Pertanika 12(1), 107-112 (1989)

COMMUNICATION IV

Lime Requirements of Highly Weathered Malaysian Soils

ABSTRAK

Beberapa kaedah penentuan keperluan kapur untuk tanah terluluhawa Malaysia diuji. Lapan siri tanah dipilih, di mana lima daripadanya ialah Ultisol dan yang tiga lagi ialah Oksisol. Kaedah yang diuji ialah pengeraman gml (dianggap sebagai kaedah rujukan), titration dengan $Ca(OH)_2$ (3 kaedah) dan satu kaedah berdasarkan Al bertukarganti. Keputusan menunjukkan kaedah titration Dunn (1943) bertali rapat dengan kaedah pengeraman. Penentuan keperluan kapur berdasarkan Al bertukar ganti memberi taksiran yang baik untuk Ultisol, tetapi tidak untuk Oksisol. Gerakbalas tanah terhadap GML mengikut waktu dan kadar pengapuran juga dibincangkan.

ABSTRACT

Various methods of determining lime requirements for weathered Malaysian soils were tested. Eight soil series were selected, of which 5 were Ultisols and 3 were Oxisols. The methods tested were incubation with GML (regarded as reference methods), titration with $Ca(OH)_2$ (3 methods) and a method based on exchangeable Al. The result showed that the titration method of Dunn (1943) was well correlated with the incubation method. Determination of lime requirement based on exchangeable Al gave a good estimate of lime requirements for Ultisol, but not for Oxisol. The responses of soils to GML over time and rate of application are also discussed.

INTRODUCTION

Most upland soils in Peninsular Malaysia are extremely leached and weathered, and hence dominated by clay minerals of the 1 : 1 type and sesquioxides. These soils, of which the Ultisols and Oxisols are the most widespread, are acidic in nature, with pH values ranging from 4 to 5. The soils are reportedly high in aluminium saturation and base deficient, and the charge on the exchange complex varies with the change in pH (Tessens and Shamshuddin 1983). Liming with ground magnesium limestone (GML) to raise soil pH to the level suitable for plant growth is the standard practice to improve the fertility status of the soils, except for rubber and oil palm which are more tolerant to Al toxicity.

It is often thought that under the condition of low pH, aluminium and maganese are present in the soil solution in quantities physiologically toxic to plant growth (Foy 1984). There are many factors contributing to the increase of soil acidity in Malaysian soils, among which leaching and the continued use of acid forming fertilizers are often quoted. This particular aspect of soil chemistry has been dealt with at length by Thomas and Hargrove (1984).

Many methods of lime requirement determination have been proposed and tested. These include those based on exchangeable Al (Kamprath 1970, 1984; Lathwell 1979), titration with a base (Dunn 1943; McLean *et al.* 1978; Gillman and Sumpter 1986) and incubation with lime (Trans and van Lierop 1982). But in recent years the method based on KCl extractable Al (exchangeable Al) values has been accepted and is popular for weathered tropical soils. The relationship between the amount of $CaCO_3$ required to neutralize a given amount of exchangeable Al is given by the equation $CaCO_3$ equivalent (t/ha) = factor x cmol (1/3 Al^{3+}) kg^{-1}; the factor ranges from 1.5-3.3 (Kamprath 1984), depending on soil chemical properties. Lathwell (1979) used a factor of 2 to calculate lime requirements of soils in South America. However, Gillman and Sumpter

(1986) found that lime requirement determination based on exchangeable Al^{3+} was suitable for Ultisols containing substantial amounts of Al^{3+}, but not for oxidic soils (Oxisoils).

The objectives of this paper were to compare various methods of determining lime requirements currently in use for weathered tropical soils and to propose a quick and reliable method for determining lime requirement of weathered Malaysian soils.

MATERIALS AND METHODS

Soils

Eight top soils (0-15 cm depth) of acidic and highly weathered Malaysian soils were selected for the study. These are the soils of Rengam, Serdang, Bungor, Kuala Brang, Lanchang, Segamat, Sg. Mas and Munchong Series, representing the most common sedentary soils in Peninsular Malaysia, where rubber, oil palm and food crops are mostly grown. The taxonomic classification of these soils is given in Table 1. The samples were air-dried, ground, sieved through a 2 mm sieve and kept for treatment and various analyses.

