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Variable Lime Requirement Based on Differences in Organic Matter Content of Iso-acidic Soils

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ABSTRACT

Understanding the factors affecting lime requirement (LR) is important for soil acidity management. Twenty samples with almost similar pH (4.51±0.05) but varying widely in organic matter (OM) and clay contents were selected for studying the importance of OM and clay content in determining the LR of acidic soils. Despite the iso-acidic nature of these soil samples, there were more than three-fold variations in the LR which ranged between 5.6 to 18 t ha^{-1}. Interestingly, the highest values of buffering capacity index (BCI=1.49) and LR (18 t ha^{-1}) was associated with the soil with highest OM content (4.89%). Similarly; the lowest BCI (0.55) and LR (5.6 t ha^{-1}) was found in the soil having the lowest OM content (1.03%). OM content of soil was strongly correlated with BCI (r= 0.824**, p< 0.01) and LR (r= 0.862**, p< 0.01). Regression analysis also showed strong dependence of BCI (R^2=0.678) and LR (R^2=0.743) on soil OM content. Clay content did not correlate with BCI or LR of the soils. Results suggest that the LR of the soils even with similar pH may vary drastically based on differences in their OM content.

Keywords: Buffering capacity, Lime requirement, North-east India, Soil acidity management

INTRODUCTION

Acid soils occupy more than 30% of the world's ice-free land and nearly 50% of the potentially arable land (von Uexkull and Mutert 1995). About 68% of these soils occur in the humid tropics. In India, nearly 25 million hectares of land are having pH below 5.5 and 23 million hectares fall under the pH range of 5.6-6.5 (Mandal 1997). Majority of these soils (54%) are concentrated in North Eastern Region (NER) of India where more than 95% area is affected by soil acidity, with around 65% of the area being under extreme forms of soil acidity (pH below 5.5) (Sharma and Singh 2002). Crop productivity on such a soil is mostly constrained by aluminium (Al) and iron (Fe) toxicity, phosphorus (P) deficiency, low base saturation, impaired biological activity and other acidity-induced soil fertility and plant nutritional problems (Manoj-Kumar 2011). Because of these constraints, despite having ~6% of the total geographical area and ~13% of the total rainfall in the country, the NER contributes only 1.5% to the national food grain production (Singh and Satapathy 2007). Amelioration of soil acidity is, therefore, accorded top priority for enhancing crop productivity and ensuring food security of the region.

Application of lime is a widely recommended practice for amelioration of soil acidity and alleviation of acidity-induced soil fertility and plant nutritional problems (Haynes 1984; Patiram 1991). Since liming involves a considerable cost in crop production on acid soils, knowledge of its required amount to be applied for raising the soil pH to a target level (lime requirement) is important. There is a general impression among the farmers and the extension workers that the soils with low pH require high amount of lime application and vice-versa, which may not be always correct. In fact, the existing soil pH is just an indication, whether liming is required or not; it does not suggest the actual amount of lime required to raise the soil pH to a desired level. Lime requirement depends largely on cation exchange capacity (CEC) of soils. Soils with high CEC possess high buffering capacity, and therefore, more amounts of lime is required to cause a unit increase in pH of such soils. The CEC and hence the buffering capacity of soils are mostly determined by their organic matter and clay

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contents. Therefore, the lime requirements for the soils with high organic matter and clay contents can also be expected to be high, and *vice-versa* (Keeney and Corey 1963; Ross et al. 1964; Aitken et al. 1990; Husni et al. 1995; Pagani and Mallarino 2012).

