NUTRIENT RESPONSES ON A YELLOW EARTH SOIL IN NORTHERN CAPE YORK PENINSULA

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SUMMARY

Nutrient requirements of Stylosanthes guianensis *pastures growing on a yellow earth soil in northern Cape York Peninsula were studied in the field. Previous work at this site had demonstrated the extreme deficiency of P, so all experiments were given basal dressings of phosphatic fertilizers.*

The soils were found to be so deficient in Cu and Zn that no growth was made unless both were added. Rates of five kg ha^{-1} of copper and zinc sulphates were required for maximum growth. Good responses were also obtained to additions of K —with a total of 100 kg ha^{-1} of K being required over the three years of the experiment to maintain a reasonable legume component in the pasture. There was no evidence of growth responses to additions of S, Co, Mn, Mo, or B.

INTRODUCTION

The first phase of this investigation of the nutrient status of the yellow and red earth soils of northern Cape York Peninsula was chemical analysis of the soils and glasshouse experimentation on eleven of them (Isbell *et al.* 1976). The tentative conclusions drawn from these studies were that there would be 'widespread deficiencies of nitrogen, phosphorus, potassium, zinc, calcium and probably copper, with a lesser likelihood of sulphur'. It was also noted that the total soil contents of cobalt and manganese were extremely low. However, it was recognized that confirmation was required on at least one of the sites before confidently extrapolating these results to the region as a whole.

Since the soil phosphorus levels were so low and the shape of the response curve and residual value of applied phosphorus were so important, this nutrient was studied separately (Winter and Gillman 1976). Subsequently, attempts were made to modify the phosphorus requirements by placement and liming (Probert *et al.* 1977) and detailed studies were made on the role of calcium (Probert 1977).

Thus it remained for the other nutrients (including cobalt and manganese) to be studied in order to answer a number of questions.

a. In the work of Jones (1973a) on some granitic sands in Cape York Peninsula only half of the eight soils tested gave significant copper responses in glasshouse studies whilst in the field copper was the most severe deficiency. Of the eleven soils collected at our site only three gave significant copper responses even though the copper content of the soil was only 3–6 ppm. Field experimentation was needed to clarify this point and to determine the optimum rate of application.

b. Zinc was obviously grossly deficient and it remained to determine the optimum rate of application in the field—particularly at the high rate of phosphorus required at this site.

c. According to Isbell *et al.* (1976) there was a possibility of manganese deficiency, considering the low soil and plant levels. This possibility required checking in the field.

d. Although cobalt was not shown to be deficient in the glasshouse despite low soil values, Winter *et al.* (1977) reported very low plant concentrations and marked

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animal responses to supplementary cobalt. It was therefore of interest to determine whether there was a plant response to cobalt in the field and to what level and for what period cobalt fertilizer would increase plant cobalt concentrations.

e. The surface soils used in the glasshouse experiments which gave rise to severe sulphur deficiency contained only five ppm phosphate-extractable S, but with depth this increases to 25 ppm at 40–60 cm and 95 ppm at 120–150 cm (Probert 1974). If the prediction of Isbell *et al.* (1976) that 'sulphur deficiency may not be a field problem once plant roots reach about 40 cm depth' were true then it might be possible to use high analysis phosphatic fertilizers resulting in reduced costs. If the prediction were not true then an alternative source of sulphur to that provided in superphosphate might be considered.

f. Apart from overcoming a primary deficiency of potassium which may increase with time (Jones 1973a) potassium fertilizer can also influence the botanical composition of pastures because of the differing competitive abilities of grasses and legumes (Hall 1971). Field studies were necessary in order to make recommendations on the potassium requirements of mixed pastures.

In this paper we have tried to answer many of the questions put above and thus we hope to add to our knowledge of the nutrition of plants in this wet tropical environment on poor sandy soils.

MATERIALS AND METHODS

The area selected for an experimental site was on a yellow earth with heath vegetation located about 150 km NE of Weipa. (Described as site 1 by Isbell *et al.* 1976.) The vegetation was rolled, then burnt, in mid 1970. When required for experiments, areas were ploughed to about 15 cm depth, then stick-raked and rolled after early wet season storms. Plot sizes were 4 m × 5 m in experiments 1, 2 and 3 and 5 m × 8 m in experiments 4 and 5. Details of the treatments are given in Table 1.

