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# EFFECT OF INCREASING LEVELS OF LIME ($CaCO_3$) ON SOIL CHEMICAL PROPERTIES OF ACID SOILS

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An incubation experiment was done to determine the lime requirements of Sri Lankan and Kenyan tea soils as well as of an U.K. acid soil and to study the effect of increasing rates of liming ($CaCO_3$) on soil chemical properties. The results indicate that with increasing rates of applied $CaCO_3$ the pH values increased linearly, but exchangeable aluminium and exchangeable acidity decreased. Liming increased effective Cation Exchange Capacity and % base saturation of all the soils. The enhanced pH values of these soils did not change materially at the end of 1 and 2 months of incubation indicating that the added liming had reacted with neutralizable acidity within one month of incubation.

## INTRODUCTION

Liming is a common agronomic practice most often used in the control of soil acidity. Reports show that Al toxicity (Foy, 1984) and Ca deficiency (Clark, 1984) are two major factors determining crop response to lime in acid soils. The lime added to soils is normally ground chalk or limestone ($CaCO_3$) or slaked lime ($Ca(OH)_2$) or calcium oxide ($CaO$) - quick lime or calcium magnesium carbonate (dolomite).

Lime requirement of a soil is the amount of liming material which must be applied to a soil to raise its pH from an initial condition to a level selected for optimum plant growth. Several buffer methods have been developed and verified for measuring the lime requirements of mineral soils (Woodruff, 1948; Shoemaker, McLean and Pratt, 1961; Mclean, Reicosky and Lakshamanan, 1965; Mehlich, 1976; Yuan, 1976; McLean *et al.* 1979; Fox, 1980; Tran and Van Lierop, 1981, 1982). In most crops pH was adjusted to 6.6 for optimum growth.

Tea (*Camellia sinensis*) is a unique plant which grows well in acid soils within a pH range of 4.5 to 5.5. Continuous use of nitrogenous fertilizer especially ammonium sulphate over the past few decades, has resulted in the already acid tea soils becoming more and more acidic with a pH in the range of 3.7-3.8. During oxidation of ammonium nitrogen applied as fertilizer (urea or sulphate of ammonia) hydrogen ions are released to the soil. The hydrogen ions released during oxidation of nitrogen fertilizer enhance the leaching of basic cations (K, Mg, Ca), with percolating rain water making the already acidic soils more acidic.

Under very acid conditions the retention of basic cations such as K, Ca and Mg in the soils are severely affected, thereby decreasing the efficiency of utilization of applied fertilizers by plants.

Therefore, to prevent leaching of nutrients such as K, Mg, Ca and to reduce the solubility of Fe, Al and Mn with increase in the availability of phosphate, the pH of the soil has to be increased. Tea can tolerate high levels of aluminium (> 85%) saturation (Sanchez, 1976). But high levels of exchangeable Al could be toxic to tea and limit the productivity (Sivasubramaniam and Talibudeen, 1971; Sivapalan, 1988).

The incubation experiment described in this paper was designed to examine the effect of varying levels of lime on soil pH, % Al saturation, cation exchange capacity (CEC), total exchangeable bases (TEB) and % base saturation on very acid soils.

## MATERIALS AND METHODS

Five low pH top soils (0-15 cm) were used in this incubation study. Of these three (A, B and C) were from two long term fertilizer trials on tea in Sri Lanka, one (D) was from the woodlands in Sonning (U.K.) while the other (E) was from tea land in Kenya (See Table 1). The soils were passed through 4 mm sieve and the moisture content were determined. For soils A, B and C moisture levels were brought to 35% field capacity, soil D to 18% (as this soil was a sandy soil, it was not possible to bring its moisture content to 35% field capacity) and soil E to 36% field capacity by adding distilled water.

