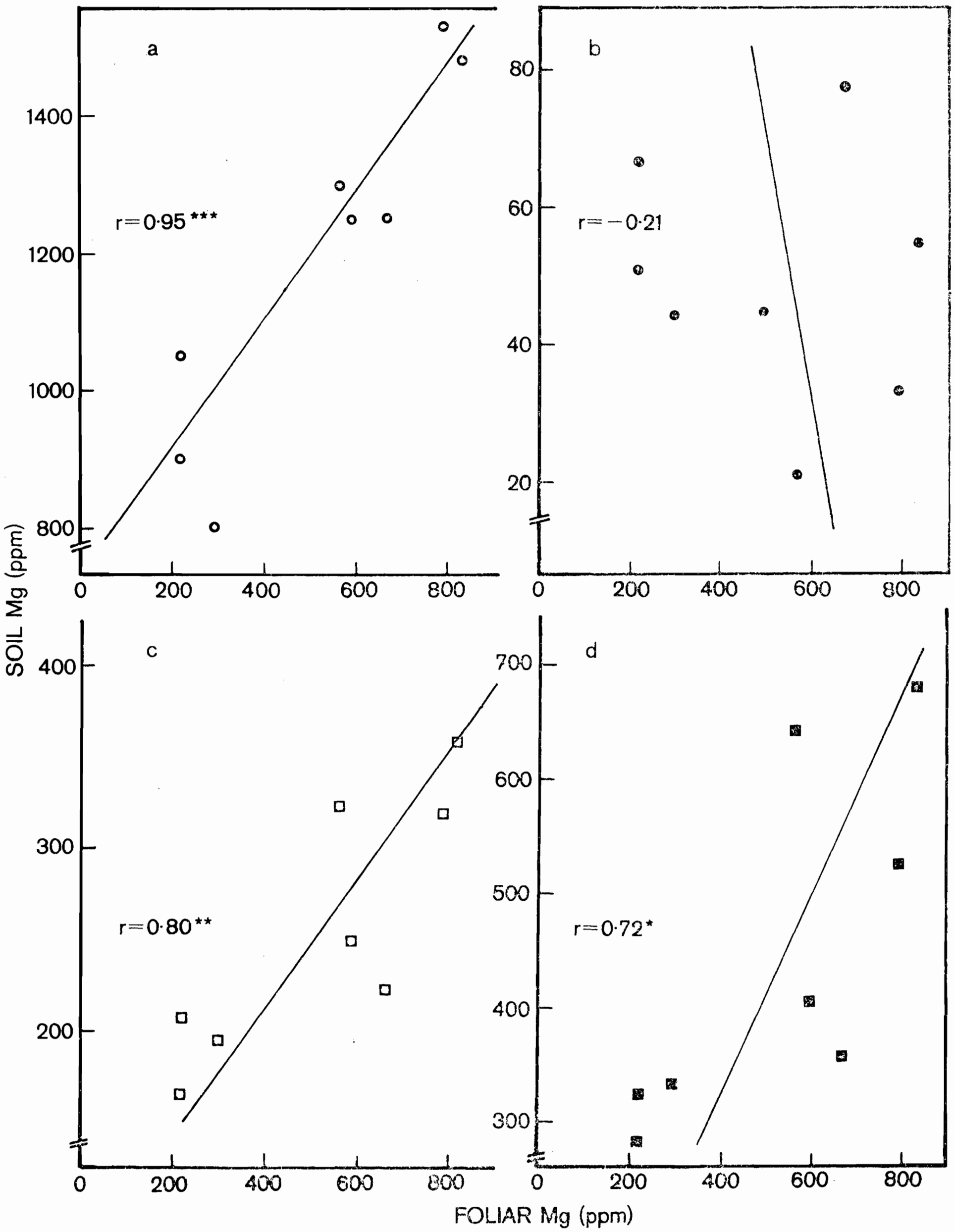

FIG. 1—Relationships between (a) total Mg, (b) exchangeable Mg, (c) HNO_3-soluble Mg, (d) HCl-soluble Mg, and foliar Mg in the sampled radiata pine (* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$).

pine. This has resulted in a patchy distribution of organic matter over the planted area.

Both HCl-soluble and HNO_3-soluble Mg are related to foliar Mg levels (Fig. 1) with HNO_3 showing the higher correlation. The HCl reagent extracts 50 to 100% more Mg than the HNO_3 reagent but both extract similar fractions of soil Mg as is shown by a very highly significant correlation between the Mg extracted by the two reagents (r = 0.97 * * *). The extracted Mg is closely related to the total Mg contents of the samples as shown by the correlation coefficients of 0.90 * * * and 0.80 * for HNO_3 and HCl respectively.

Although HNO_3-soluble Mg is the more strongly correlated with foliar Mg, the HCl extractant shows a more distinct separation of the critical foliar levels between deficient and non-deficient soils. Levels of soil Mg corresponding to the critical foliar level of 0.06-0.08% (600-800 ppm) in this study are approximately 300 ppm of HNO_3-soluble Mg and 500-600 ppm of HCl-soluble Mg.

It has been shown that total, HNO_3-soluble, and HCl-soluble soil Mg are correlated with foliar Mg levels in an area of radiata pine in Westland. Critical soil Mg levels can be estimated for the soil type studied. Further studies will investigate which method provides the best measure of Mg uptake by radiata pine over a range of soil types.

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