TABLE 1

Forms and rates of fertilizer used in the experiments.

	Rate of application (kg ha^{-1})*				
Form	Expt 1	2	3	4	5
$NaH_2PO_4.2H_2O$	250+125	—	—	—	—
$Ca(H_2PO_4)_2.H_2O$	—	400	400	—	—
Superphosphate†	—	—	—	—	625
Super King‡	—	—	—	290+250+250	0+250+250
$CaCO_3$	0 or 600	—	—	various (see text)	—
$MgCO_3.7H_2O$	0 or 45	35	35	35	35
KCl	0 or 100	100	100	100+50+50	0→400
$CaSO_4.2H_2O$	—	200	200	0→535	—
Elemental Sulphur	0 or 30	—	—	0→100	—
$ZnCl_2$	0 or 10	—	—	—	—
$ZnSO_4.7H_2O$	—	0→10	5	10	10
$CuCl_2$	0 or 7	—	—	—	—
$CuSO_4.5H_2O$	—	0→10	5	10	10
$Na_2MoO_4.2H_2O$	0 or 0·7	0·7	0·7	—	—
$Na_2B_4O_7.10H_2O$	0 or 6	—	—	—	—
$MnCl_2.4H_2O$	0 or 10	—	—	—	—
$CoSO_4.7H_2O$	—	0·14	0→1·4	—	—

†Commercial grade ex ACF-Austral Pty. Ltd. 9·6%P; 10%S
‡Commercial grade ex ACF-Austral Pty. Ltd. 20·5%P; 1·5%S
*A plus sign indicates that the fertilizer was applied in successive years. An arrow indicates that a range of rates were used (see methods section for further details).

Design of experiments

Nutrient factorial (*Experiment* 1)

The experiment was designed as a 2^6 half factorial confounded into two blocks and was sown with *Stylosanthes guianensis* cv. Oxley with basal phosphorus. Factors were the presence or absence of K, S, Ca, (Cu + Mo), Zn, and (B + Mn + Mg). The experiment was sown in December 1970 and was harvested in April and July 1971 and July 1972.

Copper and zinc (*Experiment* 2)

In experiment 1 no growth occurred in the absence of copper or zinc (see results and discussion section). In such severely deficient situations the recommended rates of copper and zinc sulphates are generally similar. Thus in order to determine the optimum rates of application the plots were established with equal rates of the two salts; i.e. in the first year there were eight replicates of four rates of Cu + Zn (0, 2.5, 5.0 and 10.0 kg ha^{-1} each of $CuSO_4 . 5H_2O$ and $ZnSO_4 . 7H_2O$).

In the second year the equality of the copper and zinc effects was checked by dividing the 0 and 2.5 kg ha^{-1} Cu + Zn plots and superimposing a 2 × 2 factorial of Cu or Zn, each at the rates of 0 or 2.5 kg ha^{-1} of the salts. The experiment was sown in December 1973 with *S. guianensis* cv. Cook and basal P, K, S, Mg and Mo. Plots were harvested in April 1974 and in February and June 1975.

Manganese (*Experiment* 2*a*)

In the second year of experiment 2 the 10 kg ha^{-1} Cu + Zn plots were divided and treatments of either 0 or 10 kg ha^{-1} of $MnCl_2 . 4H_2O$ were applied. The plots were harvested in February and June 1975.

Cobalt (*Experiment* 3)

Cobalt was applied at four rates (0, 140, 700 and 1400 g ha^{-1} of $CoSO_4 . 7H_2O$) in factorial experiment with six replicates. Sowing and harvesting details are as for experiment 2.

Sulphur (*Experiment* 4)

Two sources of sulphur (elemental S and $CaSO_4$) were compared at five rates of S (0, 12.5, 25, 50 and 100 kg ha^{-1}) in a factorial design with two replicates. The plots were sown with *S. guianensis* cv. Cook, *Brachiaria decumbens* cv. Basilisk and basal nutrients in December 1971. Calcium was equalized in all plots using $CaCO_3$. Harvests were made in July 1972 and 1973 and in February and August 1974.

Potassium (*Experiment* 5)

The potassium requirements of a mixed pasture was studied over three years using a split plot design with four replicates; main plots received 0, 50, 100, 200 or 400 kg ha^{-1} of KCl initially and the subplots 0, or 50 kg ha^{-1} KCl in the second and third years. The experiment was sown in December, 1971 with *S. guianensis* cv. Cook and *B. decumbens* cv. Basilisk and basal nutrients. Harvests were made in July 1972 and 1973 and March and August 1974.

