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LIME AND PHOSPHORUS REQUIREMENTS FOR HILL COUNTRY YELLOW-BROWN EARTHS

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Abstract

Three fertiliser trials on hill country yellow-brown earths are discussed, The results show that on a newly sown ryegrass *(Lolium perenne)* white clover *(Trifolium repens)* Pasture 90% maximum pasture production was achieved at an Olsen P level of 13-15 ppm. On a reverted browntop *(Agrostis tenuis)* pasture an Olsen P concentration of at least 25 ppm was required for 90% maximum production. Reasons for this difference are discussed. Liming increased pasture dry matter production on all sites and the largest increases in production occurred at low (1.25 t/ha) rates. There was no evidence that liming enhanced P availability and therefore lime and P requirements for these soils should be considered independantly. Phosphorus applications generally increased legume production but the effects of lime were variable. On the Mahoenui soil liming increased grass growth at the expense of the legume component but on the Marua soils liming increased the legume content. An explanation for this is suggested. The practical implications of these results are discussed.

Keywords: lime, phosphorus, fertiliser requirements, yellow brown earths, hill country, pasture production, pasture composition, ryegrass, white clover, browntop.

INTRODUCTION

Low soil phosphorus (P) status and low pH are considered to be the two major soil fertility factors limiting pasture production on hill country soils. The objectives of this paper are to discuss fertiliser P and lime requirements for the North Island yellow brown earths which make up a large part of the North Island hill country.

Blackmore et *al.* (1969) concluded that an initial application of 500 kg/ha superphosphate was necessary for pasture establishment on a range of yellow -brown earths in the Wanganui district. They considered that rates of superphosphate of between 180 to 250 kg/ha would be sufficient for maintaining pasture growth. On established pasture on a related soil type at Te Kuiti, O'Connor *et al (1973)* found no responses in animal performance or pasture growth at rates greater than 250 kg superphosphate/ha. Together these results suggest that annual P inputs of between 18 to 25 kg P/ha are required to maintain pasture production. Calculated soil P requirements for these soils to maintain 90% maximum production range from 15-30 kg P/ha/an depending on stocking rate and pasture utilisation (Cornforth & Sinclair 1982).

The yellow-brown earths are also known to be lime responsive even in the presence of adequate molybdenum (During 1972) and O'Connor *et al.* (1981) have shown that liming at low rates (1.25 t/ha) can be economic,

This paper reports the results from three field trials which were designed to further refine P and lime requirements of these soils,

MATERIALS AND METHODS

Three field trials were conducted, two on Marua clay loam, a yellow brown earth derived from greywacke (NZ Soil Bureau 1968) at Te Kauwhata, and the third on a Mahoenui silt loam, a steepland yellow brown earth derived from silt-stones (NZ Soil Bureau 1968) at Te Kuiti.

Brief details of the trials and soils are given in Table 1. All of the sites have comparable soil pH but the P status of the Mahoenui site is higher. Soil aluminium (AL) concentrations are higher on the Marua soil than on the Mahoenui.

Table 1: SOILS AND SOIL CHEMISTRY

Location	Soil Group and Type	Soil Chemistry pH*	Olsen P*	Mg*	K*	Al**
Te Kauwhata	yellow-brown earth Marua clay loam	5.2	8	39	9	7.1
Te Kauwhata	yellow-brown earth Marua clay loam	5.2	11	32	8	5.3
Te Kuiti	yellow-brown earth Mahoenui silt loam	5.4	14	49	11	1.4

* MAF soil quick tests (Cornforth 1980). Soil samples were collected annually. Soil pH are the mean values over time. Olsen P, Mg, K and AL are the values at Autumn 1983.

** 0.01 M $CaCl_2$ extractable Al (μg^{-1} soil)

Marua Trials

Two randomised block experiments with four replicates were laid down with two levels of lime (nil and 2.5 t/ha limestone) and four levels of applied P, the rates of P application were different for the two trials according to their initial P status, A basal dressing consisting of sulphur (S) (50 kg/ha; 50:50; gypsum: elemental S), and potassium (K) (250 kg KC1/ha) was applied annually. Molybdenum (350 g sodium molybdate/ha) was applied in 1978 and 1981. These trials were only grazed by sheep as part of the normal rotational grazing system. Pasture production was measured by placing two small (90 x 50cm) cages on representative areas of each plot and handcutting to grazing height after 4 to 13 weeks regrowth depending on growth rate.

