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AN EVALUATION OF CHATHAM RISE PHOSPHORITE
AS A DIRECT-APPLICATION PHOSPHATIC FERTILIZER

A thesis presented in partial fulfilment of
the requirements for the degree of
Doctor of Philosophy in Soil Science
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ABSTRACT

Chatham Rise phosphorite (CRP) occurs as nodules on the sea floor some 800 km to the east of the South Island of New Zealand. The phosphate component is a carbonate fluorapatite and the material contains approximately 9% phosphorus (P) and 25% CaCO_3 . Several lines of evidence suggest that CRP has potential as a direct-application phosphatic fertilizer for pasture.

In an initial evaluation in the glasshouse, CRP was found to be an effective source of P for ryegrass when compared to superphosphate over six harvests with four soils. The form (powdered or pelletised) and method (surface applied or incorporated) of application of CRP were found to have a marked effect on the agronomic effectiveness of this P source in the glasshouse. The effectiveness of CRP, when compared at 90% of the yield maxima obtained with superphosphate, which was assigned a value of 100, decreased in the order of powdered and incorporated (100 to 106) > powdered and surface applied (96 to 100) > pelletised and surface applied (85 to 104) > pelletised and incorporated (83 to 90).

Results from a comprehensive, long-term field evaluation of CRP at four contrasting sites under permanent pasture over 3 years confirmed and extended the findings of the preliminary glasshouse study with CRP. Apart from some initial differences, pelletised CRP was as effective as superphosphate at all four sites and at two of the hill-country sites (Ballantrae and Wanganui) it showed a marked residual effect in the third year. This was particularly pronounced in the clover component of the sward at these two sites. In fact at these two sites a single, initial application of 70 kgP ha^{-1} as CRP was agronomically as effective in the

third year as three annual applications of 35 kgP ha^{-1} as superphosphate. This finding has implications to the strategy of fertilizer use. The origin of the marked residual effect shown by CRP at Ballantrae and Wanganui in the third year appears to result from the effect of CaCO_3 on the rate of release of P from CRP.

The findings that pelletised CRP was almost always as effective as both powdered CRP and superphosphate in the field contrasts with the results of the preliminary glasshouse study with four soils. This discrepancy probably results from the fact that in glasshouse studies a number of factors which can operate in the field and which may contribute to an increased effectiveness of a surface-applied, pelletised phosphate rock (PR) material are excluded (e.g. earthworms).

In a glasshouse study, earthworms increased the effectiveness of CRP as a source of P to ryegrass by 15 to 30% over seven harvests. Subsequent studies showed that both the burrowing and casting activity of earthworms indirectly increased the availability to ryegrass of P in the PR by improving the physical distribution and degree of contact of the PR particles with the soil. Interestingly, good agreement was found between the agronomic effectiveness of pelletised CRP in the field and in the glasshouse when earthworms were included as a treatment in the glasshouse. Consequently, care must be taken in extrapolating to the field situation, the results obtained with pelletised PR materials in the glasshouse in the absence of biological mixing.

In a comparison in the glasshouse, using six soils and both ryegrass and white clover as indicator species, CRP was as effective as North Carolina phosphate rock (NCPR) and Sechura phosphate rock (SPR), both of which are reactive PR materials. The agronomic data from this glasshouse study were used to evaluate a number of conventional, single chemical-

extraction procedures used for assessing the likely agronomic effectiveness of PR materials. Of these, 2% formic acid appears to offer the most promise. However, sequential extraction appears to be necessary with PR materials which contain appreciable amounts of CaCO_3 .

A procedure involving a single extraction with 0.5M NaOH was developed for measuring the extent of dissolution of a PR in soil. Because apatite minerals are largely insoluble in dilute NaOH and because this reagent extracts sorbed inorganic P, increases in 0.5M NaOH-extractable P in a soil to which a PR is added, provide a good estimate of the amount of P dissolved and retained on sorption sites. The extent of dissolution of SPR, measured by NaOH extraction, was found to vary from 22% of added P on the low P-sorbing Tokomaru soil to 48% on the high P-sorbing Egmont soil during incubation at 15°C for 90 days. A high correlation ($r = 0.935^{**}$) was obtained for the relationship between the dissolution of SPR, measured by NaOH extraction, and the P-sorption capacity of the six soils used.

Whereas increasing the P status of the Wainui soil, by the addition of KH_2PO_4 , had no measurable effect on the extent of dissolution of SPR, increasing addition of $\text{Ca}(\text{OH})_2$ markedly decreased the dissolution of SPR in this soil. Of the decrease measured in the dissolution of SPR on liming the Wainui soil from pH 5.2 to 6.9, 75-79% of the decrease could be accounted for by the effect of Ca, which also increases on liming. Results with the Egmont soil indicate that a PR can dissolve at pH 6.5. This suggests that the effect of a higher pH on dissolution is decreased in a soil of high P-sorption capacity.

Although the extent of dissolution of SPR increased as the P-sorption capacity of the soils increased, the amounts of water-, Bray-, and bicarbonate-extractable P in the same soils decreased. Of these three estimates of plant-available P, both the Bray and bicarbonate procedures

were found to be useful indicators of short-term, plant-available P when SPR and CRP were added to three contrasting soils. Of the two procedures, the Bray procedure accounted for more of the variability, possibly reflecting the difference in the mechanisms by which these two extractants remove P from soil. In contrast, a single water-extraction procedure grossly underestimated the amount of short-term, plant-available P in the soil to which a PR was added.

A simple model, based on a modified Mitscherlich equation, was developed to describe and predict the dissolution of SPR in soil. The model, which was developed and evaluated using contrasting soils, appears to have good practical application and should prove useful in future studies of the reactions of PR materials in soils.

Although not yet commercially available, CRP appears to have very good potential as a direct-application P fertilizer for pasture and, of particular relevance to hill country farming, it shows a good residual effect. A possible disadvantage is the relatively low P content.

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