Harvesting and analytical techniques

Experiment 1

A 4 m × 1 m autoscythe cut at 10 cm height was taken from each plot. At the end of each season, two 0.25 m^2 quadrats were cut to estimate the yield from 0–10 cm.

Experiments 2, 3, 4 *and* 5

At each harvest, all the vegetative material from within two 0.5 m^2 quadrats was collected after cutting the stems to within 10 cm of the crown using a shearing handpiece (Jones 1973b).

The fresh weight of harvested material was determined in the field and a subsample taken for determination of botanical and chemical composition, and dry matter percentage. All material above 10 cm was removed after each harvest either by forage harvester or after mowing with an autoscythe. Dried material was bulked across replicates (where applicable), finely ground and analysed for nitrogen and phosphorus on a "technicon" autoanalyser, for K by flame photometry, for S by the method of Johnson and Nishita (1952), and for Cu, Zn and Co by atomic absorption spectrophotometry. Large samples (approx 20 g) were required to give sufficient Co for analysis by the method of Gelman (1972). In the second year of experiment 3, cobalt was determined for replicates of unground and ground samples so as to *a*, eliminate possible contamination from the grinding mill and *b*, to give an estimate of this "mill contribution" for correction of the previous year's analyses.

Rainfall

The rainfall for the five seasons 1970/71 to 1974/75 was 2050 mm, 1550 mm, 1300 mm, 1910 mm and 1980 mm respectively compared with the 30 year mean of 1715 mm. In each year the growing seasons were close to the average of 30 weeks.

RESULTS AND DISCUSSION

Establishment

Germination and establishment of seedlings was excellent in all experiments. However, most seedlings on the nil Cu + Zn treatment of experiment 2 died after about 6 weeks. The *Rhizobium* strain CBI221 applied to Oxley stylo in experiment 1 proved effective; the Cook stylo used in the remaining experiments was effectively inoculated by indigenous rhizobia.

Copper and zinc

The only plots which made appreciable growth in the nutrient factorial experiment were those which received both (Cu + Mo) and Zn additions. In other words, there were highly significant (Cu + Mo) × Zn interactions at all harvests. For example, yields (kg ha^{-1}) of legume harvested in July 1971 were as follows:

	Zn_0	Zn_1
$(Cu + Mo)_0$	10	207
$(Cu + Mo)_1$	50	1300

In such extreme situations factorial designs have severe limitations, since responses to other nutrients can only be expected on a fraction of the total number of plots (8/32 in this case). There was a trend, however, for the best plots to be those which have received Ca and/or K as well, but in general this was not significant.

With both nutrients supplied in equal amounts the rate of five kg ha^{-1} of each salt gave maximum dry matter yields in both years in experiment 2 (Figure 1). The addition of Cu or Zn to the nil Cu + Zn plots in the second year did not significantly affect the yield, but the addition of both increased the yield from 500 kg ha^{-1} to 2050 kg ha^{-1} ($P < 0.05$). This latter yield is similar to that obtained in the first year at that rate of application.

Applications of 2.5 kg ha^{-1} of copper and zinc salts in the first year gave about 80 per cent of maximum yields in both years and fresh applications of either copper or zinc to these plots in the second year failed to give a significant increase in dry matter yield but did increase the plant copper and zinc values. Plants containing Cu values of 3–4 ppm are deficient according to Andrew and Thorne (1962) and Zn values of <10 ppm extremely deficient based on data for other legumes (Chapman 1966). Such concentrations were only barely attained at the 2.5 kg ha^{-1} rate in the second year; however, additional zinc raised the zinc concentration to 22 ppm and additional copper raised the copper concentration to six ppm.

Thus it appears that equal amounts of each of the nutrients are required to overcome their deficiencies and that maximum yields can be obtained with five kg ha^{-1} of each salt.

Manganese

There was no increase in dry matter yield with the addition of Mn but Mn levels were increased from 21 to 134 ppm in February and from 12 to 84 ppm in June 1975.

