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Feasibility of Using Soil pH Buffering Capacity for Dolomite Recommendation for Tea Growing Soils in Sri Lanka

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ABSTRACT

Soil pH buffering capacity is the key parameter to accurately determine the lime requirement to neutralize soil acidity to a desired pH. Tea [*Camellia sinensis* (L.) O. Kuntze] prefers to grow well between pH 4.5-5.5. If pH drops below 4.5, liming is undertaken as a desirable agronomic practice where dolomite has been the most commonly used material for long to reduce soil acidity in tea in Sri Lanka. The present practice for lime recommendation is based on just a single point pH measurement which may introduce over and lower liming at times for a given type of soil.

This study has hence attempted to introduce a refined liming procedure by making use of pH buffering phenomena of soils. Differential behaviour of soils for pH buffering was examined in this study. Top-soil samples were collected to represent all benched-marked soil series, from 30 locations to represent 18 tea growing soil series, where dolomite has not been applied for the past 10 years. Soil pH buffer curves were established by treating the soils with calcium hydroxide liming solution. Treated samples were equilibrated for 45 minutes, confirmed by a pre-test conducted for two days to ascertain the best equilibrating time.

Soil series studied were categorized into three classes based on their buffering abilities. From the results Mattakelle series, Nuwara Eliya series, Rikillagaskada series, Kandy series and Ukuwela series showed higher buffering abilities whereas Bandarawela series, Akurana series, Pallegoda series, Galigamuwa series and Matale series showed low pH buffering abilities indicating higher changes of pH for lesser amount of lime added. Hunnasgiriya series, Malaboda series, Maskeliya series, Mahawalatenna series, Dodangoda series, Beliatta series, Weddagala series and Ragala series stood in the medium range.

The results indicate the need for making differential dolomite recommendations in correcting soil pH, based on different pH buffering abilities. Consequently, refining of the present procedure of recommending dolomite appeared to be essential and timely.

Key words: Acidity, pH buffering, soil series, tea

INTRODUCTION

Soil reaction is the measure of the degree of soil acidity, neutrality or alkalinity which primarily affects nutrient availability and microbial activity influencing plant growth. Soil acidity comprises two main components, namely, active acidity and potential acidity. Active acidity is the concentration of H^+ ion in the solution phase of the soil and is measured by pH but is not a measure of the total soil acidity. The potential acidity refers to the amount of H^+ and Al^{+++} ions on cation exchange sites of negatively charged clay and organic matter fractions of the soil which may contribute to active acidity when exchanged to soil solution and Al^{+++} ions get hydrolysed (Schroeder, 1984). Acidity or the alkalinity is caused by the protonation or deprotonation of minerals and organic compounds (Weavera *et al.*, 2004). As different crops prefer different soil pH levels for their optimum growth, adjustment of soil pH has become an invariable need, which could be achieved by addition of alkaline or acidulating materials.

Soil acidity in a particular soil is governed by addition and formation of H^+ and Al^{3+} ions accompanied by dealkalization through rain fall, leaching and plant uptake of alkaline cations, addition of acidic fertilizer, amendments etc and further by some intrinsic soil properties as well.

Tea exclusively prefers an acidic soil environment ranging from pH 4.5 to 5.5 (Gadd, 1928). A fall in pH below 4.5 requires an addition of dolomite to soils. The dolomite requirement of tea soils is assessed at present solely by looking at the prevailing pH of a particular soil (Anon, 2000). However, in order to perfectly determine the amount of dolomite essential to compensate soil pH to a preferred level, ascertaining the soil pH buffering capacity is required. Though the information on soil pH alone could aid in assessing the dolomite requirement, such procedure does not consider the ability of a soil to resist pH change. Hence, pH buffering becomes more suitable to compute the dolomite requirement to reach a desired pH level (Adams and Evans, 1962).

pH buffering is simply the ability of a particular soil to resist pH changes. This resistance is mainly established due to four buffering systems present in soils namely carbonate-bicarbonate system, phosphate system, ion exchange system and aluminium buffering system. The degree of occurrence of these buffering systems varies with chemical and mineralogical properties of the soil (Weavera *et al.*, 2004). The Ca $(OH)_2$ titration method suggested by Dunn (1943) is a widely accepted method for evaluating the buffering ability of a particular soil. However, Dunn's method is also a time consuming procedure and hence not suitable for routine analysis in soil testing laboratories (Min Liu *et al.*, 2004).