One experiment was on a reverted browntop-dominated pasture (slope 40°, aspect NW, 90% browntop *(Agrotis tenuis)* and chewings fescue *(Festuca rubra* L.)) originally oversown with white clover and ryegrass from kanuka *(Leptospermum ericaides)* scrub in 1970. Annual fertiliser inputs up till the trial commenced in 1978 were estimated as 370 kg superphosphate/ha annually. Molybdenum was also applied. The average annual rates of application of P were 5, 35, 70 and 105 kg P/ha as monocalcium phosphate.

The pasture in the second experiment (Slope 40°, aspect W, 80% ryegrass *(Lolium perenne)* and white clover *(Trifolium repens)*) was established in 1978 by oversowing directly following burning of the kanuka scrub. A good white clover-ryegrass based pasture was established and the treatments were applied in 1980. The average annual rates of P used in this experiment were 0, 21, 58 and 91 kg P/ha as monocalcium phosphate.

The results discussed in this paper cover the period 1980-83 for both trials.

Mahoenui Trial

This trial (slope 20°, aspect W, 20-30% legumes, mainly white clover and 70-80% grasses, mainly ryegrass) consisted of 10 treatments including six rates of lime (nil, 1.25, 2.5, 5.0, 7.5, 10.0 t/ha) in a randomised block design with four replicates. All rates of lime were in the presence of adequate P (50 kg/ha) but three further treatments of lime (nil, 5.0, 10.0 t/ha) were included with no P applied.

Pasture production was measured using a mowing-clippings return technique (Lynch 1966). Herbage was harvested to mower height (3cm) when the pasture height reached 10-15 cm. Pasture botanical composition was also determined at each harvest.

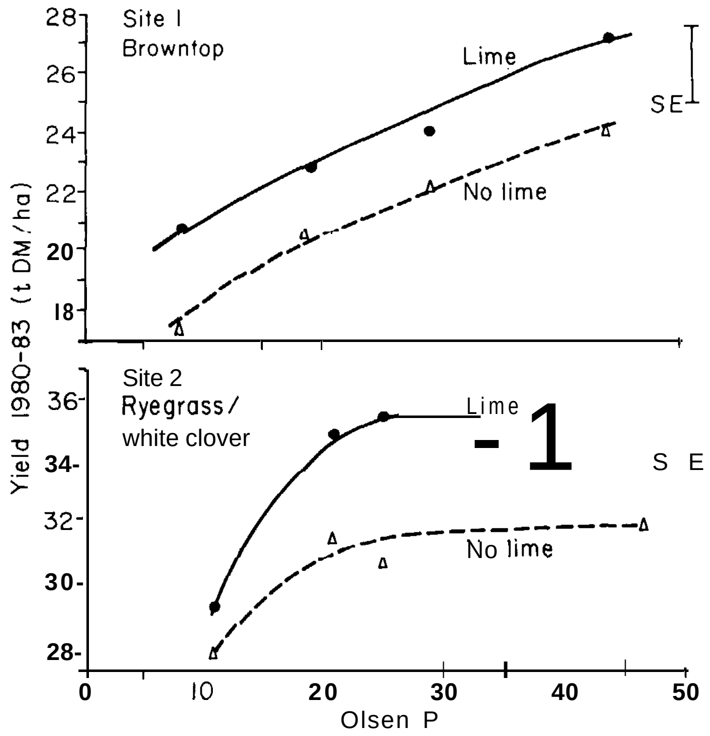

Figure 1: The relationship between phosphorus status (Olsen P) and pasture production in the presence and absence of lime on two trials on a Marua clay loam.

RESULTS

Marua Trials

The results from the two trials on the Marua soil are summarised in Figure 1. On the browntop dominated pasture total production was less than that of the ryegrass-white clover pasture at all levels of P status and pH and pasture production increased ($P<0.05$) with increasing P status up to Olsen P level of 45 ppm. Liming increased ($P<0.05$) pasture production at all levels of P status and there was no significant interaction between lime and phosphate. On the ryegrass-white clover pasture the maximum production was obtained at an Olsen P level of 20 ppm in the presence of applied lime. The results also suggest that liming had a greater effect on pasture production in the presence of applied P (Olsen P 20) than in the absence of applied P (Olsen P 10), however this positive lime x P interaction was not significant.

On both sites lime and P applications increased ($P<0.05$) legume growth (Table 2). in addition, on the ryegrass-white clover pasture, ryegrass growth increased with P. These changes occurred at the expense of other grass species.