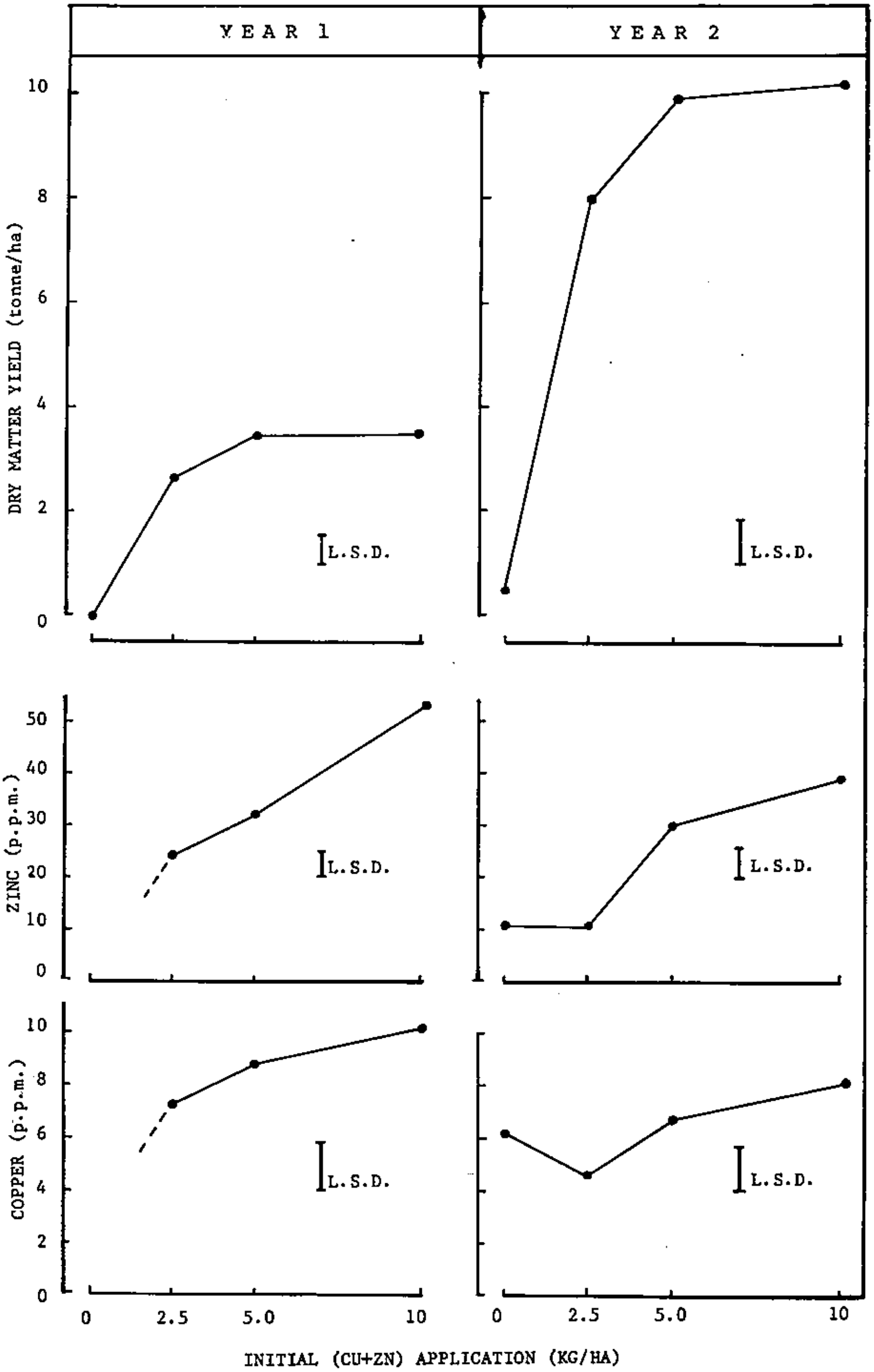

FIGURE 1
Total dry matter yields and mean concentrations of Cu and Zn in the plant tops in each year of experiment 2. The least significant differences ($P < 0.05$) between (Cu + Zn) means are indicated.

The former levels in each case were quite low compared with the critical values of other species of about 30 ppm (Chapman 1966).

Cobalt

Applications of Co did not affect either dry matter yields or nitrogen contents of the plants. However concentrations of cobalt in the plants increased linearly with application rate from 0.03 to 0.07 ppm in the first year and from 0.003 to 0.045 ppm in the second year. Estimates of the "mill contribution" for Co varied between 0 and + 0.043 with a median value of 0.011, so that data for the first year are probably too high by about this amount. (In the second year samples were not ground prior to analysis.)