TABLE 1 – *Details of soils used*

| Code No. | Site | Type of Cultivation | pH | %C | EC µ S/CM | % N |
|---|---|---|---|---|---|---|
| A | *A 8 Field Experiment<br>Talawakele<br>Sri Lanka | Tea | 4.5 | 3.59 | 0.11 | 0.31 |
| B | **A 12 Field Experiment<br>Talawakele,<br>Sri Lanka | Tea | 3.7 | 4.47 | 0.19 | 0.31 |
| C | ***A 12 Field Experiment<br>Talawakele,<br>Sri Lanka | Tea | 3.7 | 4.83 | 0.22 | 0.34 |
| D | Sonning, Reading<br>U.K. | Woodland | 3.4 | 2.03 | 0.16 | 0.36 |
| E | Kenya Tea Land | Tea | 4.1 | 2.56 | 0.14 | 0.21 |

* No nitrogen fertilizer applied
** Nitrogen applied as S A at the rate of 336 kg ha$^{1}$
*** Nitrogen applied as S A at the rate of 560 kg ha$^{1}$

Note : A8 and A12 field experiments refer to long-term trials conducted at the Tea Research Institute, St. Coombs Estate.

Soils were air-dried and passed through 2 mm sieve and used to determine lime requirement, pH, exchangeable Al, CEC and TEB. Soil pH determination was done at a soil to solution ratio of 1:2.5 using a pH meter. Exchangeable Al was leached with IN KCl and Al was determined by Atomic Absorption Spectrophotometre (ASS) using Acetylene/Nitrous oxide flame. The same leachate was used to determine exchangeable acidity, titrating with 0.05N NaOH, and phenophthalein as indicator. Total exchangeable bases were leached with 1M ammonium acetate (pH 7) and K, Ca, Mg and Na by ASS. The ammonium acetate leached soils were again leached with 1 N KCl and entrapped ammonium (CEC) determined by Auto Analyzer. Soil organic carbon was determined by modified Walkley Black method (Walkey and Black, 1934).

Lime requirements of soil were estimated by ADAS (Agricultural Development and Advisory Servies, U.K.) which is a modified Woodruff buffer method, where the optimum pH is defined as 6.5. The description of the method is given below.

### Woodruff buffer solution

The buffer solution was prepared by adding 80 g calcium acetate, 18 g para (4) nitrophenol and 1.2 g MgO in a 2l volumetric flask making the volume up to the mark by distilled water; pH of this solution is 7.

### Measurement of lime requirement

Ten g portions of soil were weighed in 100 ml shaking bottles and 25 ml distilled water added, capped and the bottles shaken for 30 min. in a mechanical horizontal shaker and the pH measured using an Orion pH meter. Twenty ml of buffer (buffer : water, 1:1) solution was added to the above, the bottles capped and shaken for another 5 min. and the decrease in pH of the buffer solution measured. A 1:1 buffer $H_2O$ solution was used to adjust the pH meter to 7. The lime requirement as tonnes $ha^{-1}$ of $CaCO_3$ can be obtained when the indicated pH is subtracted from 7.00, multiplied by 22.4 and a value of 1.12 deducted from the result.

The lime requirement of all the 5 soils were determined by the above method and the maximum values (maximum amount of $CaCO_3$ needed to bring the pH from initial value to pH 6.5) obtained for soils A, B, C, D and E were 15.23, 21.5, 21.5, 15.0, 10.0 tonnes $ha^{-1}$, respectively.

In this incubation study all the soils were subjected to varying levels of lime treatments. The amount of $CaCO_3$ (pure A R grade) added as % lime requirement determined by the method described above is given in Table 2.

TABLE 2 – *Per cent lime requirement (LR) added*

| Treatment | Soil A | Soil B | Soil C | Soil D | Soil E |
|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 |
| 2 | 33 | 33 | 33 | 10 | 10 |
| 3 | 66 | 66 | 66 | 20 | 20 |
| 4 | 100 | 100 | 100 | 40 | 30 |
| 5 | – | – | – | 50 | 40 |
| 6 | – | – | – | 60 | – |

$CaCO_3$ was added according to the treatment to 300 g of soil, A, B, C and E in triplicate, mixed thoroughly, kept in polythene bags loosely tied and incubated at 20°C. In the case of soil D 1 kg of soil was used.

Moisture lost by evaporation was added by weighing from time to time. The soils were kept in a random manner. At the end of of the 1st and 2nd months sub samples were drawn from the polythene bags, air dried and used for all the above analysis. All the results were a mean of triplicate samples.

## RESULTS AND DISCUSSION

The initial soil properties of soil used in this study are given in Table 3.