Soil acidity in the northeastern region of India is mostly caused by excessive rainfall, the other management factors, including chemical fertilization being relatively less important. Thus, soils with the acidity levels falling within a narrow range can be found over a fairly large area receiving a similar amount of rainfall (barring some latitudinal and geologically-borne differences). However, since organic matter content of soil (SOM) is highly subjective to management practices, even field-to-field variation in SOM content (and hence the soils buffering capacity) within an area may not be uncommon. This implies that although the soils of an area may have similar acidity (pH) levels, their lime requirement may vary considerably based on differences in organic matter and also the clay contents. If so, the blanket dose of lime application cannot be recommended in an area; rather, lime requirement must be worked out for the individual fields for the best result. In this backdrop, the present study aims to test the above-laid hypothesis in the acidic soils of Meghalaya, North-East India. In this study using the soils with similar acidity levels (iso-acidic soils with pH 4.51±0.05), we have attempted to provide an evidence for the fact that even the soils with similar acidity levels may vary drastically in their lime requirement based on their differential buffering capacity caused by differences in organic matter content.

MATERIALS AND METHODS

From a pool of around 400 soil samples (0-20 cm depth) collected from across the seven districts of Meghalaya, India; 20 samples with almost similar acidity levels (mean pH 4.51) were selected for this study. These soils are hereafter referred to as "iso-acidic soils". While selecting the samples, due care was taken to accommodate a wide variability in soil organic matter and clay contents therein. The soil samples were processed and analyzed for pH, organic carbon, particle size distribution, lime requirement and other related variables. These parameters of the selected iso-acidic soils along with their summary statistics are shown in Table 1 and 2, respectively.

Table 1: Experimental soils (20 cm depth) with their pH, organic matter and clay content, and the lime requirement related variables

Sample No.	pH (1:2)	Buffer pH (BpH)	ÄpH (BpH-pH)	BCI (1/ÄpH)	LR (t ha^{-1})	Organic matter (%)	Clay (%)	Textural class
1	4.42	5.99	1.57	0.64	9.48	2.40	20.6	SL
2	4.5	5.17	0.67	1.49	17.98	4.89	23.3	SCL
3	4.46	5.42	0.96	1.04	15.79	4.34	24.0	SL
4	4.51	5.69	1.18	0.85	12.64	3.28	22.6	L
5	4.54	5.62	1.08	0.93	13.61	3.39	28.6	SCL
6	4.49	5.84	1.35	0.74	11.66	2.77	21.3	SCL
7	4.45	6.06	1.61	0.62	8.5	2.09	20.6	SCL
8	4.57	5.70	1.13	0.88	12.64	2.64	23.3	SCL
9	4.48	6.05	1.57	0.64	8.5	1.81	23.3	SCL
10	4.56	6.38	1.82	0.55	5.59	1.03	19.3	SL
11	4.6	6.15	1.55	0.65	7.53	1.14	22.6	SCL
12	4.57	5.91	1.34	0.75	10.69	2.59	24.6	SCL
13	4.59	5.92	1.33	0.75	10.69	2.04	19.3	SL
14	4.49	5.84	1.35	0.74	11.66	2.74	32.6	SCL
15	4.52	5.84	1.32	0.76	11.6	2.09	26.6	SCL
16	4.42	5.82	1.4	0.71	11.6	2.07	30.6	SCL
17	4.58	6.09	1.51	0.66	8.5	1.32	34.6	SCL
18	4.49	5.94	1.45	0.69	10.69	2.04	34.0	SCL
19	4.48	5.42	0.94	1.06	15.79	3.88	20.6	SCL
20	4.5	5.49	0.99	1.01	14.58	1.76	28.6	SCL

BCI: Buffer capacity index; LR: Lime requirement in terms of pure $CaCO_3$; SL: Sandy loam; L: Loam; SCL: Sandy clay loam

Table 2: Summary statistics of the parameters involved in the study (n=20)

Parameters	Mean	Minimum	Maximum	Std. Deviation
pH (1:2 soil-water)	4.51	4.42	4.60	0.05
BpH	5.82	5.17	6.38	0.29
ÄpH	1.31	0.67	1.82	0.28
BCI	0.81	0.55	1.49	0.22
LR (t ha^{-1})	11.47	5.59	17.98	3.07
OM (%)	2.52	1.03	4.89	1.02
Clay (%)	25.02	19.28	34.56	4.86