Table 2: EFFECTS OF LIME AND APPLIED PHOSPHORUS ON THE YIELD (t/ha) AND PROPORTIONS (%) OF RYEGRASS, OTHER GRASSES AND LEGUMES ON BROWNTOP-DOMINATED AND RYEGRASS-WHITE CLOVER PASTURES ON A MARUA CLAY LOAM OVER 1980-82. (Dead matter not included.)

Trial	Treatment	Pasture Component (%)		
		Ryegrass	Other Grasses	Legumes
Browntop	No P	2.1 (19)	7.5 (67)	1.6 (14)
	P	2.6 (20)	7.8 (62)	2.3 (18)
	No Lime	2.3 (20)	7.6 (67)	1.5 (13)
	Lime	2.4 (19)	7.8 (62)	2.4 (19)
	SED	0.4 (3)	0.5 (3)	0.4 (3)
Ryegrass/white clover	No P	11.4 (59)	4.9 (25)	3.0 (16)
	P	14.9 (64)	3.9 (17)	4.3 (19)
	No Lime	12.7 (63)	4.3 (21)	3.2 (16)
	Lime	13.7 (61)	4.5 (20)	4.2 (19)
	SED	0.7 (2)	0.5 (2)	0.2 (1)

Table 3: THE EFFECT OF LIME IN THE PRESENCE AND ABSENCE OF APPLIED PHOSPHORUS ON GRASS AND LEGUME PRODUCTION (t/ha) OVER 2 YEARS (1980-82) ON A MAHOENUI SILT LOAM.

Pasture Component	P Treatment	Lime (t/ha)		
		0	5	10
Grasses	- P	12.8	14.7	16.3
	+P	12.5	13.8	15.5
	SED	1.1		
Legumes	- P	3.6	3.2	3.0
	+P	3.7	4.2	3.8
	SED	0.4		

Mahoenui Trial

Pasture growth increased with increasing rate of lime up to the highest pH. Soil AL concentrations decreased rapidly with increasing pH (Figure 2). The largest incremental increase in production occurred at the lowest rate of application. There was no DM response to applied P either in the presence or absence of lime (data not shown).

The increase in total pasture production resulting from liming was due solely

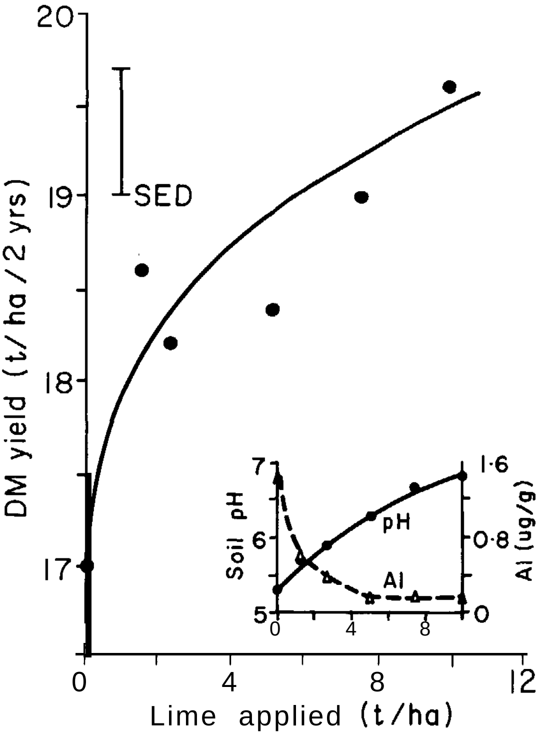

Figure 2: The relationship between lime application and pasture production, soil pH and aluminium concentration on a Mahoenui soil.

to an increase ($P<0.05$) in grass growth but P application increased ($P<0.05$) legume growth in the presence of lime (Table 3).

DISCUSSION

These results confirm that the Marua and Mahoenui soils are both P deficient and respond to liming, a conclusion which is generally applicable to many of the yellow-brown earths in the North Island (During 1961, 1962, 1972, Blackmore *et al.* 1969, O'Connor *et al.* 1973, Lambert *et al.* 1981, **1983,** Lambert & Grant 1980). These soils are also known to be MO deficient (During 1961, 1962, Blackmore et a/. 1969, Lambert & Grant 1980). However the effects of lime measured in these trials were in the presence of adequate applied MO and are therefore due to effects over and above the release of Mo by liming.

