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LIME-ALUMINIUM-PHOSPHATE INTERACTIONS IN SELECTED ACID SOILS FROM FIJI

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ABSTRACT

Poor crop production in Fiji has long been associated with Al-toxicity and/or P deficiency problems. Although attempts have been made to alleviate these problems, the lack of suitable soil-testing procedures and a limited understanding of lime-Al-P interactions are restricting the better utilization of these soils.

Following a preliminary investigation, 4 contrasting Fijian soils (Batiri, Koronivia, Nadroloulou, and Seqaqa) were chosen for a lime-Al-P interaction study. The soils, which had pH and M KCl-extractable Al values ranging from 3.9 to 4.9 and 35.6 to 0.3 mmol kg^{-1}, respectively, were used to investigate the effect of liming on surface charge, P-sorption characteristics, the amounts of P extracted by a number of soil-testing procedures, and plant uptake of P.

A study was conducted to compare M KCl-extraction procedures for exchangeable Al and analytical techniques used in the determination of Al. For each soil, different extraction procedures and analytical techniques measured significantly ($P < 0.01$) different amounts of extractable Al. It was recommended that extractable Al in Fijian soils could be best determined by the oxine reagent following a 2 x 1-h shaking with M KCl.

The ion retention method, which is commonly used to measure charge, was examined critically with a view to standardising it for the range of soils used in the present study. The method involves an initial washing of soils with an electrolyte of high concentration to remove exchangeable ions, equilibration of the washed soils with an electrolyte of the desired concentration and subsequent extraction of the equilibrated soils. The concentrations of prewash electrolyte (0.5M $CaCl_2$, 0.1M $CaCl_2$, and 0.01M $CaCl_2$) used to remove exchangeable ions prior to equilibration with 0.01M $CaCl_2$ and the soil:solution ratio were found to have a marked effect on the magnitude of the surface negative charge of unlimed soils. However, these differences were largely related to the amount of Al removed during the prewash and the equilibration procedures. Thus when the Al released in the extracting solution (0.5M KNO_3) was included in the calculation of charge, the differences in the measured negative charge obtained either because of varying concentrations of prewash electrolyte or for the effect of soil:solution ratio were reduced.

Surface charge, determined in 0.01M $CaCl_2$, was always found to be higher than that determined in 0.03M NaCl and this difference was more pronounced in limed soils at high pH values. Subsequent studies revealed that this anomaly was largely due to the inability of Na to exchange with Ca at high pH values. The results of these studies, together with those involving the prewash electrolytes and the soil:solution ratio, suggested that a suitable method of measuring surface charge of limed soils would use 0.01M $CaCl_2$ as the equilibration electrolyte and include in the calculation of charge the amount of Al released in the extracting solution.

Incubation of soils with added lime caused a large increase in surface negative charge. However, the magnitude of increase in the negative charge varied considerably between soils. For example, the negative charge in the Seqaqa soil increased from 8 to over 38 cmol(p)kg^{-1}, compared to only a small increase of 2 to 10 cmol(p)kg^{-1} in the Batiri soil over the same pH range.

In contrast to liming, P additions resulted in only a small increase in negative charge. Interestingly, all soils possessed positive charge up to 1 cmol(p)kg^{-1}, even at pH values as high as 7. Subsequent studies showed that this may have been due to substitution of Ti^{4+} and/or Mn^{4+} in the iron oxide lattice.

Extraction of lime- and P-treated soils with Olsen and Mehlich reagents showed that liming had a marked effect on the amount of P removed. Whereas Olsen P increased on either side of pH values 5.5 - 6.0, Mehlich P consistently decreased with increasing soil pH. For example, in the high P-sorbing Seqaqa soil, Mehlich P decreased from 0.2 mmol kg^{-1} at pH 4.5 to < 0.01 mmol kg^{-1} in soils with pH higher than 7.0. The decrease in Mehlich P was shown to be due to the neutralizing effect of lime on the extractant. An isotopic-exchange study revealed an increase in exchangeable P up to a pH approximating 7, above which there was a sharp decrease, possibly indicating the formation of insoluble Ca-P compounds.

Although liming had only a small effect on the sorption of added P, this was sufficient to have a significant effect on equilibrium solution P concentration. Generally, liming caused an increase in equilibrium solution P concentration up to pH values of 5.0 - 6.0, above which there was a marked decrease. The initial increase in equilibrium solution P concentration appeared to result from an interaction between added P,

surface negative charge and electrostatic potential in the plane of sorption. Subsequent sorption studies using Nadroloulou soil incubated with either KOH or $Ca(OH)_2$ showed that the decrease in solution P at high pH values was probably due to the formation of insoluble Ca-P compounds.

The effects of lime and P addition on the growth of the tropical legume *Leucaena leucocephala* were studied in a controlled-climate laboratory. With all 4 soils, there was an initial increase in the dry matter yield of the plant tops with liming which was followed by a marked decrease. This trend was most pronounced in the Seqaqa soil where dry matter yield of tops increased by ~2000% at the pH at which maximum growth occurred. Similar but smaller increases were noted in the other soils.

The concentration of Al in plant tops increased on either side of the pH of maximum growth, but Al uptake by the whole plant (tops + roots) declined steadily with increasing pH. Poor growth at low pH values was attributed to Al-induced P deficiency within the plant and at high pH values largely to a soil P deficiency and to a smaller extent to the increased concentration of Al in the plant tops. P deficiency at high pH values was attributed to the formation of insoluble Ca-P compounds and this was supported by the data obtained from isotopic-exchange and P-sorption studies.

A further plant growth study was conducted on the limed soils, previously used for the growth of *Leucaena leucocephala*. Ryegrass (*Lolium perenne L*) plants were initially grown in sand and then transferred onto the soils. Plant growth was again retarded at low and high pH values but comparison with control plants grown in a similar manner but not transferred onto the soils demonstrated that the poor growth at both high and low pH was due in part to a toxicity effect rather than simple P deficiency. It is likely that Al was responsible.

Comparision of the data obtained by resin extraction and plant P uptake gave a close 1:1 relationship. In contrast, Olsen-, Colwell-, Bray (I)-, Bray (II)-, and Mehlich-extractable P were only weakly correlated with P uptake. The difficulty in relating plant P uptake data to extractable P levels was attributed to the problems associated with extracting P from limed soils.

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