BCI: Buffer capacity index; LR: Lime requirement in terms of pure $CaCO_3$; OM: organic matter

Soil pH (1:2 soil-water suspension) was measured using glass electrode. Organic carbon was determined by wet digestion method (Walkley and Black 1934) and the organic matter content was calculated using a conversion factor of 1.724. Particle size analysis was done by hydrometer method (Bouyoucos 1962). Lime requirement (for a target soil pH 6.0) was estimated using SMP buffer method (Shoemaker et al. 1961). SMP buffer acts as a quick acting liming material. Upon its addition (and equilibration) to soil, the pH of soil-buffer mixture increases, and the magnitude of increase depends on the buffering capacity of soil. Soil with high buffering capacity (high reserve acidity) allows less change in pH, and *vice-versa*. Therefore, difference in the soil-buffer pH and the initial soil pH (Ä pH) indicates buffering capacity of the soil. Higher the ÄpH, lower would be the buffering capacity, and *vice versa*. To simplify the relationship further, reciprocal of the ÄpH was taken as an index of soil buffering capacity, hereafter referred to as "Buffering Capacity Index" (BCI). Lime requirement has been expressed in terms of pure $CaCO_3$. Pearson's correlation coefficients were used to determine the strength of relationships among the various soil attributes, lime requirement and related variables. All the statistical analyses were performed using SPSS version 16.0 software.

RESULTS AND DISCUSSION

As hypothesized at the beginning of this study, variations in organic matter content of soils did exert significant influence on the lime requirements of the iso-acidic soils used in the study. Table 1 and 2 show that initial pH of the soils were almost similar, with a mean pH of 4.51 and standard deviation of ±0.05. Despite the iso-acidic nature of these soils, their lime requirement varied drastically. In fact, there were more than three-fold variations in the lime requirement which ranged between 5.6 to 18 t ha^{-1}. Interestingly, the highest lime requirement (18 t ha^{-1}) was associated with the soil (sample no. 2) with highest organic matter content (4.89%). The change in soil pH upon addition of SMP buffer (ÄpH) was also found lowest (0.67) in the same soil, which indicates its highest buffering capacity. It is clearly reflected by the highest buffering capacity index (BCI) of this soil (1.49). Similarly, the highest magnitude of ÄpH (1.82), the lowest BCI (0.55), and thereby the lowest lime requirement (5.59 t ha^{-1}) were all associated with the soil (sample no. 10) having the lowest organic matter content (1.03%). The strong correlations of the soils' organic matter content with their BCI ($r= 0.824^{**}$, $p< 0.01$) and the lime requirement ($r= 0.862^{**}$, $p< 0.01$) are amply evident in the correlation matrix shown in Table 3. The role of soil's buffering capacity in deciding the lime requirement is also evident from their strongly positive correlation ($r= 0.922^{**}$, $p< 0.01$).

The dependence of lime requirement on buffering capacity of the soil and that of buffering capacity on soil organic matter content can be better appreciated by their relationships shown in Fig. 1. A large proportion of the variability in soils buffering capacity was explained by organic matter content ($R^2= 0.6785$). Similarly, BCI accounted for 85% of the lime requirement, and the organic matter accounted for 74% of the variability in lime requirement. Clay content, though often considered an important factor governing the soils buffering capacity and the lime requirement, was not significantly correlated with any of the parameter related to lime requirement of the soils in present study (Table 3).