Phosphorus Requirements

For the white clover/ryegrass pasture it can be shown that 90% maximum production was achieved at an Olsen P value of 13. This is in general agreement with results (Grigg 1966, Smith & Gregg 1983) which show that the critical Olsen P value (value at which 90% of maximum production is achieved) for other yellow-brown and yellow-grey earths is 18-20 μP/g soil. When converted. to a soil volume basis, as used in the MAF quick test procedure (Cornforth 1980), these are equivalent to Olsen P values of 15-16. This is also consistent with the fact that no pasture DM responses to applied P were obtained on the Mahoenui soil, Olsen P 14.

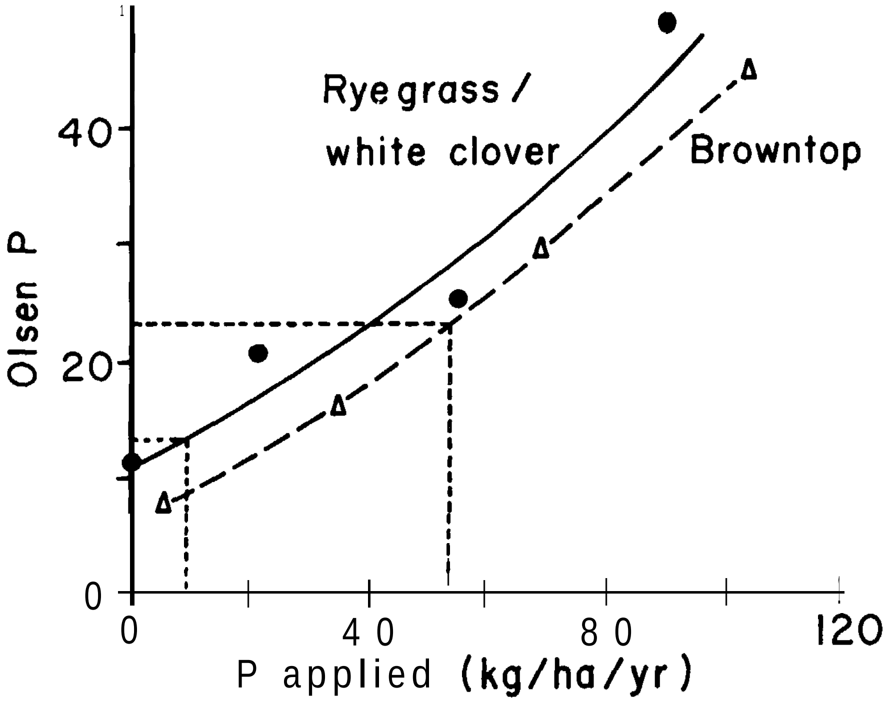

Figure 3: The relationship between the rate of phosphorus application and Olsen P level for two trials on a Marua clay loam.

To achieve this soil P status an input of approximately 10kg P/ha/year for three years was required (Figure 3). This estimated P requirement is lower than that suggested by either other experiments on these soils (Blackmore *et al.* 1969; O'Connor *et al.* 1973) or from modelling calculations (Cornforth & Sinclair 1982). The most likely reason for this is the relatively high P status of this site. In an undeveloped condition these soils would typically have Olsen P values of less than 5. A further reason for this discrepancy is suggested by the effect of pasture composition on P requirements, in particular the presence of browntop.

On the low yielding browntop-dominated site pasture production increased slowly with increasing P application up to the highest rate. If the highest level of production achieved is taken as a maximum then an Olsen P value of at least 25 is required to achieve 90% of maximum production. This required an input of 60kg P/ha annually for five years (Figure 3). These results demonstrate that on browntop pastures with very little legume higher rates of P application are required to stimulate increases in production. This is consistent with the results of Lambert *et al.* (1981) showing that browntop dominated pastures with low legume content are less responsive to P applications at least for the initial few years following application, and are therefore less efficient in terms of DM production per unit of P applied.

Jackman & Mouat (1973) have suggested that this effect is due to the ability of browntop to deplete the clover root zone of available P and also restrict stolon growth by shading. This explanation is consistent with the finding that applied P had a greater proportional effect on the legume component of the browntop pasture (Table 2). The high soil AL levels, particularly in the Marua soil, suggest a further consideration. It is known that high soil AL concentrations can inhibit plant P uptake (Helyar 1978) and also render soil P unavailable through the formation of insoluble AL phosphates (Haynes 1983). Thus, Munns (1965) attributed the initial poor response to applied P to be due to an inhibition by AL, until sufficient P was added to eliminate AL toxicity and overcome P deficiency. It is possible therefore that the combination of browntop dominance and high soil AL together with the lack of a vigorous legume component results in a poor response to plant growth per unit P applied.

