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DIAGNOSIS AND TREATMENT OF MOLYBDENUM DEFICIENCY IN PASTURES

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Abstract

Despite the use of molybdenum on New Zealand pastures for 30 years the diagnosis of molybdenum deficiency is not easy nor is it clearly understood. In this paper we show how a knowledge of the function of molybdenum and factors that affect the molybdenum concentration in plants can be used to make a confident assessment of pasture molybdenum status. The MAF recommended rate of application of molybdenum has been reduced to 50 g/ha sodium molybdate every four years and the basis for this change is discussed.

Keywords: molybdenum, trace elements, nitrogen fixation, pastures, clover, topdressing.

INTRODUCTION

It is now over 30 years since molybdenum (Mo) deficiency was first identified in New Zealand pastures (Davies 1952). Whilst topdressing pastures with molybdic superphosphate has been an effective way of overcoming the low level of plant available Mo in many of our soils, the diagnosis of Mo deficiency is still difficult. There is no satisfactory soil test and plant analysis is not always straightforward and conclusive.

In this paper we identify a number of factors which affect Mo availability. Consideration of these effects will allow an assessment of the Mo status of pastures to be made with confidence.

FUNCTION OF MOLYBDENUM

Mo is essential for all plants as it is a constituent of two important enzyme systems which are both involved in nitrogen (N) metabolism.

1. All plants require the enzyme **nitrate reductase** because N absorbed as nitrate must be reduced before it can be used to synthesise amino acids and proteins within the plant.
2. In legumes, N fixation by the nodule bacteria requires the enzyme **nitrogenase.** The Mo requirement for this process is much greater than that for nitrate reduction. This is the reason why all the Mo responses in New Zealand pastures have been due to increases in the clover component and subsequent increases in the amount of N fixed. Consequently the symptoms of Mo deficiency in pasture are those of N deficiency.

FACTORS AFFECTING Mo AVAILABILITY

Soil Type

Trace element deficiencies are often associated with specific soil types due to the nature of the parent material and to soil forming processes. This is certainly true for Mo (Fieldes and Wells 1957, During 1962). Soon after the first pasture response to Mo was obtained in New Zealand, hundreds of field trials were laid down throughout the country by the Department of Agriculture. These were mainly observational trials but they delineated all the soil types on which there was a potential Mo deficiency. Numerous articles in the Journal of Agriculture throughout the 1950's identified these soil types. The map in Figure 1 gives a generalised picture and shows that deficiency was widespread throughout the South Island, particularly on soils formed from

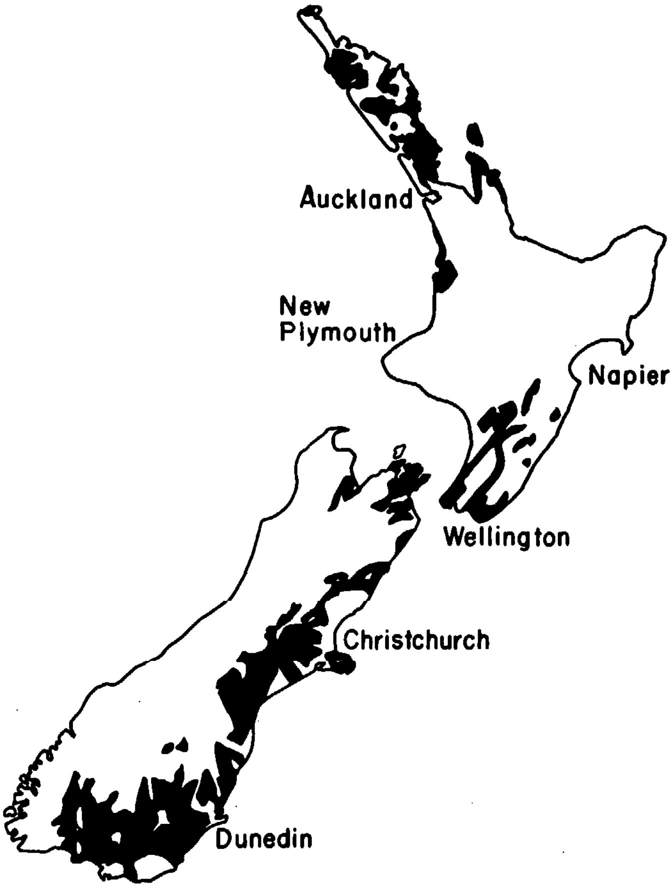

FIGURE 1: Distribution of Molybdenum Deficient Soils in New Zealand.

greywacke loess and alluvium in Southland, Otago and Canterbury, as well as in isolated pockets in Marlborough and Nelson. In the North Island deficiencies were found around the base of the Ruahine and Rimutaka ranges and in Manawatu, on yellow-brown earths in Raglan county and on many soil types in Northland. More details of responsive soils are available in local MAF offices and perhaps the best summary is available in During's (1984) book. However, when those trials were carried out the land was still in the development stage and many soils had low pH. Since then Mo has been widely used and many of the soils have been limed so they are not now nearly as responsive. The map should now be regarded as indicating that a potential deficiency may exist on these soils but other factors must also be considered in the assessment of Mo status.