Hence, the objective of this study was to distinguish the making use of the pH buffering abilities of benched marked soil series in tea growing areas of Sri Lanka to fine tune the Lime Recommendation, in place of the presently used single soil pH value method. A categorization of Soil Series related to pH buffering has also been look forward to.

MATERIALS AND METHODS

Soil samples were collected from 30 locations representing 18 tea growing soil series covering all tea growing areas giving attention to benched-marked soil series, including Low country, Mid country, Up country and Uva region, to which dolomite had been not applied for more than 10 years. The pH of each soil was measured in water suspension of 1:2.5. A pre-test was conducted using several representative soil samples by introducing a freshly prepared 0.22 M $Ca(OH)_2$ liming solution at the rates of 0 (T_1), 1 ml (T_2) and 2 ml (T_3) of $Ca(OH)_2$) to 10 g of air dried soil (Weavera *et al.*, 2004). The resulting pH was measured after 0, 20, 40 minutes and 1 hour, 1 hour and 20 minutes, 2, 4, 6, 24 and 48 hours to ascertain the equilibrium time required for maximum neutralization using the similar Soil:Solution. Measurement of pH in the suspensions was done potentiometrically using an Orion Model 710A pH meter and an Orion 9170 Triode Electrode. Two drops of chloroform were added to each suspension to curtail microbial activities and the containers were covered with parafilms to arrest evaporation as well as the interaction with the laboratory atmosphere. Using the time duration gained for equilibrium from the above pre-test, the pH buffer curves for all soil series were plotted adopting the same procedure. Organic carbon content and the CEC were also determined to be used for interpretation by using modified Walkley and Black method (Rayment and Higginson, 1992) and Na_2SO_4-NH_4Cl method (Rayment and Lyons, 2011) respectively.

RESULTS AND DISCUSSION

Equilibrium time

The results of the pre-test indicated that the maximum incubation duration to achieve the equilibrium status could be taken as 45 minutes as shown in Figure 1 which depicts two extreme example situations as highly buffered soils from Nuwara Eliya series and low buffered soils from Galigamuwa series. Hence, it was decided to incubate the samples representing the soil series to establish their Buffer curves for 45 minutes prior to pH measurement. Min Liu (2004) has also observed similar results.

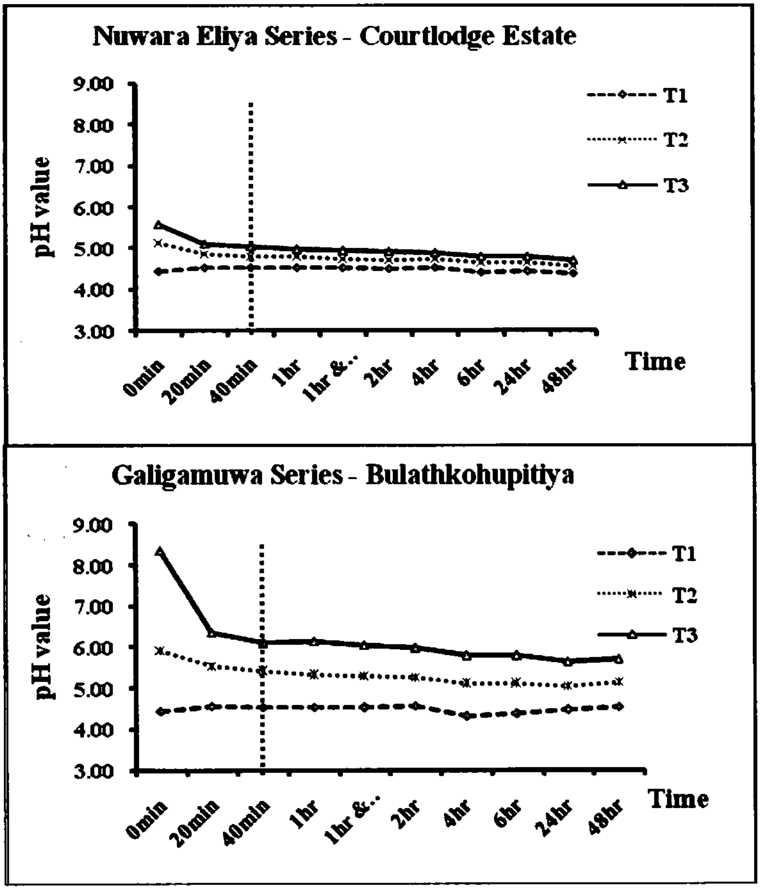

Figure 1. Change of pH with time after adding $Ca(OH)_2$ of different concentrations (T_1=0 ml, T_2=1 ml and T_3=2 ml)

Estimation of pH buffering capacities

Buffer curves obtained for Low country and Mid country as well as for Up country and Uva region soils are shown in Figures 2, 3, 4 and 5 respectively. pH changes of all tested soils showed linear relationships ($r^2 > 0.99$) to the alkali added, which is also vital to compute a single value for pH buffering capacity according to Min Liu *et al.*, (2004).

