



UNIVERSITI PUTRA MALAYSIA

**LIME REQUIREMENT DETERMINATION OF TROPICAL PEAT
SOILS.**

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**LIME REQUIREMENT DETERMINATION OF TROPICAL PEAT
SOILS.**

By

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Thesis Submitted in Fulfilment of the Requirement for the Degree of
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Tropical peat soils are acidic usually with pH values less than 4 and have very low exchangeable bases. The acidity develops as a consequence of dissociation of the functional groups, such as carboxyl and phenolic hydroxyl groups attached to the humic substances of organic matter. Liming is a standard practice to alleviate the acidity and to improve the fertility status of the soil.

In Malaysia, lime requirement (LR) studies are conducted by relating crop responses to liming, but so far there is no specific method for



determining LR in peat soils. Therefore, the following objectives on the LR determination and soil acidity components were formulated:

- i) to calibrate and evaluate five buffers [Shoemaker, McLean and Pratt (SMP), Mehlich, Ba, Ca and NH_4 acetate] for determining the LR of tropical peat soils;
- ii) to determine the buffer capacity and LR of the soils using potentiometric titration; and
- iii) to separate the humic fraction of peat into humin, humic acid (HA) and fulvic acid (FA) and to determine the amount of carboxyl and phenolic hydroxyl groups in HA, and to examine the relationships between LR and soil acidity components.

The calibration study showed that the SMP and Mehlich buffers were less precise than the $\text{Ba}(\text{OAc})_2$, $\text{Ca}(\text{OAc})_2$ and NH_4OAc . The evaluation study indicated that the $\text{Ba}(\text{OAc})_2$ buffer is the most accurate, followed by $\text{Ca}(\text{OAc})_2$ buffer. The $\text{Ba}(\text{OAc})_2$ buffer method is recommended for LR determination of tropical peat soil, while $\text{Ca}(\text{OAc})_2$ is an alternative method (i).

Buffer capacity and LR of the tropical peat soils can be obtained using potentiometric titration. Lime requirement can be estimated by multiplying the amount of base (mL) needed to raise the pH of the soil to

5.0 by a LR factor 1.0. The LR factor 1.0 implies that there is 1:1 linear relationship between soil acidity and LR which indicates that the buffering action of the peat soils is dominated by H^+ ion (ii).

Humic acid (HA) is the major component of the humic fraction in tropical peat soils and the carboxyl group in HA is the major functional group influencing the soil acidity. $pH(H_2O)$, % HA, buffer capacity, meq COOH, meq phenolic OH and meq total acidity $100g^{-1}$ peat are significantly correlated with LR. The LR of peat soils with high soil pH is low regardless of the effect of other variables (% HA, meq COOH, meq phenolic OH, meq total acidity $100g^{-1}$ peat and buffer capacity). This indicates that soil $pH(H_2O)$ is an important factor influencing the LR of tropical peat soils. Milliequivalent COOH g^{-1} of HA is inadequate criteria for determining peat soil acidity component because meq COOH g^{-1} of HA changes with humification. Milliequivalent COOH $100g^{-1}$ peat (meq COOH g^{-1} of HA x % HA) is significantly correlated with LR and this implies the importance of % HA as soil acidity component in tropical peat soils. Buffer capacity is also significantly correlated with % HA, meq COOH, meq phenolic OH and meq total acidity $100g^{-1}$ of peat. Stepwise multiple regression analysis indicate that $pH(H_2O)$, % HA and buffer capacity are factors influencing the LR of tropical peat soils (iii).

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Lazimnya tanah gambut tropika adalah berasid dengan pH tanah kurang daripada 4 dan mempunyai keupayaan pertukaran bes yang rendah. Keasidan disebabkan oleh penceraian kumpulan berfungsi seperti kumpulan karboksilik dan fenolik yang terikat kepada sebatian humik pada bahan organik tanah. Pengapuran adalah satu kaedah untuk mengurangkan keasidan dan memperbaiki kesuburan tanah.