TABLE 3 - *Initial soil properties*

| Soil | CEC (pH 7) me% | Exch. Acidity me% | Exch. Al me% | Exch. K me% | Exch. Ca me% | Exch. Mg me% | Effective CEC me% | Al Satn % | Base Satn % |
|---|---|---|---|---|---|---|---|---|---|
| A | 19.0 | 4.2 | 3.8 | 0.1 | 2.0 | 0.4 | 6.7 | 56.7. | 37.3 |
| B | 20.0 | 8.1 | 7.3 | 0.3 | 0.6 | 0.1 | 9.1 | 80.2 | 11.0 |
| C | 22.0 | 8.3 | 7.5 | 0.3 | 0.4 | 0.1 | 9.1 | 82.4 | 8.8 |
| D | 11.1 | 3.4 | 2.1 | 0.3 | 1.7 | 0.3 | 5.7 | 36.8 | 40.4 |
| E | 12.0 | 3.3 | 3.1 | 0.9 | 1.4 | 0.7 | 6.3 | 49.2 | 47.6 |

Exchangeable Al varied from 2.1 to 7.52 me 100 $g^{-1}$ and aluminium saturation from 36.8 to 82.4%. Despite the high CEC in Sri Lankan soils (A, B and C) the % base saturation was low. Whereas in Kenyan tea soil (E) although the CEC is low (12 me%) when compared to Sri Lankan tea soil, the % base saturation is high (Table 3). In all tea soils Al contributed an extent of 90-94% of the exchange acidity.

### Effect of added lime on soil pH

Figure 1 shows the effect of increasing levels of lime on soil pH after 1 month of incubation. In all soils the pH increased with the increasing levels of lime after 1 month of incubation. Similar results were observed even after 2 months. Van Lierop (1983) had observed the same trend. After 2 months of incubation, the pH did not change markedly, indicating that the added lime had neutralized all the acidity in the soil.

A straight line equation was fitted to all the curves and the correlation coefficients obtained for soils A, B, C, D and E were 0.994, 0.995, 0.998, 0.988 and 0.997 respectively. This straight line equation permits the estimation of lime requirement to raise the pH to any desired level of all the 5 soils.