The linearity observed here was applicable only to the acidic range as observed by Min Liu (2004) as well. However, in contrast, the relationship could be sigmoid if observed over the whole range (Nelson *et al.*, 2010). As tea requires an acidic pH range, pH measurements at 3 points appeared to be sufficient and suitable for easy computations of dolomite requirements.

Each soil series showed different behaviours for a similar amount of liming solution added, indicating contrasting differences of buffering capacities among tested soils. Soil series such as Pallegoda series exhibited poor buffering ability for Low country soils while Weddagala series showed comparatively medium buffering ability for the Low country (Figure 2). When Mid country soils are considered, Kandy and Ukuwela series exhibited higher buffering capacities and Akurana, Galigamuwa and Matale soil series showed lower buffering capacities (Figure 3). Soils in the Up country displayed comparatively higher buffering capacities except for Maskeliya series which exhibited a medium buffering ability (Figure 4). Bandarawela series representing Uva region showed a poor buffering ability while other soils of the region showed relatively medium buffering abilities as depicted in Figure 5.

These differences on pH buffering capacities have shown strong correlations with the soil organic carbon content and the soil cation exchange capacity (CEC) in line with Weavera *et al.*, (2004) (Figures 6 and 7). Soils which had higher organic carbon contents and higher CEC expressed greater pH buffering capacities as observed for Mattakelle series which had 3.86% organic carbon and a CEC of 21.01 cmols+ kg^{-1} soil. In contrast soils having lower CEC and organic carbon contents showed lower buffering abilities for pH. Similar observations have also been made by Curtin (1996) and Bache (1988).