Soil pH

Mo differs from other trace elements because it is the only one which increases in availability with pH. This is illustrated in Table 1 of data taken from results of trials at the Masterton Research Area. The two trials were adjacent, on identical soil and separated only by a fence line, but one area had been limed earlier and pH was 6.4 whereas the unlimed area had pH 5.4. Mo concentrations were much higher at the

TABLE 1: Effect of pH on Mo Concentration (ppm) in Mixed Herbage on Kokotau Soil.

Treatment	pH 6.4	pH 5.4
Control	0.72	0.17
Control + Lime	0.71	0.50
140 g/ha Na_2MoO_4	2.09	0.68
140 g/ha Na_2MoO_4 + Lime	2.30	1.56

TABLE 2: Effect of Soil Moisture on Mo Concentration in Clover in Manawatu Sand Country Trials (Means of 5 Comparisons in the Same Paddocks).

Moisture Status	Mo Concentration (ppm) untreated	Mo applied
Dry	0.17	0.31
Wet	0.26	0.74

higher pH and lime increased Mo concentration only at pH 5.4. Note also that 140 g/ha sodium molybdate at pH 5.4 raised Mo concentration to 0.68 ppm which is similar to that of the untreated control at pH 6.4. There was a dry matter response at pH 5.4 but not at 6.4. Hence the earlier liming had increased the availability of soil Mo sufficiently to counteract any response to applied Mo. On many soils a Mo response is unlikely above pH 6.0. However, some yellow-grey earths and yellow-grey to yellow-brown earth intergrades in the South Island may have an absolute Mo deficiency and require Mo irrespective of pH.

Soil Moisture Content

Mo is much more available under high moisture than under dry conditions. Data in Table 2 illustrate this effect. These were obtained in trials in the Manawatu sand country where paddocks consist of a complex pattern of wet and dry areas, but with the same parent material. Mo was applied in strips across the paddocks and clover samples obtained from both wet and dry areas. Without Mo treatment, Mo concentration was higher in wet than in dry areas and the effect of added Mo on Mo concentrations was also greater on the wet areas.

Seasonal Variation

The effect of moisture is probably the main reason for seasonal changes in Mo concentration which have been found on many soils. Figure 2 illustrates results from a trial on Hukerenui sandy loam near Whangarei in which Mo concentration in mixed pasture was monitored for a five year period. Mo concentration was at a maximum in late winter-early spring; it then fell during the summer to a minimum in February-March and then rose again. This pattern is, of course, identical to the seasonal changes in soil moisture content. The period of high Mo concentration coincides with the period when animal health problems occur in Northland. These problems are suspected to be induced copper deficiency (Smith 1973).

This seasonal variation must be considered when pasture Mo concentration is used for diagnosis. Samples should not be collected when soil is very wet or very dry.

Other Factors

Mo concentration can be affected by factors other than those already discussed, e.g. phosphate and sulphate concentration in the soil but these effects usually last for only a short time. Phosphate increases but sulphate decreases Mo concentration. However, as sulphate has a greater effect, superphosphate will tend to decrease Mo concentration in pastures.

'Pasture species also differ in Mo concentration. Generally legumes contain more than grasses when the supply of Mo is adequate but less under deficiency conditions. For this reason it is best to analyse pure clover samples.

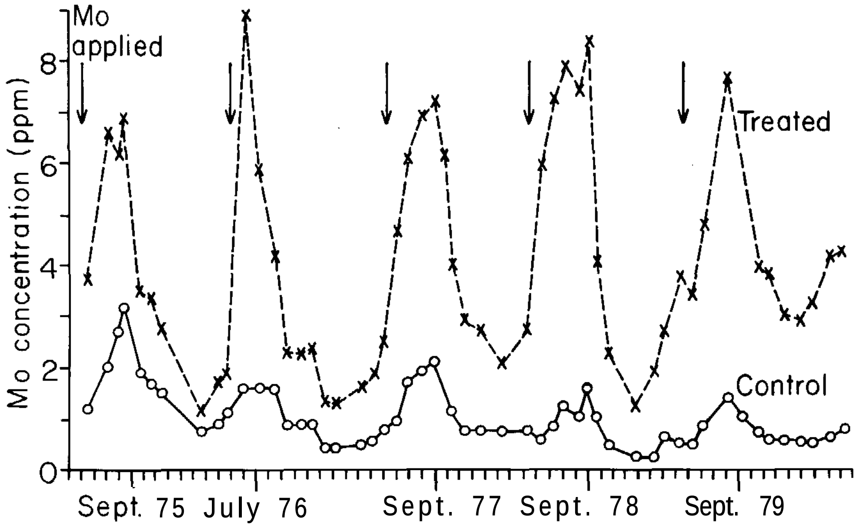

FIGURE 2: Seasonal Variation in Molybdenum Concentration in Mixed Herbage.