The soils under investigation have been classified and studied in detail, especially with respect to mineralogy and charge properties (Tessens and Shamshuddin 1983). They are either classified as Paleudult or Acrorthox, except for the Munchong Series which is classified as Haplorthox (Table 1).

Analytical Procedures

Routine Analysis. Soil texture was determined by the pipette method of Day (1965). Soil pH (1:2.5) was determined in water and in 0.002 M $CaCl_2$ after 1 day of equilibration. Cation exchange capacity (CEC) was determined by the 1M NH_4 OAc; Na and K from the NH_4OAc extract were determined by flame photometer, while calcium and magnesium were determined by atomic absorption spectrophotometer. Aluminium was extracted by 1M KCl and determined colorimetrically and organic carbon was determined by Walkley Black Method (Allison 1965).

Incubation. This method is a slight modification of the method proposed by Tran and van Lierop (1982). Appropriate amounts of ground magnesium limestone (GML) were mixed with 100 g soils in perforated plastic bottles to obtain a liming rate of 0, 2, 4, 6 and 8 tonnes/ha (on weight basis). The treatments were watered twice weekly at the rate of 25 ml with distilled water. The amount of water added is equivalent to about 2000 mm rainfall per year. Soil pH (in water and in 0.002M $CaCl_2$) was determined at the end of 2 months. The amount of GML needed to increase soil pH (pH water) to 5.5 was then determined.

Two soils, namely the Segamat and Rengam Series were selected for further investigation where the soils were limed at 2 tonnes/ha (on weight basis) and pH (H_20) was determined after 0, 1, 2, 3, 4, 5, 6, 7 and 8 weeks.

Titration (Method A). This method was proposed by McLean *et al.* (1978). Ten g soil in 50 ml water was shaken for 1 hour. It was then titrated with 0.08M $Ca(OH_2)$ to pH 7.2. Each titration for different soils was done in duplicate. Lime requirement was estimated from the amounts of $Ca(OH)_2$ used.

TABLE 1
Taxonomic classification of the soils under study

SERIES	PARENT MATERIAL	FAMILY
Rengam	Granite	Clayey, kaolinitic, Typic Paleudult
Serdang	Sandstone	Loamy, kaolinitic, Typic Paleudult
Bungor	Shale	Clayey, kaolinitic, Typic Paleudult
Kuala Brang	Shale	Clayey, kaolinitic, Typic Paleudult
Lanchang	Granodiorite	Clayey, kaolinitic, Typic Paleudult
Segamat	Andesite	Clayey, oxidic, Typic Acrorthox
Sg. Mas	Serpentinite	Clayey, oxidic, Typic Acrorthox
Munchong	Shale	Clayey, kaolinitic, Tropeptic Haplorthox

Titration (Method B). This method was proposed by Dunn (1943). In this experiment, which was also replicated twice, appropriate amounts of 0.08M $Ca(OH)_2$ were added to 10 g soil in a plastic vial, so that it had 0, 5, 10, 15, 20 and 25 ml of $Ca(OH)_2$. Water was added to make 25 ml in volume of the solution. After 1 hour of shaking and 2 days of equilibration, pH was determined. A graph of volume of $Ca(OH)_2$ was plotted against pH, and lime requirement to bring the pH to 5.5 was estimated from the graph.

Titration (Method C). This experiment was conducted following the method of Gillman and Sumpter (1986). Four g soil was put in 100 ml centrifuge tube. Forty ml 0.1M $CaCl_2$ was then added and the contents shaken for 2 hours. The samples were centrifuged and de-canted and two more washings with 0.002M $CaCl_2$ were carried out. The pH of the third suspension was adjusted to 3.5 with 0.1M HCl. One ml 0.08M $Ca(OH)_2$ was added and shaken and pH was determined after 2 days. The addi-tion of 0.08M $Ca(OH)_2$ (same rate) was conti-nued at 2-day intervals until pH 7 was reached, with the pH being recorded each time. A graph of $Ca(OH)_2$ was plotted against pH, and lime requirement to bring the pH to 6.0 was determined thereafter.