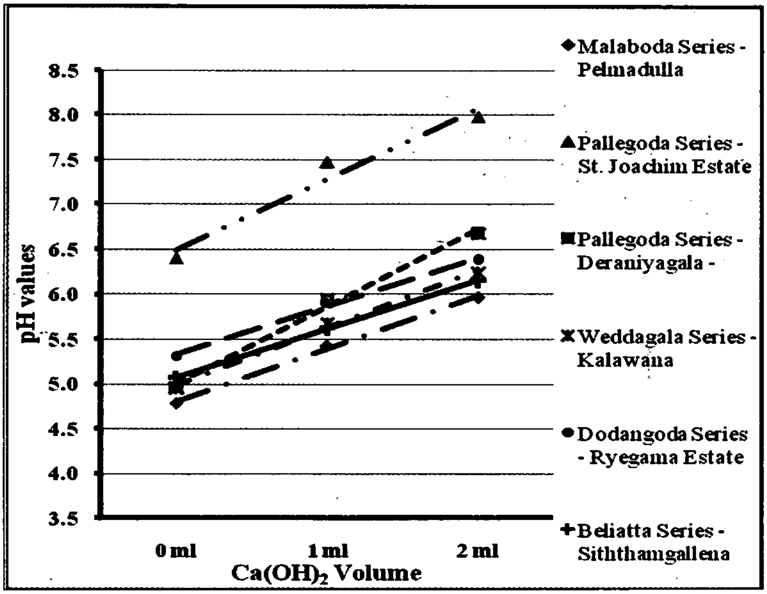

Figure 2. pH Buffer curves of Low country tea growing soils

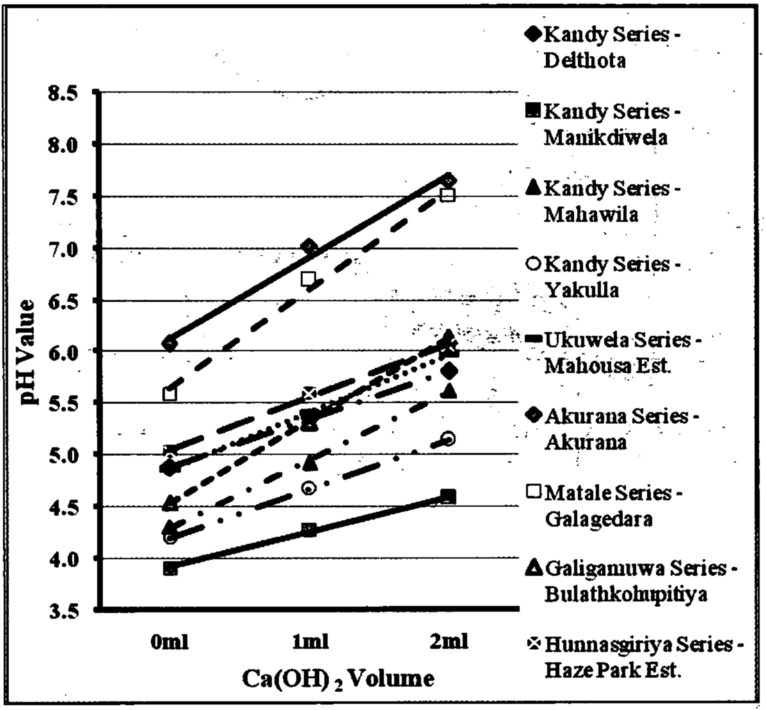

Figure 3. pH Buffer curves of Mid country tea growing soils

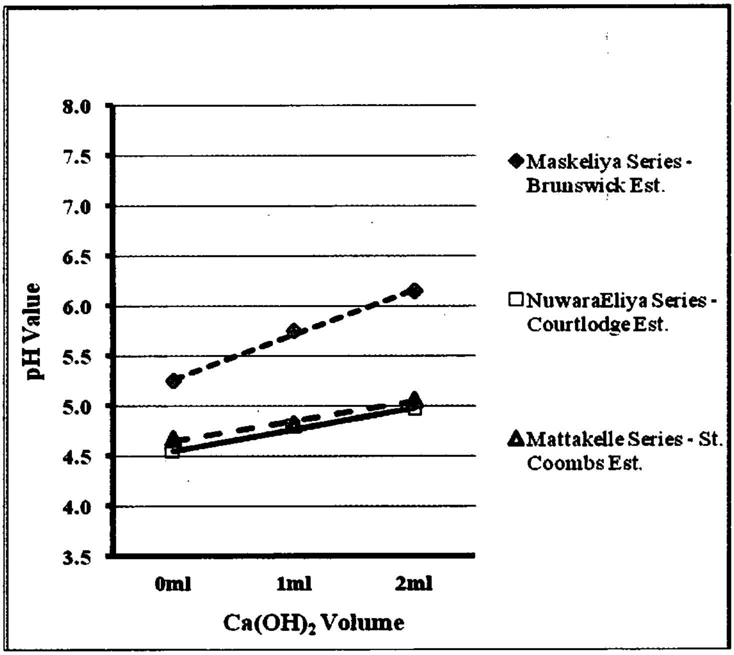

Figure 4. pH Buffer curves of Up country tea growing soils

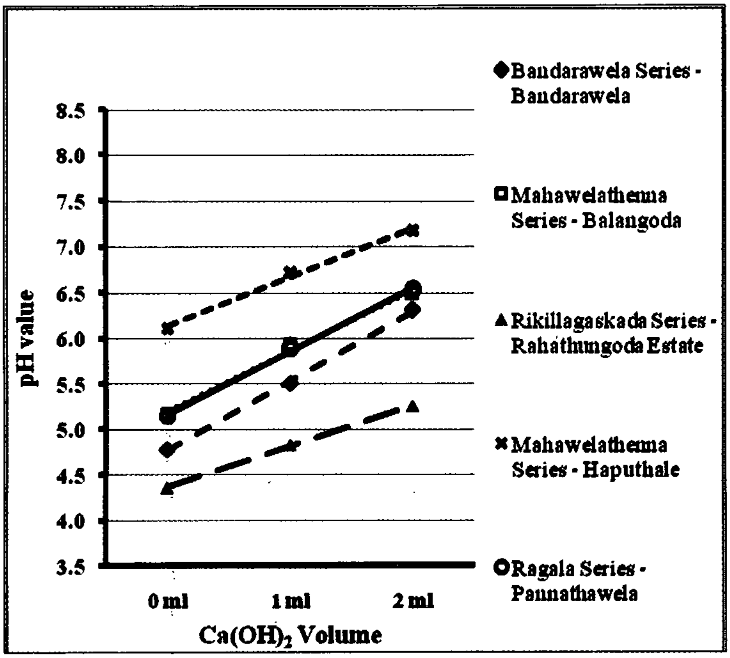

Figure 5. pH Buffer curves of Uva tea growing soils

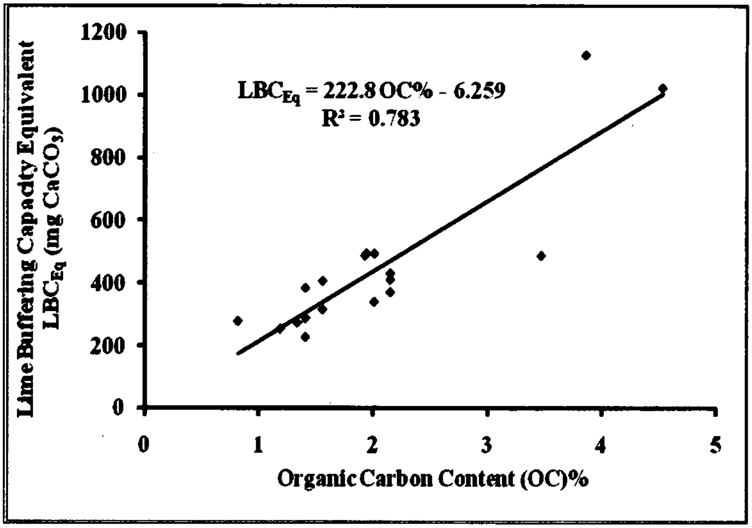

Figure 6. The correlation of soil organic carbon % to the lime buffering capacity

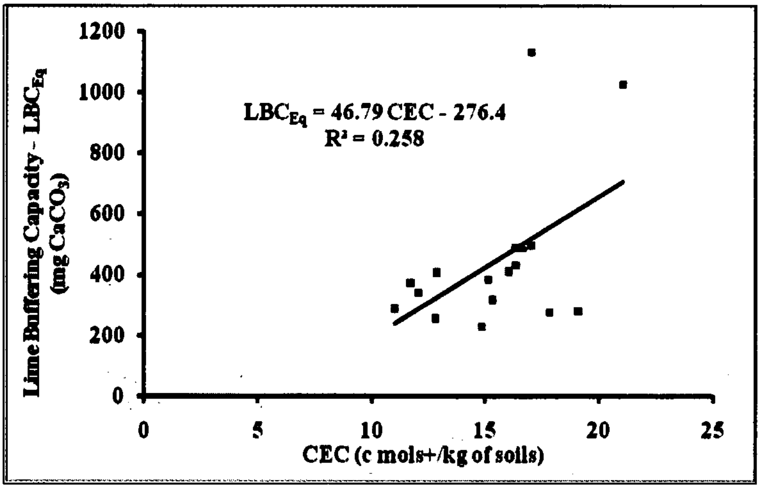

Figure 7. The correlation of Cation Exchange Capacity (CEC) to the lime buffering capacity

Almost all tea growing soils in Sri Lanka belong to soil order *Ultisols* and *Inceptisols* (Mapa *et al.*, 1999); hence the presence of active clay fraction is poor throughout the profile. Mineralogical analysis performed for *Ultisols* and *Inceptisols* of the wet and intermediate zones indicates the dominance of kaolinite which comprised 80-90% and 40% among the total clay fraction respectively (Indraratne, 2009). Therefore, one of the major governing factors of the CEC of such soil is organic carbon content which is mostly pH dependant. Consequently organic carbon has a higher influence on the CEC thereby to the pH buffering capacity.

Figure 8 illustrates the buffer curves ascertained by pooling the similar slopes (Δ) of individual buffer curves into three categories for all tested soils. Such a categorization would help for management of soil pH under regional level having similar growth situations. However, site specific management of soil pH is much appropriate and accurate as agronomic practices could alter the pH buffering capacity such as addition of organic matter would increase the pH buffering ability.