Cobalt concentrations in unfertilized plants were low compared with suggested deficiency levels for temperate species of about 0.03 ppm (Hallsworth, Wilson and Adams 1965; Ozanne, Greenwood and Shaw 1963). The lower level in the second year may have been a dilution effect, since dry matter yields were more than double that in the first year.

However, even at the relatively high rate of 1400 g ha^{-1} of cobalt sulphate, the concentration of cobalt in the plants was barely adequate for cattle nutrition (Winter *et al.* 1977). Thus it would appear futile to apply cobalt fertilizer since the plants do not respond and it is unlikely that plant concentrations would be adequate for cattle.

Sulphur

There were no significant responses to added sulphur in dry matter yields or sulphur yields per hectare in any year, nor any differences between sources of S. The N/S ratios of the legume for the nil S treatment (1972, 10:1; 1973, 14:1, 1974 (a), 13:1; 1974 (b), 9:1) were well below the optimum ratio of 17.5:1 (Dijkshoorn and Van Wijk 1967), indicating S sufficiency. The concentrations of S in the pasture were higher in the third year (0.12 per cent) than in previous years (0.08 per cent) despite the decline in legume content from 70 per cent in the first two years to 30 per cent in the third year. S concentrations in the legume were generally higher than in the grass, particularly late in the season—for example, the means for the August 1974 harvest were 0.18 and 0.04 per cent respectively.

The lack of response to sulphur in the field, although not completely unexpected, was in sharp contrast to the glasshouse results (Isbell *et al.* 1976, Figure 4). Clearly the plants were able to extract a substantial proportion of their sulphur from the comparatively sulphur rich subsoil (Probert 1974). In addition a small amount of sulphur was applied with 3.8 kg ha^{-1} in subsequent years and this undoubtedly also contributed to the sulphur nutrition of the pastures. From a practical point of view it would seem that there is little risk of sulphur deficiency on these soils if high analysis (i.e. low S) fertilizers are used, at least in the short term.

Potassium

In the first year the dry matter yield was significantly increased by addition of K —the major response being to the application of the first 50 kg ha^{-1} of KCl (Figure 2). Additional applications of K significantly increased dry matter yields in the second and third years. In this context there is good agreement between the results of soil analysis, glasshouse and field experimentation (see Isbell *et al.* 1976).

The K contents of the legume at each late season harvest, viz: 0.34, 0.56, and 0.40 per cent respectively were lower than the critical levels of 0.6–0.8 per cent obtained by Andrew and Robins (1969) for other tropical legumes, and also lower than the values for K deficient plants of other *S. guianensis* accessions (Brolmann and Sonoda 1975).

Although the low K treatments gave somewhat lower dry matter yields, the degree of the deficiency was masked by the changing botanical composition of the swards from year 1 to 3. The K deficiency may better be gauged by the K yields and