Di Malaysia, kajian keperluan pengapuran biasanya dijalankan dengan menghubungkan antara gerakbalas tanaman dengan pengapuran, tetapi tiada kaedah yang spesifik untuk menentukan keperluan kapur pada



tanah gambut. Oleh yang demikian, objektif-objektif berhubung dengan penentuan keperluan kapur dan komponen keasidan tanah telah dirumuskan:

- i) kalibrasi dan penilaian lima penampan (SMP, Mehlich, Ba, Ca dan NH_4 acetat) untuk menentukan keperluan kapur pada tanah gambut tropika;
- ii) penentuan keupayaan tampan dan keperluan kapur dengan menggunakan kaedah titratan potentiometrik; dan
- iii) memisahkan bahan humik tanah gambut kepada humin, asid humik (HA) dan asid fulvik (FA) dan menentukan jumlah kumpulan karboksilik dan fenolik hidroksil dalam asid humik, serta menyelidiki hubungan antara keperluan kapur dengan komponen keasidan tanah.

Kajian kalibrasi menunjukkan bahawa penampan SMP dan Mehlich adalah kurang sesuai berbanding dengan penampan $\text{Ba}(\text{OAc})_2$, $\text{Ca}(\text{OAc})_2$ dan NH_4OAc . Kajian penilaian menunjukkan bahawa penampan $\text{Ba}(\text{OAc})_2$ adalah paling sesuai, diikuti oleh penampan $\text{Ca}(\text{OAc})_2$. Kaedah penampan $\text{Ba}(\text{OAc})_2$ telah dicadangkan untuk penentuan keperluan kapur pada tanah gambut tropika, manakala kaedah $\text{Ca}(\text{OAc})_2$ sebagai alternatif(i).

Keupayaan penampan dan keperluan kapur tanah gambut tropika boleh ditentukan dengan menggunakan titratan potentiometrik. Keperluan kapur boleh didapati dengan mendarab jumlah bes (mL) yang diperlukan untuk meninggikan pH tanah ke 5.0 oleh faktor 1.0. Faktor keperluan kapur 1.0 ini bermaksud hubungan linear 1:1 antara keasidan tanah dan keperluan kapur yang menunjukkan tindakan tampanan tanah gambut dikawal oleh ion H^+ (ii).

Asid humik adalah komponen utama di dalam bahan humik tanah gambut tropika dan kumpulan karboksil ialah kumpulan paling utama mempengaruhi keasidan tanah dalam asid humik. $pH(H_2O)$, % asid humik, keupayaan tampan, milisetara $COOH$, milisetara fenolik OH dan milisetara jumlah keasidan $100g^{-1}$ tanah gambut sebenarnya berkorelasi dengan keperluan kapur. Bagi tanah gambut yang mempunyai pH tinggi, keperluan kapur adalah rendah tanpa dipengaruhi oleh kesan daripada faktor-faktor lain (% asid humik, milisetara $COOH$, milisetara fenolik OH , milisetara jumlah keasidan $100g^{-1}$ tanah gambut dan keupayaan tampan). Ini menunjukkan bahawa $pH(H_2O)$ tanah adalah satu faktor penting yang mempengaruhi keperluan kapur pada tanah gambut tropika. Milisetara $COOH g^{-1}$ asid humik adalah kriteria yang kurang tepat sebagai komponen keasidan tanah gambut kerana milisetara $COOH g^{-1}$ asid humik berubah dengan penghumusan. Milisetara $COOH 100g^{-1}$ tanah gambut (milisetara $COOH g^{-1}$ asid humik x % asid humik) sebenarnya berkorelasi dengan keperluan kapur dan menunjukkan kepentingan % asid

humik sebagai komponen keasidan tanah pada tanah gambut tropika. Keupayaan tampan juga sebenarnya berkorelasi dengan % asid humik, milisetara COOH, milisetara fenolik OH dan milisetara jumlah keasidan 100g^{-1} tanah gambut. Analisis regresi gandaan menunjukkan bahawa pH(H_2O), % asid humik dan keupayaan tampan adalah merupakan faktor-faktor yang mempengaruhi keperluan kapur pada tanah gambut tropika (iii).

CHAPTER ONE

INTRODUCTION

Malaysia possesses large tracts of peat land which are relatively undeveloped. In its natural state, peat is invariably waterlogged and is characterized by a very low pH (< 4.0) and poor fertility. However, it is becoming important as a potential land for agriculture in the most developed and populated areas along the coast.