Exchangeable Al. Lime requirement of the soils was calculated by the formula :

L.R (tonnes/ha) = Al cmol (p^+) kg^{-1}) x 2

following the proposal of Lathwell (1979).

RESULTS AND DISCUSSION

Chemical Properties

Table 2 summarizes the chemical properties of the studied soils. It is seen that pH is low with values less than 5 and so are the basic cations, while Al saturation is very high in the Ultisols with values greater than 70%. Of particular interest is the exchangeable aluminium of soils of Kuala Brang and Bungor Series, in which the respective values are 5.31 and 3.14 cmol $(p^+)kg^{-1}$ (Table 2). The high values are related to the presence of some weathereable minerals in the soils. X-ray diffraction investigation (not shown) showed that both soils contain some 2:1 clay minerals (vermiculite).

Soil Buffering

At the GML rate of 2 tonnes/ha, it was noted that pH was quickly raised to over 5.5 in a week for the Ultisol (Rengam Series) and then remained at 5.5-6.0 up to 8 weeks (*Fig. 1*). In the Oxisol (Segamat Series), there was a lower increase in pH although the pH at the onset of the experiment was higher than the Ultisol. The pH of the Segamat Series soil remained constant from second to seventh weeks, after which it began to decrease. The buffering action of Rengam Series soil which is dominated by kaolinite is probably controlled by Al (Shamshuddin and Tessens 1983), while that of Segamat Series is probably controlled by sesquioxides (Gillman and Sumpter 1986).

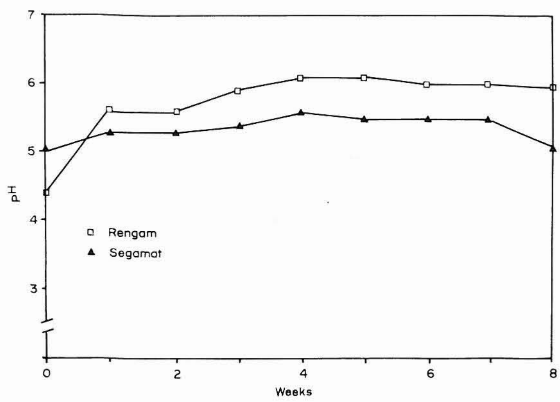

Fig. 1: Weekly pH changes of soils undergoing GML treatment

Fig. 2 gives the change in soil pH after 8 weeks with different rates of GML application. Two Ultisols (Lanchang and Kuala Brang Series) and two Oxisols (Sg. Mas and Segamat Series) were presented here to show their response to GML treatment. It was earlier deduced (*Fig. 1*) that soil with low exchangeable Al (Segamat Series, Table 2) was buffered mainly by the oxides and that the pH began to decrease after 7 weeks. In *Fig. 2*, pH of Segamat Series was found to be higher than other soils at 2, 4 and 6 tonnes/ha GML application.

The soil of Kuala Brang Series was found to be the most buffered soil. This is due to the presence of exchangeable Al, which is more

