

Comparative Efficiencies of Traditionally Used Limes and Their Effects on Potassium and Sodium Release in a Moderately Acid Soil

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ABSTRACT

Introduction and purpose Intensive cultivation has resulted, among other adverse effects, in increasing soil acidity. Moreover, some soils are acidic by origin which ultimately limits the growth of most crops. Liming is a common practice to bring the soil pH to an optimum range (6.5-7.5) for plant growth. The use of different Ca-rich and Mg-rich limes is the usual practice and their liming capability depends on different factors. **Methods** In the present study, CaO, Ca(OH)₂, CaCO₃ and MgCO₃ limes were used for 10 months period to evaluate their relative efficiencies to raise the pH to 6.5 or above and to figure out how they affect K and Na release in a moderately acid soil. **Result and discussion** It was observed that CaO was more efficient than the other liming materials to reach the desired pH. The change on soil pH also affected the K and Na levels of the soil. A positive impact of these limes on K availability was observed while the response on Na solubility was negative due to Ca-rich limes but positive for Mg-rich lime. **Conclusion and suggestion** CaO can be used for raising pH and ensuring K availability in soils, however, longer period field trial of the limes is needed to evaluate crop quality and disease infestation.

Keywords: Comparative effectiveness, impact on release of K and Na, Lime.

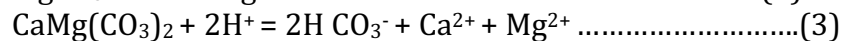
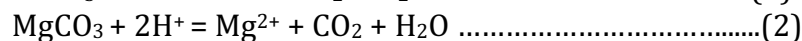
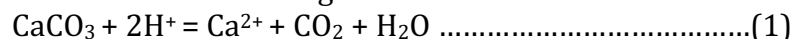
INTRODUCTION

Lime is a chemical that can be used for raising pH of soils. Limes, the materials that can cause an increase in pH or decrease in soil acidity include carbonates, oxides or hydroxides of calcium and magnesium. pH of some soils are so low in some areas that it needs to be raised to bring the soil in good productive conditions. Plants grow best in the pH range of 6.3-7.5. The lower the pH of the soil, the more acidic it is, which hampers the plants and the beneficiary

microorganisms in the soils to grow and fulfill their life cycle as well. In order to bring the pH to about 7.0, lime is added to soil. Liming is mainly required in tea soils and hill soils of Bangladesh. Although there are arguments about the negative climatic impacts of liming agricultural lands (Gibbons et al., 2014), application of limes to bring acid soils in productive conditions is known for centuries.

Popular liming materials to improve soil pH are CaO or quicklime, $\text{Ca}(\text{OH})_2$ or slaked lime, CaCO_3 (Calcite), $\text{CaCO}_3 \cdot \text{MgCO}_3$ (Dolomite), MgCO_3 , MgO etc. Among all of these CaCO_3 is a widely used lime due to its greater availability and easier solubility. But the efficiencies of these materials to raise soil pH in a comparative manner and their effect on K and Na release in acid soils of Bangladesh are yet to be determined.

Generally, the Ca^{2+} and/or Mg^{2+} ions present in liming materials neutralize soil acidity by displacing H^+ ions and thus change the chemical balance of the soils. The representative reactions for Ca and Mg rich limes can be described as:



In the acid neutralizing process, limes are found to produce $\text{CO}_2 + \text{H}_2\text{O}$ which lead to the increase of soil pH (Holland et al, 2018).

Soil pH is the most important criteria determining the lime requirement of soil. There are many known reasons for increasing soil acidity or decreasing soil pH. One of the important factors that accelerate acidification of agricultural soil is increasing crop production practices, especially with the use of nitrogenous fertilizers (Anderson et al., 2013).

Other properties such as texture, structure, percentage of organic matter, amount and type of clay also affect lime requirement. Crops to be grown in the field also influence lime requirements because the availability of plants to grow in acid soil varies with different crops. Kind of lime, its chemical composition and fineness, influences lime requirement (Imamul Huq & Alam, 2005).