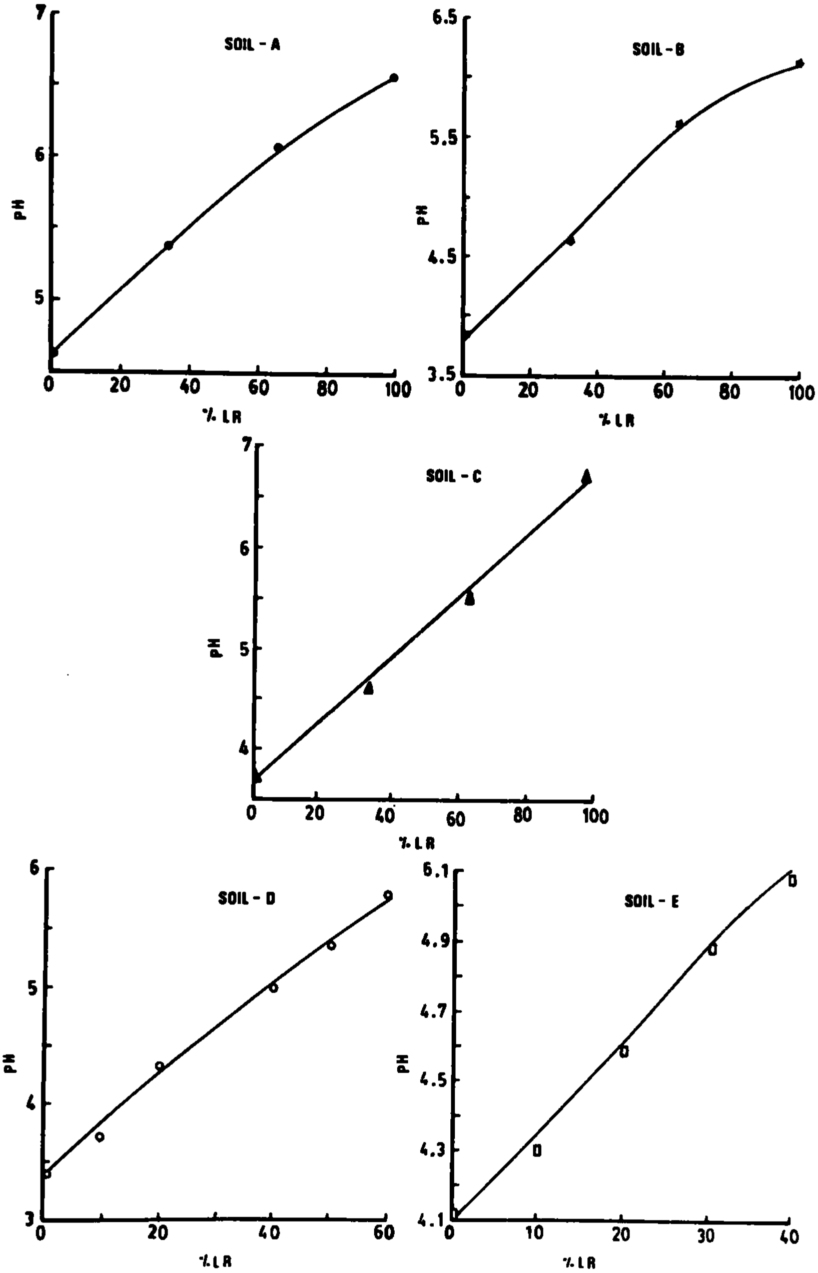

Fig. 1 — Effect of liming on soil pH
(LR = Lime requirement)