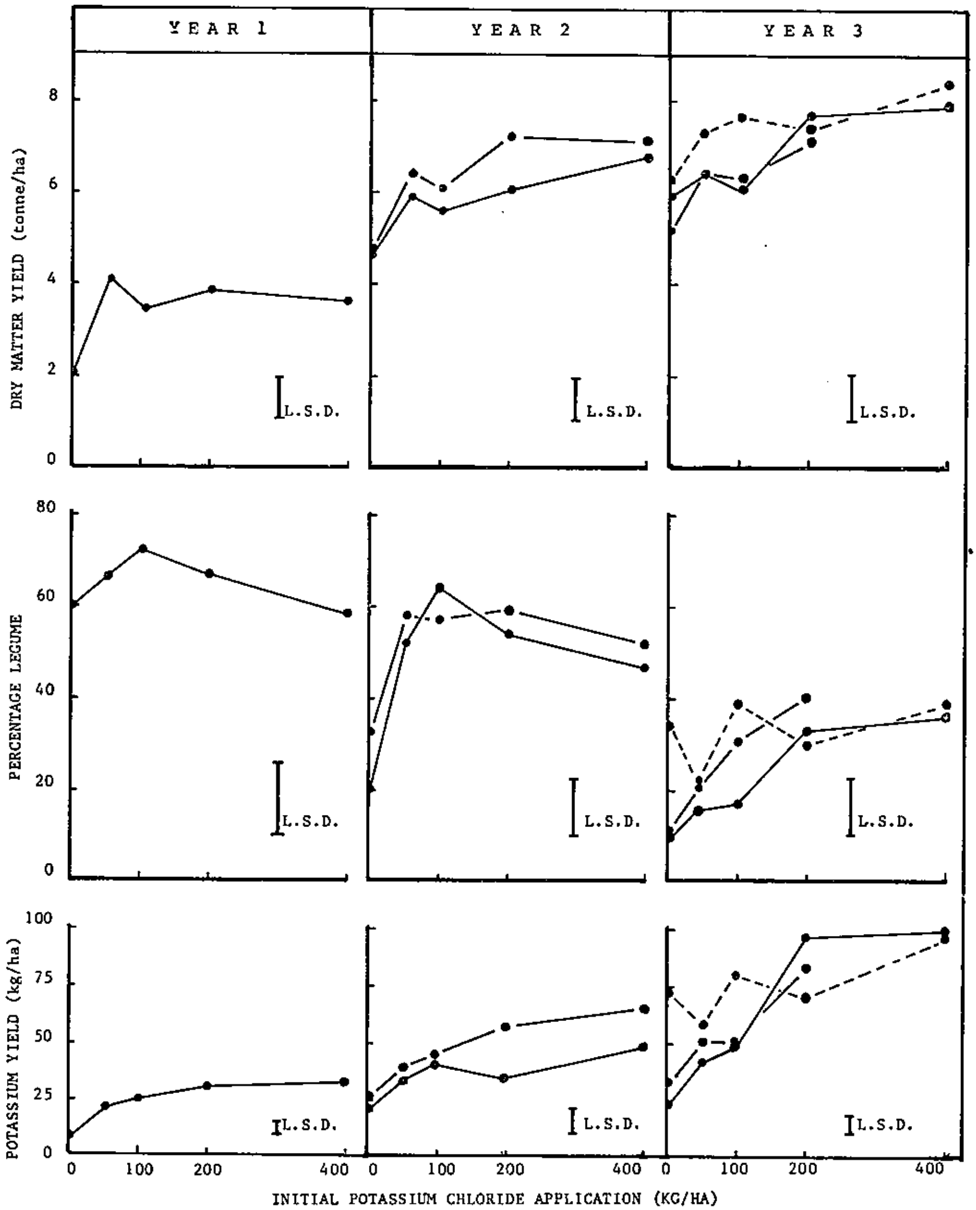

FIGURE 2

Dry matter yields, percentage legume and potassium yields in each year for treatments to which either no potassium was added after year 1 (•——•), or additional dressings were made in year 2 (•————•) or in years 2 and 3 (• – – – •). The least significant differences ($P < 0.05$) between the means are given for each year.

legume contents (Figure 2) both of which indicate that in the long term pasture production must decline as the legume disappears and that animals grazing such pastures would have a diet low in protein.

Hall (1971) has shown strong competitive effects for K in a tropical grass/legume mixture when K was in short supply. This effect was not apparent until the second year in this experiment as the growth of the grass was probably limited in the first year by the low N supply. By the third year the effect was more marked and the proportion of grass to legume was dependant upon K rate.

Compared with application of all the K in the first year, annual applications have the advantage of higher yields and maintenance of the legume in the pasture.

Other elements

There was no evidence of responses to Mg or B or of a deficiency of Fe. As there was no response to Mo in any of the soils used in the glasshouse experiments, and as pastures in experiments 4 and 5 made excellent growth without added molybdenum, we believe that the response to the (Cu + Mo) treatment in experiment 1 was entirely due to the Cu component. There was a suggestion of a response to Ca in experiment 1 but as various calcium phosphates were used as phosphorus sources in the other experiments no comment can be made on the role of Ca or the effects of liming on pasture growing on these soils. These topics will be dealt with in subsequent publications.

ACKNOWLEDGEMENTS

We thank Mr. J. J. Hodgkinson for assistance in the field; Mr. R. Megarrity and Miss Sue Joyce for chemical analyses and Mr. P. Jones and Mr. J. B. F. Field for statistical advice. The financial support supplied by COMALCO Limited is gratefully acknowledged.

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(Accepted for publication July 21, 1977)