Quality standards of liming materials are determined using different parameters such as Total Neutralizing Value (TNV) (the acid neutralizing percentage of the material which is expressed as the calcium carbonate equivalence (CCE) of the product); Calcium Carbonate Equivalence (CCE) (a standard which compares the liming materials to pure calcium carbonate (CaCO_3); Fineness (the particle size of the material which is defined by passing through sieve); and Effective Neutralizing Value (ENV) (the fraction of the CCE of a material that reacts in the first year of application to neutralize soil acidity). Calcium Carbonate Equivalences of some limes are given below:

Table-1: Calcium Carbonate Equivalence (CCE) of a few common liming materials (Carey et al., 2006)

Common name	Chemical formula	CCE
Calcitic limestone	CaCO_3	100
Dolomitic limestone	$\text{CaCO}_3 \cdot \text{MgCO}_3$	109
Burned lime or Quick lime	CaO	179
Hydrated lime or Slaked lime	$\text{Ca}(\text{OH})_2$	136

Remarks: Assuming 100% pure material

Sometimes, to ease handling, dry liming materials are moistened. This moistening doesn't influence the effectiveness of the limes but improves uniformity in spreading and reduce the off- site movement of very fine particles (<100 mesh), when the moisture content is 4-5% (Carey et al., 2006).

The moisture content of agricultural limestone does not influence its effectiveness but a moisture content between 4 and 5% will improve the spreading uniformity and reduces the off-site movement of very fine particles (<100 mesh).

Potassium is an essential macronutrient element for plants. The content of K in soil depends primarily upon the parent material and degree of weathering. A large portion of the potassium in soils is present as a part of the crystalline structure of primary and secondary minerals such as micas, feldspars and micaceous minerals of the clay fraction. A small portion is found as exchangeable ions and an extremely small part is present as soluble salt. The potassium minerals predominate in the sand and silt fraction of soil.

Though some soils respond to K-fertilization, most of the soils do not show any deficiency for K in Bangladesh. Still, about 2,30,000 tons of MoP (murate of Potash) fertilizer was recorded to be used during 2006-2007 in soils of Bangladesh (Imamul Huq & Shoaib, 2013). Mainly non-alluvial soils and the coastal saline soils respond quickly to K fertilization. The coastal saline soils usually contain more than 0.12 meq % K, yet they respond to K fertilization and the higher content of Na makes them responsive to K fertilization (Imamul Huq & Shoaib, 2013).

On the other hand, in most soils, the large part of the total sodium is present in insoluble silicate minerals. However, in saline soils, large amounts are present in soluble and exchangeable forms. Since Na is not an essential element, there is little concern about its availability to plants in the low range of exchangeable or water soluble forms in soils. Nevertheless, Na plays a part in plant nutrition in that it may partially substitute for K. That is, some plants give response to Na when K availability is low. Thus, the availability of Na in some soils may be of importance for some crops.

Soils in which Na is specifically determined are nearly always those of arid or semi-arid regions, which have become or liable to become, alkali or saline-alkali. Occasionally Na has to be determined in coastal soils, which have been inundated with seawater.

Finding out the release of K and Na with the use of above mentioned liming materials in a comparative manner is one of the objectives of this study.

OBJECTIVE

The main objective of this study is to assess the relative effectiveness of traditionally used limes (CaO , $\text{Ca}(\text{OH})_2$, CaCO_3 and MgCO_3) for increasing the pH of acidic soil and to find out the one quicker to raise soil pH to bring a favorable plant growth condition and is to measure their influence on Na and K release.

METHODOLOGY

A composite soil sample was collected from Kaligonj upazilla of Satkhira district in December, 2017. The soil belongs to the Bajoa soil series which covers about 132 sq. miles area and the physiography of the series is Ganges Tidal Floodplain (Rahman, 2005).

The pH of the soil was measured on the spot by pH meter. After transferring to the laboratory, the soil samples were spread on a polythene sheet and visible debris like concretes, pebbles, plant root or leaf parts were removed manually. Large clods were broken with a wooden hammer.

A small portion of the soil was sieved with a 0.5mm sieve and the initial content of Na and K of the soil was determined. The other part of the soil was used for *in-situ* pot experiment. Soil samples were weighed to 500g and taken into plastic pots. Finally the lime requirement of the soil was calculated and the measured amount of each lime was added in each pot [$\{\text{CaO} - 1,2,3\}$; $\{\text{Ca}(\text{OH})_2 - 1,2,3\}$; $\{\text{CaCO}_3 - 1,2,3\}$ and $\{\text{MgCO}_3 - 1,2,3\}$]. A total of 12 pots were set for the experiment. That means, there was a triplicate of each experimental set. pH of the soil samples were determined by using a soil-water solution where the ratio of soil and water was 1:2.5 (Jackson, 1965).

An acre of land is usually recorded to contain 2 million pounds of soils (Landschoot, 2016) and to raise the pH of the soil from 5.5 to 6.5 the requirement of lime is 2.0 tons/acre (Vossen, Undated). This value was determined for the soil of 5.5 pH by the SMP buffer test method in 1961 (Anderson et al., 2013).