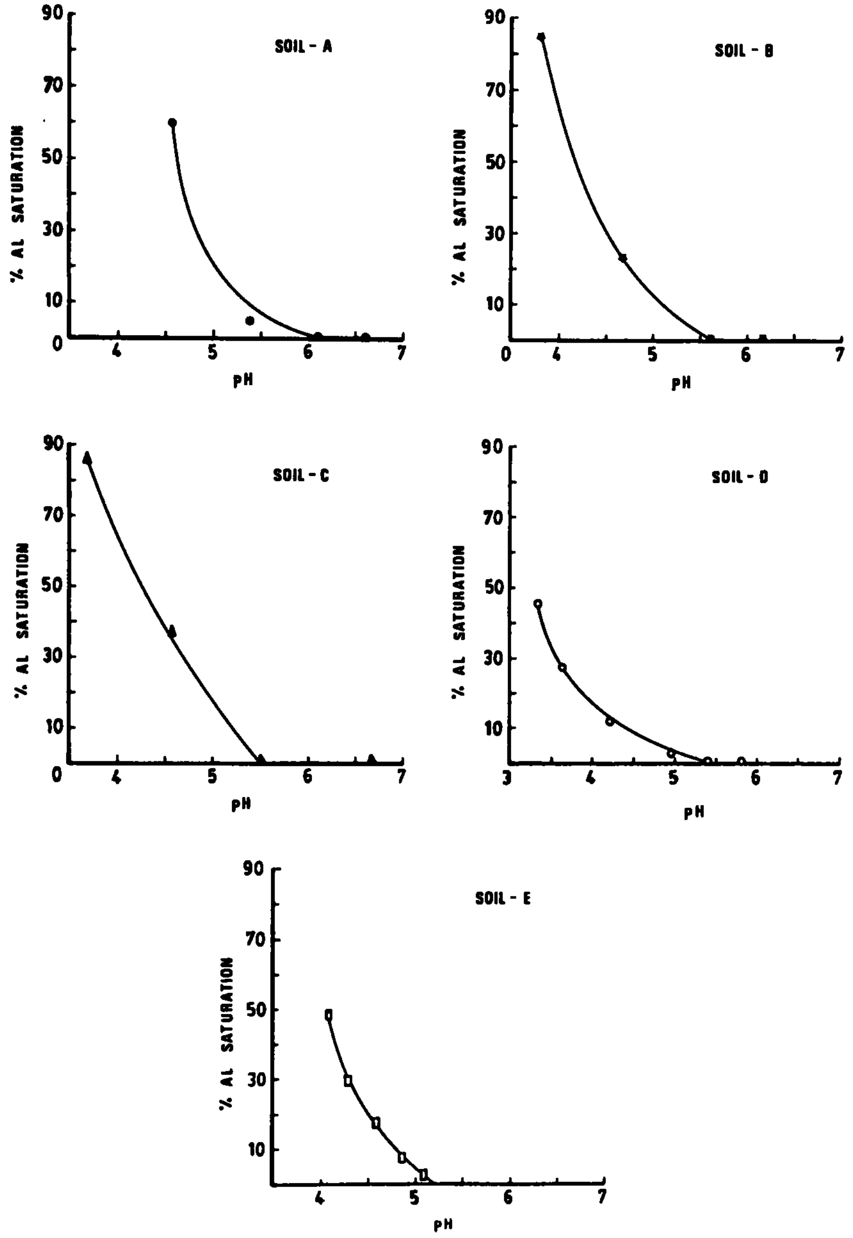

Fig. 2 — Relationship between % Al saturation and pH

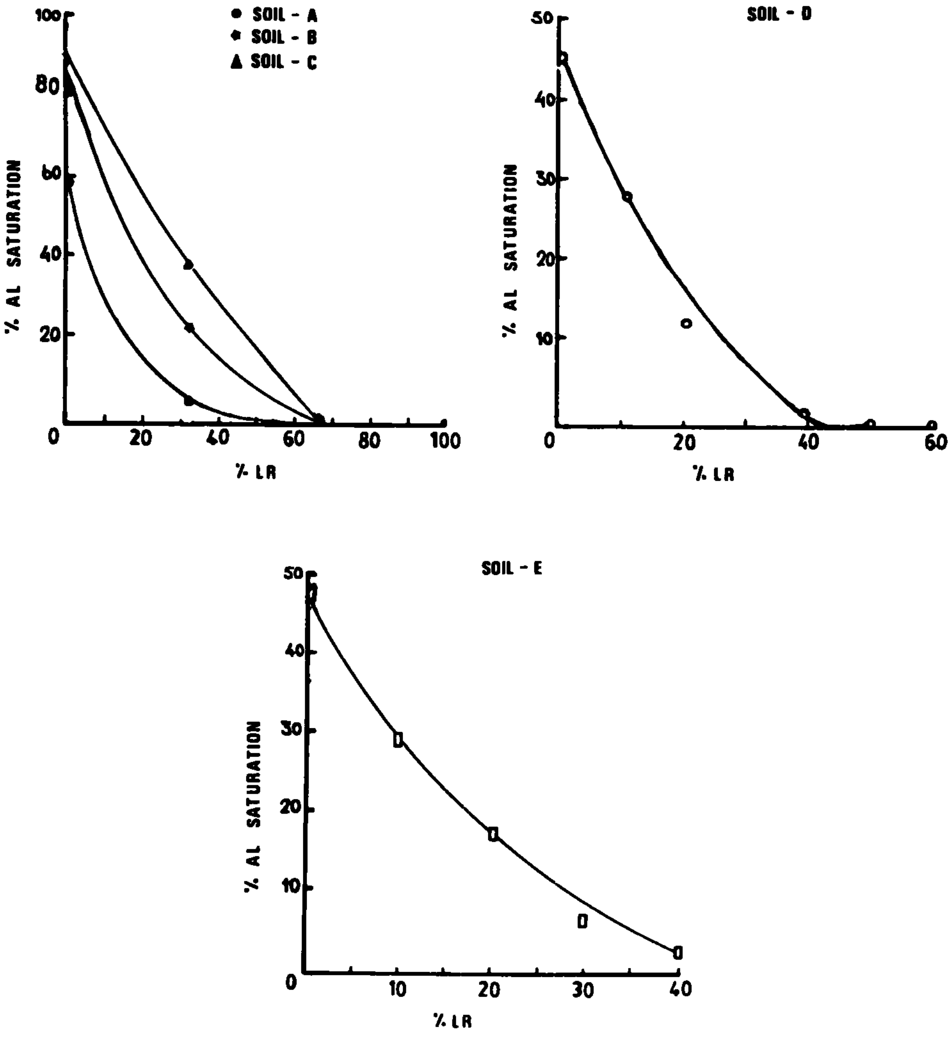

Fig. 3 — Effect of liming on % Al saturation

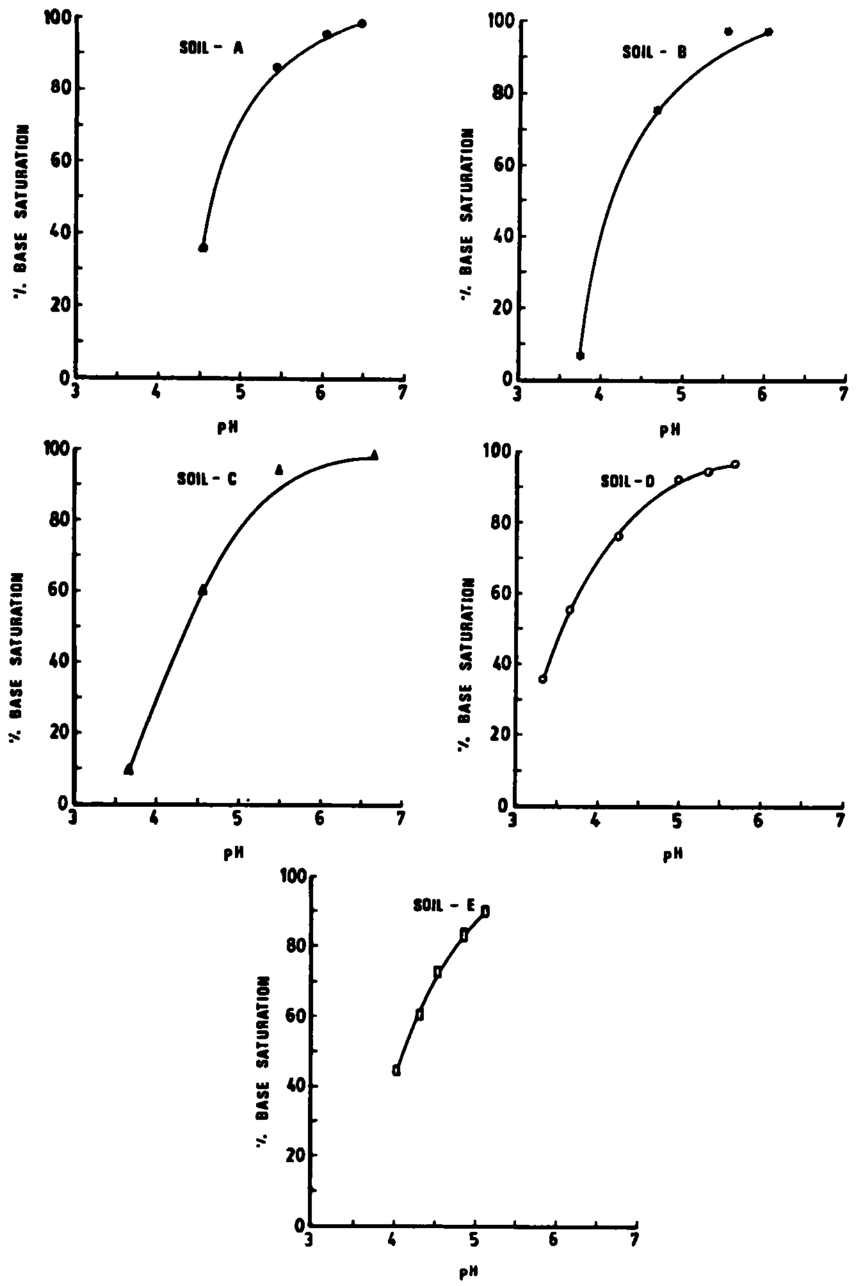

Fig. 4 — Relationship between pH and % Base Saturation

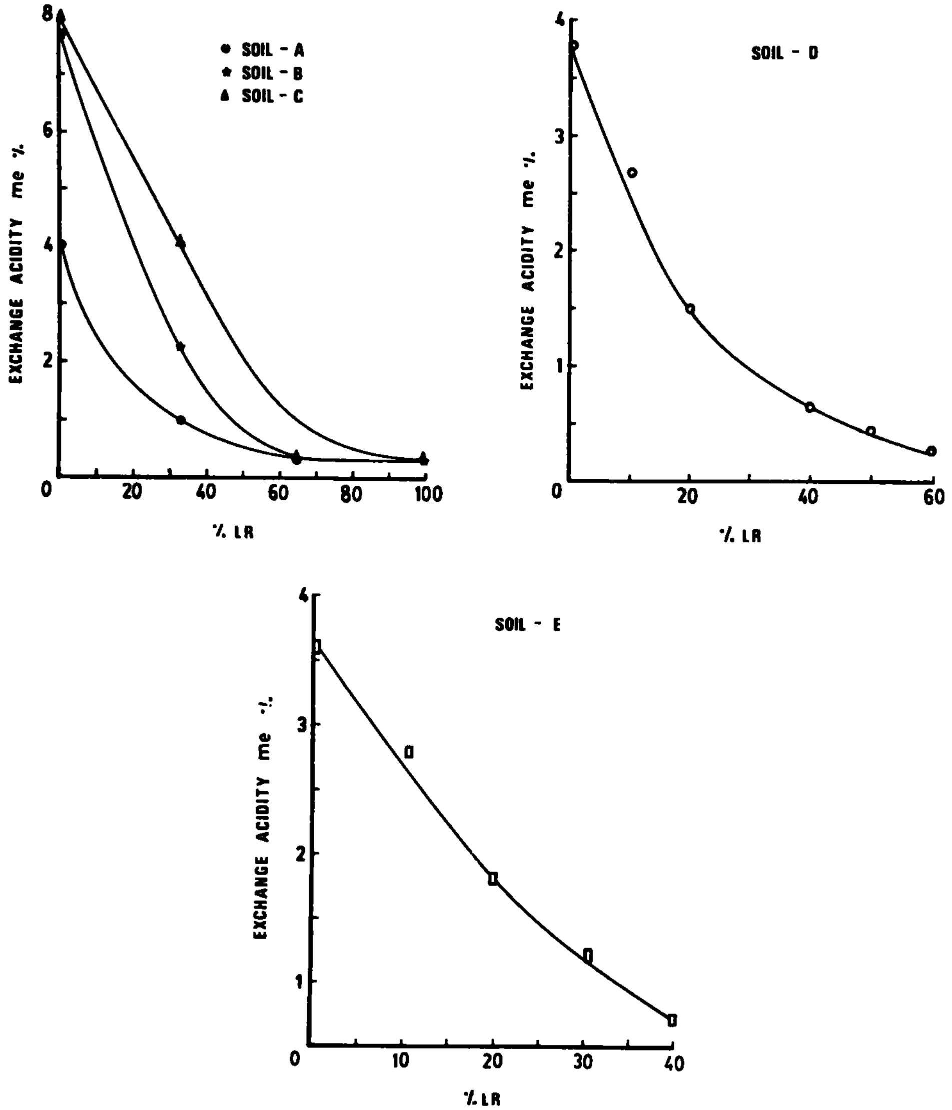

Fig. 5 — Effect of liming on exchange acidity

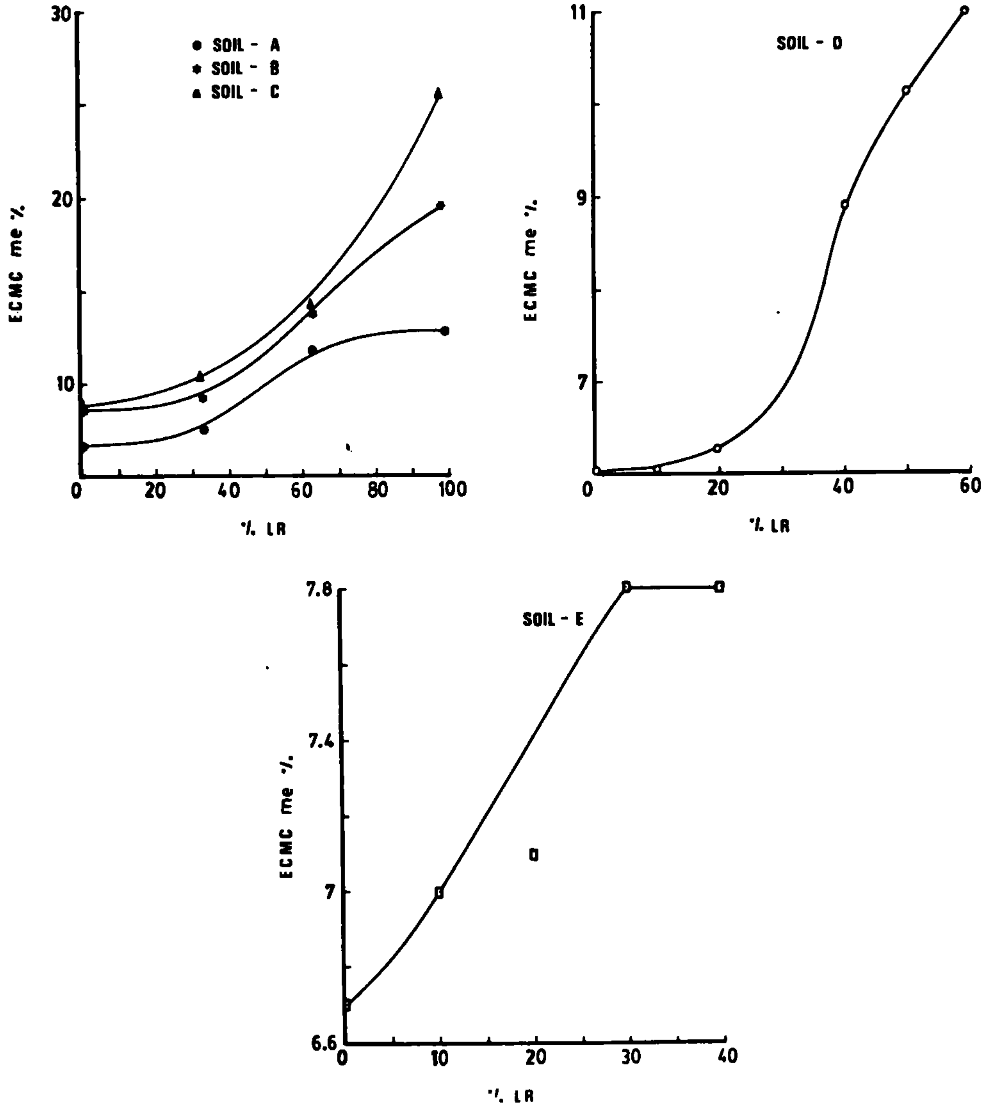

Fig. 6 — Effect of liming on E.C.E.C.

### Effect of Liming on % Al saturation

The relationships between % Al saturation and pH achieved by adding varying levels of lime for the soils A, B, C, D and E are given in Figs, 2 and 3. Increasing the pH by added lime resulted in decrease in % Al saturation. This is due to the added Ca ions gradually displacing the $H^+$ $Al^{3+}$ ions from the exchange sites of the colloidal complex. It is quite