MOLYBDENUM AND NITROGEN CONCENTRATIONS IN CLOVER

Because Mo is so important in the N fixation process both Mo and N concentration in clover must be considered if plant analysis is used to diagnose Mo deficiency. Under deficiency conditions, Mo and N are both below optimum and when Mo is added, much of it is used to optimise N fixation. Consequently N concentration increases greatly but Mo concentration in the shoots increases only in proportion to the surplus Mo not required by the nodule bacteria.

In cases where Mo is low in the shoots but N is adequate the fixation process must be working satisfactorily. In this situation if Mo is applied, very little is needed by the bacteria so it moves up into the shoots. Hence there is a relatively large increase in Mo but only a small increase, if any, in N concentration.

These effects are well illustrated in Figure 3, with data from the Manawatu sand country trials mentioned before. The A and B sites are in different parts of the same paddocks. On untreated areas in each paddock Mo concentrations were similarly low at A and B sites but N concentrations were much higher on B than on A sites. When Mo was applied increases in Mo concentration at the A sites were small compared to those at the B sites whereas the increases in N concentration at the A sites were large compared with those at the B sites. Dry matter yield responses to applied Mo occurred only at the A sites. Hence Mo and N must both be below optimum (0.1 ppm and 4% N respectively) before a growth response to applied Mo will occur. The critical value for Mo deficiency is 0.1 ppm in clover but a few cases of Mo response have been obtained at slightly higher values. This may be due to sampling or analytical errors. The determination of molybdenum is difficult at such low concentration. It is important that analyses are carried out by a laboratory with good quality control.

DIAGNOSING Mo DEFICIENCY

We can now write a check list for the diagnosis of Mo deficiency. It is important that

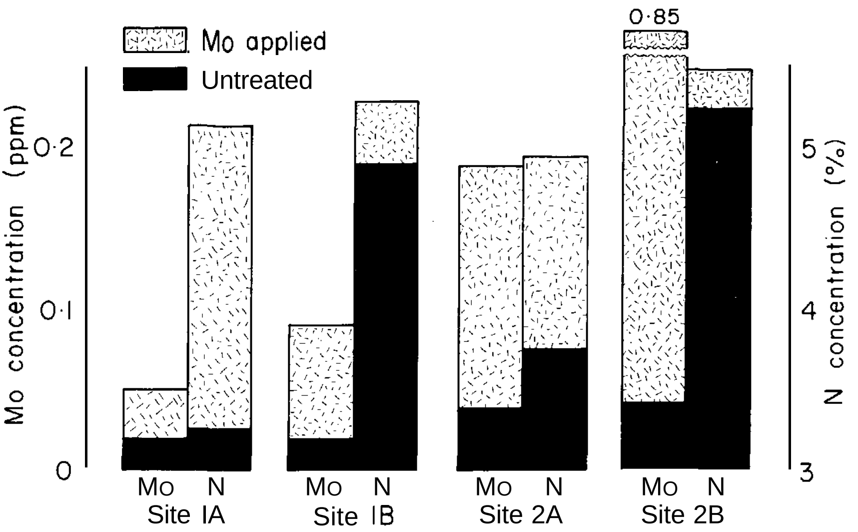

FIGURE 3: Effect of Molybdenum on Molybdenum and Nitrogen Concentrations in Clover in Manawatu Sand Country Trials.

all the factors are considered as it is not possible to make an accurate diagnosis from any single factor.

1. Clover content and vigour
2. Soil type
3. Soil pH
4. Previous Mo and lime usage
5. Mo and N concentrations in clover

If these still do not permit a conclusive diagnosis to be made then there is one more thing that can be done and that is a

6. Field test strip

A strip or small area of the suspect paddock is sprayed with a solution of sodium molybdate and observed to see if there is a response. In some cases it may take 12-18 months for a response to show up.

TREATMENT OF Mo DEFICIENCY

The MAF recommendation for Mo fertiliser has been changed recently to 50 g/ha sodium molybdate every four years (Sherrell and Metherell 1984).

The former recommendation of 140-175 g/ha (2-2½ oz/ac) sodium molybdate dates back to the early 1950's and was chosen arbitrarily before many rates of Mo trials had been carried out. In experiments with rates above 175 g/ha very few showed a need for higher applications so this rate was adopted as a general recommendation for most of the country and was used in all the trials to map Mo deficiency.