The acid condition is reclaimed by liming, and it is possible to grow many annual crops on peat through liming (Kanapathy, 1967; Joseph *et al.*, 1974). Although research and development of peat in Malaysia have been going on since 1950, no satisfactory acidity amendment recommendation has been developed (Ahmad *et al*

Lime requirement (LR) is generally a measure of the base (lime) required to neutralize the acidity of the soil and it can be determined by several methods (Adams and Evans, 1962; Shoemaker *et al* and van Lierop, 1982). In the case of temperate Histosols, the Mehlich and



Nommik buffers were originally calibrated for determining the LR (Mehlich, 1976; Nommik, 1983). However, it has been shown that the methods were not successful in estimating the LR (van Lierop, 1983). Lime requirement of organic soils using SMP buffer was published but there was no detail information on the calibration (McLean, 1973). This shows that for temperate organic soils, very few buffer-pH verifications have been carried out. However, verification of the single-buffer calibration was studied by van Lierop (1983). He concluded that SMP and Woodruff buffers were less precise compared to Mehlich, $\text{Ba}(\text{OAc})_2$ or $\text{NH}_4(\text{OAc})$ buffers for temperate organic soils. In Malaysia, LR studies on peat soils are generally conducted by relating crop responses to liming (Chew, 1971; Chew *et al.*, 1981a; Leong, 1982). There is no published literature on buffer-pH methods to estimate the LR of tropical peat soil to achieve a specific soil pH. The use of reliable laboratory buffer-pH methods to estimate target pH values would save time over a field trial.

One of the methods suggested for estimating the lime requirement of Malaysian soils is potentiometric titration (Shamshuddin and Tessens, 1983). The method has been developed for mineral soils where the LR was obtained by multiplying the base needed with a factor 1.3. However, for organic soils the researchers only recommended the amount of lime for soils under study, but did not propose potentiometric titration as a method (Shamshuddin *et al.*, 1985). Hence, study on this is also needed, so that the

potentiometric titration can be developed as a method and also to know the behaviour of peat soil upon the addition of a base.

Organic matter consists mainly of humic acids, fulvic acids and humins. The primary source of the acidity in peat soils is the dissociation of carboxyl and phenolic hydroxyl groups which are attached to the humic and fulvic acids (Schnitzer and Gupta, 1965). Wright and Schnitzer (1959) showed that for mineral soils the fulvic acid (FA) was more acidic than humic acid (HA) because the former had more carboxyl groups than the latter.

To date, very few research have been done on humic substances of tropical peat. Research carried out by Norhayati (1989) showed that HA was the major component of the humic fraction in tropical peat, but the carboxyl and phenolic hydroxyl groups in these soils were not quantified.

Thus, a study was undertaken with the following objectives:

- i) to calibrate and evaluate five buffers for the LR determination of tropical peat;
- ii) to determine LR using potentiometric titration method and develop an indirect method for LR determination; and

- iii) to separate the humic fraction of peat and determine the components in HA which contribute to soil acidity, and to examine the relationship between LR and soil acidity component.

CHAPTER TWO

REVIEW OF LITERATURE

Peat Soil

Peat is defined as organic soil having mineral contents not exceeding 35 % and an area of at least one hectare with depth of 0.5 m or more (Soil Survey Staff, 1990). It is the product of organic matter rotted or semi-rotted for over hundreds of years in water-logged or formerly water-logged areas. The soil consists largely of partially decomposed plant materials in addition to some mineral fractions such as clay, sand and silt.

In reconnaissance soil surveys, two important criteria have been used for the identification of peat soil namely, percentage loss on ignition (Law and Selvadurai, 1968) and thickness of peat materials (Abdul Jamil Mohd. Ali *et al.*, 1989). Based on the loss on ignition, the peat soils are classified as organic clay (20 - 35%), muck (35 - 65%) and peat (>65%), while the thickness was divided to four phases namely, shallow (> 1.0 m), moderate (1.0 - 1.5 m), deep (1.5 - 3.0 m) and very deep (> 3.0m).

Peats are highly suitable when limed. Crops with shallow rooting and fibrous root systems such as oil palm, pineapple, vegetables, cassava, liberica coffee, mulberry, banana and sago are successfully cultivated on peat soils. In Sarawak, relatively large areas of the peat swamps are bearing species of valuable timber such as the 'Ramin' (*Gonystylus bancanus*) (Mutalib *et al.*, 1991).