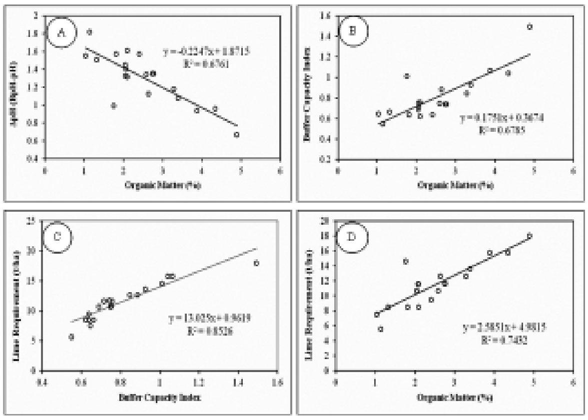

Fig.1: Relationships among the organic matter content, buffering capacity index and lime requirement of the soils under study (n=20)

The importance of organic matter as a determinant of lime requirement in iso-acidic soils, as observed in our study, can be attributed to its contribution in the buffering capacity of soil which, in turn, is governed by the CEC of the soil. High organic matter containing soils, by virtue of their higher CEC, can possess more amount of reserve acidity, neutralization of which requires higher amount of lime application. The strong correlation between soil organic matter content and lime requirement has also been reported by Keeney and Corey (1963), Ross et al. (1964), Aitken et al. (1990), Husni et al. (1995), and recently by Pagani and Mallarino (2012). Keeney and Corey (1963) working with incubation experiments in Missouri, correlated lime requirement with various soil properties. They reported that SMP buffer pH was the best single predictor variable for lime requirement ($r = 0.95$), which was also observed in our study (Table 3). Their results also showed that both organic matter and soil pH explained the largest proportion of variation in lime requirement across soils compared to initial soil pH alone. In our study, initial soil pH did not correlate with lime requirement because the soils were iso-acidic in nature, while the effect of organic matter was quite evident (Table 2&3, Fig.1).

Considering the importance of organic matter in determining the lime requirement of soil, a combined parameter was calculated as the desired target pH minus initial soil pH multiplied by organic matter content (Keeney and Corey, 1963). The combined parameter was well correlated ($r = 0.88$) to lime requirement. Because most routine soil testing laboratories measure pH and organic matter in soil samples, they proposed that lime requirement could be predicted using an equation based on soil pH, target pH, and organic matter content. Having witnessed similar results in our study, such equations may also be developed for calculation of lime requirement for the acidic soils of northeast India.

Although clay content is also considered to exert the similar influence, such effect was not observed in the present study, which may be due to the fact that variability in clay content of the soils under study was not as pronounced as that in organic matter contents, and thus the possible impact of clay might have been masked by that of organic matter. Also, since organic matter content of soils in the study area is relatively higher, much of the soils CEC and buffering capacity may be expected

Table 3: Correlations of lime requirement and related variables with organic matter and clay content of the iso-acidic soils under study (n=20)

	pH	BpH	ÄpH	BCI	LR	OM	Clay
pH	1						
BpH	0.266	1					
ÄpH	0.082	.982**	1				
BCI	-0.093	-.940**	-.954**	1			
LR	-0.263	-.995**	-.978**	.922**	1		
OM	-0.325	-.856**	-.822**	.824**	.862**	1	
Clay	-0.035	-0.042	-0.037	-0.043	0.072	-0.148	1

** Correlation is significant at the 0.01 level (2-tailed). BCI: Buffer capacity index; LR: Lime requirement; OM: organic matter to result from the soil organic matter rather than the clay contents, and this explains the observed dominance of organic matter over clay in determining the lime requirement of iso-acidic soils in present study.

CONCLLUSIONS

Lime requirement of the soils even with similar acidity (pH) levels may vary widely based on the differences in their organic matter contents, and therefore, lime application should not be advocated merely on the basis of existing soil pH. Rather, proper testing of lime requirement is needed for the best results in terms of soil acidity amelioration and crop productivity improvement. Further, considering the importance of organic matter in determining the lime requirement of soils in study area, simple equations based on soil pH, target pH, and organic matter content may also be developed for easier estimation of lime requirement in the acidic soils of northeast India.

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