Several trials with rates of Mo have now been conducted and have shown that maximum response occurs at rates below 175 g/ha. This is illustrated in Figure 4 drawn from the data of Scott (1963). There was a marked response up to 35 g/ha initially. After four years, treatments were reapplied to half of each plot so that comparison could be made between yields on the original and reapplied portions. In year five, there was no response to reapplication at 70 and 140 g/ha but there was to 35 g/ha. In other words, the optimum rate was between 35 and 70 g/ha applied every four years. We chose 50 g/ha and data in Figure 5 indicate this is adequate.

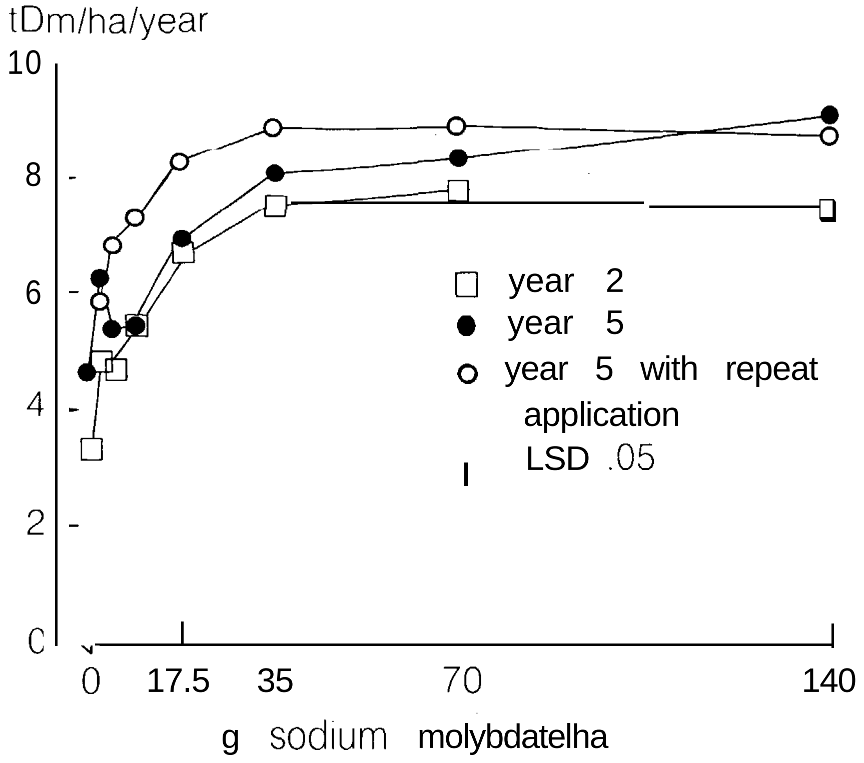

FIGURE 4: Response of Pasture to Molybdenum on Warepa Silt Loam (After Scott 1963).

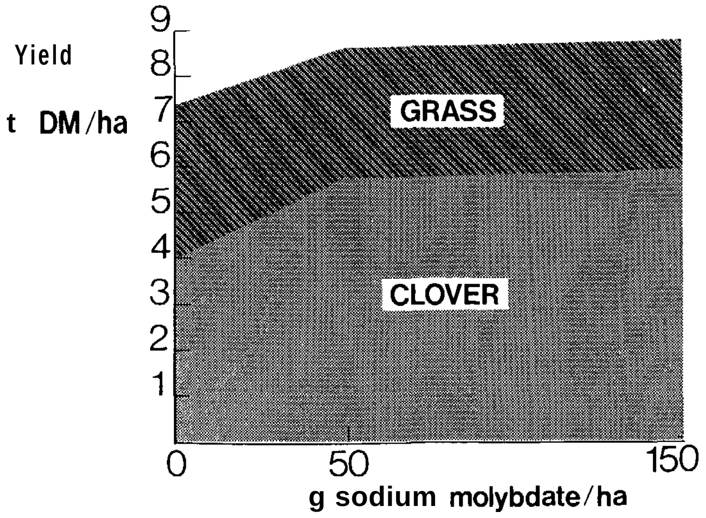

FIGURE 5: Effect of Molybdenum on Pasture Production on Te Houka Soil.

This new rate of application will give the maximum dry matter yield and reduce the risk of stock health problems associated with elevated Mo concentration in herbage. It can be achieved by applying 100 kg/ha of 0.05% Mo superphosphate (South Island) or 330 kg/ha of 0.015% Mo superphosphate (North Island). At pasture establishment or over-sowing the use of Mo-coated seed is a good alternative as this ensures an immediate Mo supply for all seedlings.

Molybdenum is still cheap, costing only 30 cents per ha per year. Thus the aim should be to eliminate all possibility of a molybdenum deficiency limiting the maximum response to other fertilisers. This should be achieved if the diagnostic criteria are carefully considered and the above recommendations are followed.

Acknowledgements

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