evident that in soils having a pH of above 5 the content of Aluminium in available form is negligible. In all soils above a pH of 5 the exchange surfaces of the clay complex are almost saturated by bases (Fig. 4.)

### Relationship between pH and % Base Saturation

Relationships between pH and % base saturation for the different soils are given in Fig. 4. An increase in pH resulted in an increase in % base saturation. Quadratic equations were fitted to these curves and the correlation coefficients obtained for soils A, B, C, D and E were 0.991, 0.997, 0.998, 0.909 and 0.998 respectively. At pH 5.0 the base saturation was different for all the soils. This may be due to the variation in the organic matter and clay content of the soils. But at pH 6.5, 100% base saturation was attained for all the soils.

### Effect liming on exchange acidity

Relationships between exchangeable acidity and lime added as % lime requirements for soils, A, B, C, D and E are presented in Fig. 5. Exchange acidity varied from 3.3 to 8.3 me $100^{4}$ g. Exchange acidity is derived from hydrogen and aluminium ($Al^{3+}$ + $H^+$) ions, and is closely related to pH and % base saturation of soil. As expected, on incubation with increasing levels of lime the exchange acidity decreased markedly. Quadratic equations were fitted to these curves and the correlation coefficients for soils A, B, C, D and E were 0.907, 0.995, 0.993, 0.994 and 0.996 respectively.

### Effect of liming on effective cation exchange capacity

The CEC determined at pH 7 with 1M ammonium acetate did not change appreciably with increasing levels of lime. But ECEC of the soil (sum of exch $Ca,^{2+}$ $Mg,^{2+}$ Exch $Al^{3+}$ + $H^+$) increased with increasing rates of lime. The ECEC of soil is very much lower than the CEC determined at pH 7. This may be due to the presence of large amounts of amorphous polyhydroxy complexes of Al, Fe and Mn, which could block some of the exchange sites of the clay colloidal complex. The effective CEC of these soils increased (Fig.6) with increasing rates of lime. This is probably due to precipitation of polyhydroxy amorphorus complex of Al from the exchange sites and thus exposing more sites for exchange reaction.

## CONCLUSIONS

The following conclusions were drawn from this experiment. Liming increased pH linearly, but decreased exchangeable Al and exchange acidity. Above pH 5.5 exchangeable Al was nil. Effective cation exchange capacity and % base saturation increased with increasing rates of lime.

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