TABLE 2
Selected chemical properties of the soils under study

Series	pH (1:2.5)		Basic Cations (c mol(p+)kg^{-1})				Al		CEC	Texture Analysis (%)		
	H_2O	$CaCl_2$	Na	K	Mg	Ca	(c mol(p+)kg^{-1})	O.M.(%)	(c mol(p+)kg^{-1})	Clay	Silt	Sand
Rengam	4.3	3.8	0.09	0.08	0.11	0.23	1.09	1.98	4.90	39.2	17.6	42.2
Serdang	4.6	3.8	0.06	0.05	0.06	0.02	0.86	1.05	3.25	26.3	2.7	71.0
Bungor	4.1	3.6	0.07	0.15	0.13	0.24	3.14	1.45	6.00	37.9	12.5	55.6
Kuala Brang	4.4	3.9	0.06	0.17	0.07	0.18	5.31	2.03	9.50	22.4	33.5	44.1
Lanchang	4.5	4.1	0.06	0.15	0.18	0.12	1.36	2.78	8.93	56.1	6.9	37.0
Segamat	4.9	4.6	0.04	0.12	0.96	1.10	0.31	3.00	9.18	86.0	10.2	3.4
Sg. Mas	4.6	3.9	0.04	0.18	0.46	0.24	0.62	1.60	7.18	45.2	17.9	36.9
Munchong	4.4	4.1	0.06	0.30	0.14	0.84	1.51	2.41	9.05	68.8	9.8	21.4

than 5 cmol$(p^+)kg^{-1}$. This soil needs more than 8 tonnes/ha GML to bring the pH to 5.5. The soil of Lanchang Series, which containes less exchageable Al(1.36 cmol $(p^+)kg^{-1}$, was less buffered than the Kuala Brang Series.

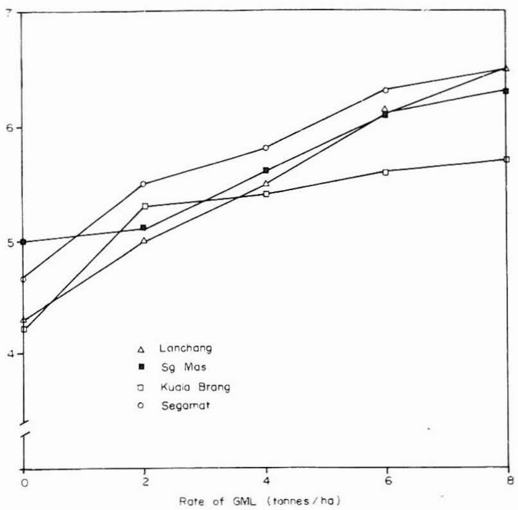

Fig. 2: The change in pH with different rate of GML application

Lime Requirement

It is found that there exists a good correlation between the incubation method and the titration method of Dunn (1943), as seen in Table 4. The correlation between incubation and other methods of lime requirement is not significant, including the method based on exchangeable Al proposed by Lathwell (1979). The relationship between the method of Gillman and Sumpter (1986) and the method based on exchangeable Al is also good (Table 4). The relationship between the method of McLean *et al* (1978) and the method of Dunn (1943) is given by the equation:

$$Y = 1.82 + 0.82X$$
$$R = 0.84, P < 0.01$$

It is seen that the Lathwell (1979) method is able to estimate the lime requirement of Ultisols (Rengam, Serdang) accurately. However, it can not estimate the lime requirement of Oxisols (Segamat, Sg. Mas). This is similar to what has been found by Gillman and Sumpter (1986) for the highly weathered soils of Northern Queensland, Australia. The methods of determining lime requirement based on exchangeable Al as proposed by Kamprath (1970 and 1984) and Lathwell (1979) are only suitable for the Ultisols, where the amounts of Al in the soils are rather high. The Ultisols, with kaolinitic mineralogy, contain more Al than the Oxisols (Table 2). This paper suggests that the method of determining lime requirement proposed by Dunn (1943) can be adopted to determined lime requirements of Oxisols and Ultisols in Malaysia. For the Ultisols with high amounts of Al, however, the method of Lathwell (1979) can also be used.

CONCLUSION

In the Ultisol, pH increases to above 5.5 in about a week and remains at this value for more than 8 weeks. In contrast, for the Oxisols pH started to go down after 7 weeks. The best method for determining lime requirements of weathered soils (Ultisols and Oxisols) is the titration method of Dunn (1943). For Ultisol, the method of Lathwell (1979) which is based on exchangeable Al is acceptable.

ACKNOWLEDGEMENT

The author wishes to record his appreciation to UPM for funding this research and to the laboratory assistants in the Soil Mineralogy Laboratory for their help during the period of the research.

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(Received 17 December, 1987)