Distribution and Land Use of Peat in Malaysia

There are approximately 2.73 million ha of peat and organic soils in Malaysia accounting to about 8% of the total land area of the country. Sarawak has the largest area of peat in the country covering about 1.66 million ha (Wong, 1991), while 0.98 million ha and 0.09 million ha occur in Peninsular Malaysia (Law and Selvadurai, 1968) and Sabah (Acres *et al.*, 1975), respectively.

In Peninsular Malaysia approximately, 313 600 ha of peat area have been developed for agriculture, representing 32% of the total peat area (Siew, 1984). The major crops grown are oil palm, rubber, coconut, paddy, pineapple and mixed horticulture. In Sarawak, about 55 000 ha or 3% of peat land have been utilised for agricultural development with popular crops such as oil palm, liberica coffee, coconut, sago and annual crops. In Sabah, peat development for agriculture is still limited.

Physical and Chemical Properties of Peat

The bulk density of undisturbed tropical peat is low and varies from 0.10 g cm^{-3} to 0.20 g cm^{-3} (Tie and Kueh, 1979; Ismail, 1984) and field moisture content ranges from about 100 to 1300 percent, on dry weight basis (Mohd. Yusuf, 1984). The mineral content varies with location and the loss on ignition ranges from 40 to more than 90 percent (Ismail, 1984). The peat is also characterized by woody nature and poor trafficability (Purushothman, 1979).

Malaysian peat is usually very acidic with a pH generally less than 4 and an exchangeable hydrogen of about $88 - 170 \text{ me } 100\text{g}^{-1}$ (Zahari *et al.*, 1982). The other chemical properties commonly attributed to peat include high organic matter content ($> 90\%$), low mineral content, high C:N ratio (40:1), high CEC (average about $140 \text{ me } 100\text{g}^{-1}$) and very low base saturation (Chew *et al.*, 1976a).

Acidity Development in Peat Soils

The acidity in soil arises from several different sources. In peat soils, the development of soil acidity is strongly influenced by the organic matter content. Soil organic matter contains a high amount of carboxyl groups and phenolic hydroxyl, which are important in exchange reactions and as sources of acidity (Thomas and Hargrove, 1984).

During the breakdown or humification of organic material, the insoluble and soluble products containing substituted radicals such as -COOH, phenol-OH, alcohol-OH, -NH₂ and quinones are released. The acidity developed as a consequence of the dissociation of hydrogen from the acidic groups of carboxyl and phenolic hydroxyls (Schnitzer and Gupta, 1965).

The organic matter in peat reacts with iron and aluminium ions to form complexes (Martin and Reeve, 1958; Bhumla and McLean, 1965; Schnitzer and Gupta, 1965; Griffith and Schnitzer, 1975). These complexes tend to undergo hydrolysis to yield hydrogen ions.

Liming

Liming to correct soil acidity is one of the most common agricultural practices. It is defined as addition of any calcium or calcium and magnesium containing compound to the soil which is capable of reducing the soil acidity.

Generally, liming will increase solubility or the availability of the various plant nutrient and minimize the concentrations of elements such as Al, Fe and Mn which may be present at toxic levels.

In peat soil, liming increases the uptake of applied nutrients and increases the rate of peat soil mineralization as well as releasing the originally bound N, P, and other nutrients. Lime application increased the uptake of N, P, K, Ca and Mg (Chew *et al.*, 1975, 1979, 1981b; Chew *et al.*, 1976a). About 4 % of N was released by the peat over a one-year period (Chew *et al.*, 1976b).

Liming also increased the mineralization rate which attributed to the improvement in microbial activities as the soil pH increased (Rajagopalan and Siow, 1975). Research by Farrell and McDonnell (1986) indicated that the addition of lime to peat could increase crop production but it also increased the rate of decomposition which resulted in subsidence or the accelerated compaction and continual lowering of the surface. However, Gjessing (1976) reported that results have shown that lime (and exchangeable Ca) retards the decomposition of humic substances because of the formation of calcium-humate and organo-mineral compounds less available to microorganisms. Therefore, the researcher concluded that lime intensifies the disintegration of fresh plant residues but retards decomposition during the later stages of humification.

Mechanism of Lime Reaction in Peat Soils

The mechanism of lime reaction with acid soils is complex. There are several factors, such as source and solubility of liming materials, rate