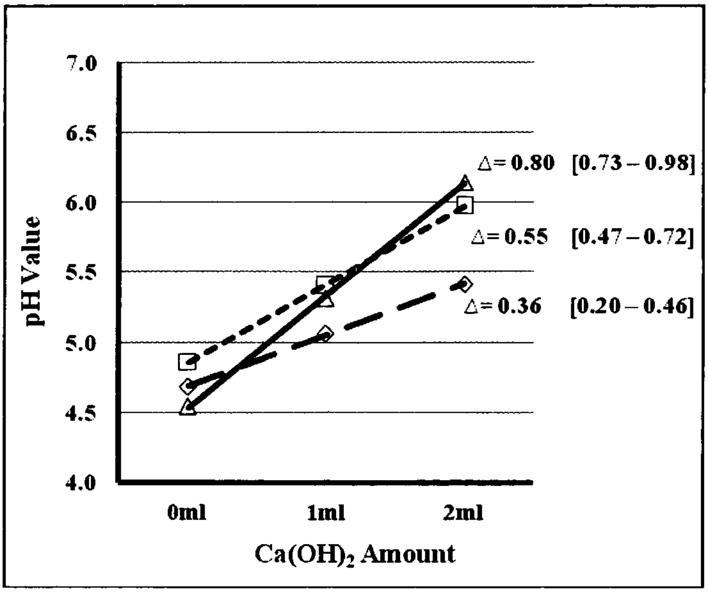

Figure 8. Pooled pH buffering capacities of soils showing similar trends

Results indicate differential behaviour of soils in buffering so that different amounts of liming materials would be required to correct the soil pH. A soil which has lower slope (Δ) is strongly resistant to pH changes, thus requiring a comparatively large amount of liming material, whereas lesser amount for a soil having a higher Δ.

Table 1 shows the calculation of dolomite requirement ($CaCO_3$-55%: $MgCO_3$-44%) for correction of soil pH by one unit in three different soil series tested under laboratory environment. In terms of lime, this is considered the equilibrium lime buffering capacity (LBC_{Eq}) defined as the weight of pure lime ($CaCO_3$), in milligrams, needed to raise the pH of one kilogram of soil by one unit (Kissel *et al.*, 2005).

Table 1. Indication of dolomite requirement to raise soil pH by a single unit

Soil Series	$Ca(OH)_2$ (ml)	Dolomite Equi: (mg)*	Dolomite (kg/ha)	CEC (meq/100g)	OC (%)
Mattakelle	5.13	10.38	1038	21.01	3.86
Rikillagaskada	2.22	4.49	449	16.31	3.47
Pallegoda	1.16	2.35	235	10.97	1.19

* 1 ml of 0.22 M $Ca(OH)_2 \equiv 2.023$ mg of Dolomite

Table 2 shows the categorization of soil series based on buffering capacities. Three classes have been identified based on contrasting differences of slopes during the pooling of more or less similar curves. Cube-root Cumulative Frequency method of stratification was used to bundle the similar slopes of obtained buffering capacities (Singh and Manget, 1996). In general most of the soils in Up country fall into high pH buffering group except Maskeliya series whereas majority of Mid country soils come under medium buffering capacity group and greater part of Low country soils exhibits low buffering ability for pH. This elevation based differences have been considered in previous dolomite recommendation (Anon, 1989).

Table 2. Categorization of tea growing soil series based on their pH buffering capacities (Δ)

Class 1 (Δ<0.46) Soil Series	Class 2 (Δ =0.47 - 0.72) Soil Series	Class 3 (Δ>0.73) Soil Series
Mattakelle	Ragala	Bandarawela
Kandy	Maskeliya	Galigamuwa Akurana
NuwaraEliya	Rikillagaskada	Pallegoda
Ukuwela	Mahawellathenna	Matale
	Dodangoda	
	Beliatta, Malaboda	
	Weddagala	
	Hunnasgiriya	

CONCLUSIONS

Results indicated the differential behaviour of soils in pH buffering which demands different amount of liming material to raise the pH to desired level. As tea requires pH in slightly acidic range, pH measurement at three points would be enough to derive the titration curve prior to computation of dolomite requirement. Soil organic matter content and cation exchange capacity show significant relationship to the soil pH buffering capacity.

There is an imperative need of revisiting the dolomite recommendation to tea soils. Such would help to overcome the possible over or lower liming took place up to now, affecting the growth and quality of made tea. Hence, it is anticipated to coin a new formula to compute future dolomite recommendations giving attention to secondary influencing factors such as efficiency and purity of dolomite, their duration of neutralization, climatic factors and acidity development in the soil by events such as added types of fertilizer as well as leaching and plant uptake of alkaline nutrient ions.

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