Lime Requirements

Lime responses were measured in all three trials and on the Mahoenui soil liming increased pasture production up to the highest pH (pH 6.7). Although it is known that these soils are responsive to liming (During 1961, 1962, 1972, Blackmore *et al.* 1969, Lambert & Grant 1980, O'Connor *et al.* 1981) this result is surprising for there is strong evidence from summarised field trials that the optimum pH for most North Island mineral soils is between 5.8-6.0 (Edmeades *et al.* 1983b). However, the important practical result from this trial is that the largest increases in production from liming occurred at low rates. It is probable for this reason that low rates of liming on this soil (1.25 t/ha) result in economic increases in pasture and animal production (O'Connor *et al.* 1981).

In none of these trials was there a negative lime x P interaction indicating that on these soils liming does not release soil P. This is consistent with much other evidence (Edmeades *et al.* 1981, Mansell *et al.* 1983) showing that the so called P sparing effect of lime is not common on North Island soils. Lime should not therefore be used in the belief that P applications can be reduced. On the Marua trial with a ryegrass/white clover pasture a positive lime x P interaction is indicated showing that the P response (or lime response) is enhanced by the application of lime (or P). This suggests that for maximum production on this soil both lime and P are required.

Botanical Composition

Phosphorus applications generally increased the proportion of legume in the pasture. This is expected given that legumes have a higher P requirement than grasses (Jackman & Mouat 1972). However the effects of lime are not predictable. On the two Marua sites liming increased legume growth but on the Mahoenui soil liming depressed legume growth and stimulated grass growth. The reasons for these differing effects can be explained by the mechanism of the pasture responses to liming.

In glasshouse experiments using these soils (Edmeades *et al.* 1980, Edmeades *et al.* 1983a) it has been shown that the initial response to liming up to pH 5.5 is due to the alleviation of AL toxicity. Soil AL levels decrease rapidly with increasing pH (Figure 2) and it is for this reason that small rates of lime result in large increases in plant growth, At higher pH the effect of lime is due primarily to the stimulation of breakdown of organic N and hence the alleviation of N deficiency. The soil AL concentrations in these soils, particularly the Marua soil, are considered to be toxic (Edmeades *et al.* 1983a). Legumes are more sensitive to AL toxicity than grasses (Helyar 1978) and for this reason on soils with low pH (<5.5) low rates of liming stimulate legume growth relative to grasses. At higher soil pH resulting from higher rates of lime application, as in the Mahoenui trial, liming stimulates grass growth due to the release of organic N.

PRACTICAL IMPLICATIONS

The results discussed in this paper emphasise the need for both P and lime on yellow-brown earths to maximise production. They also demonstrate the importance of vigorous pasture with a good legume base not only to maximise production but also to ensure efficient use of fertiliser P in terms of pasture production per unit of P applied.

Decisions about the amounts of P and lime and their priority will depend on the individual objectives and situation.

On improved white clover-ryegrass pastures where the objective is to maximise production, maximum pasture production may be obtained at Olsen P levels of between 13-15. This was achieved in the present trial by an annual application of 10kg P/ha for a period of three years. The addition of lime together with P will not only maximise production but ensure efficient use of applied P. If however it is necessary to decide between lime and P then the present results suggest that priority should go to P. Responses to lime in the absence of P are likely to be smaller than in the presence of P. However the results from the browntop dominated pasture suggest that as the pasture deteriorates and the legume component decreases at the expense of low fertility grasses such as browntop, the total production will decrease and the requirement for P to achieve near maximum production increases. Thus on low yielding browntop pastures, where the long term objective is to increase production by improving pasture composition, then both lime and P are suggested. Both of these treatments encourage legume growth and pasture vigour. The amounts of P required in such situations as indicated by the results of Blackmore et *al.* (1969) and O'Connor *et al.* (1973) will be between 18-25 kg P/ha annually although this may be modified by stocking rate and pasture utilisation as suggested by Cornforth and Sinclair (1982). Rates of lime not greater than 2.5 t/ha are suggested.

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