The SMP buffer test method is named after three soil scientists, Shoemaker, Mclean and Pratt, who published the method. The correlation between lime requirement measured by SMP and lime requirement found by adding lime to soil was found to be acceptable by setting incubation studies of western Oregon soils. SMP is recommended as a guide for lime requirement based on the adequacy of the lime application rate in which soil pH is measured after lime application. The table used in the SMP test for recommending lime is given below:

Table-2: Lime requirement test (SMP) interpretation

	Desired soil pH		
	pH 5.6	pH 6.0	pH 6.4
Lime requirement test value (SMP)	"Lime to apply" to attain desired soil pH (ton/a)		
6.7	0	0	0
6.6	0	0	1.0
6.5	0	1.0	1.7
6.4	0	1.1	2.2
6.3	0	1.5	2.7
6.2	1.0	2.0	3.2
6.1	1.4	2.4	3.7
6.0	1.7	2.9	4.2
5.9	2.1	3.3	4.7
5.8	2.5	3.7	5.3
5.7	2.8	4.2	5.8
5.6	3.2	4.6	6.3
5.5	3.6	5.1	6.8
5.4	3.9	5.5	7.3
5.3	4.3	6.0	7.8
5.2	4.7	6.4	8.3
5.1	5.0	6.9	8.9
5.0	5.4	7.3	9.4
4.9	5.8	7.7	9.9
4.8	6.2	8.3	10.4

Remarks: "Lime to apply" values are based on application of 100-score lime and 6-inch soil sampling depth. For example, lime to apply = 1.7 t/a when desired soil pH is 5.6 and the lime requirement test (SMP) value is 6.0. "Lime to apply" recommendations are usually accurate to ± 0.5 ton lime (Anderson et al., 2013).

Using these references, the amount of lime to raise the pH of the given soil sample was calculated as 1.1g lime/ 500g of soil. Pots with soil and lime samples were preserved for 10 months. A volume of 100 ml distilled water was added in every 15 days to keep the soil slightly moistened and to ease the release and mixture of limes to the soils. Distilled water was added with the aim to add no additional element to the soil from the outside of the system which affect pH change. Readings of pH of the preserved soil samples were measured with a pH meter every month. Each of the samples was measured thrice and the average value was noted down as result.

On the other hand, the content of K and Na of the soil samples were measured every month by extracting with neutral 1N NH_4OAc as stated by (Imamul Huq & Alam, 2005) and the content of both Na and K were determined with flame photometer. The amount of K was recorded as 0.17 meq/100g soil and the amount of Na was recorded as 0.011 meq/100g soil.

RESULTS AND DISCUSSION

Within the ten months period of liming, soil samples were tested to detect changes in pH. Each of the samples was tested and a mean value of pH for each lime-treated soil was recorded. The same procedure was repeated in every month and the pH data were recorded as follows:

Table-3: pH value of soils after liming with different limes in 10 month period

Months	CaO	Ca(OH) ₂	CaCO ₃	MgCO ₃
1	5.5	5.5	5.5	5.5
2	5.9	5.7	5.7	5.7
3	6.0	5.9	5.9	5.8
4	6.2	6.0	6.0	5.9
5	6.3	6.1	6.0	5.9
6	6.4	6.1	6.1	6.0
7	6.5	6.1	6.1	5.7
8	6.5	6.1	6.0	5.8
9	6.5	6.1	6.0	5.8
10	6.5	6.2	6.0	5.8

It is apparent from Table-3 that among the above mentioned limes, CaO is found to be more efficient in raising the pH of the soil. In a 10 months experiment, CaO raises the pH of the soil more efficiently and the estimated goal of pH was achieved whereas the effect of MgCO₃ was not so prominent. To achieve estimated goal in soil pH, either more time is needed or more MgCO₃ should be applied to the soil. But application of more amount of MgCO₃ may cause other harmful effects in both soil and plants.

On the other hand, it is also noticeable from the table that Ca(OH)₂ has raised soil pH reasonably within the estimated time. Among the above mentioned limes, CaCO₃ shows better effects than MgCO₃ but the effect is not as good as the effects of the other two. The result of present study coincides with the interpretation of Holland et al. (2018) stating that calcitic or Ca-rich limestones perform better than dolomitic or Mg-rich limestones with better aggregation effects (Vance et al. (2002).

The graphical expression of the efficacy of the above mentioned limes in raising soil pH is given below:

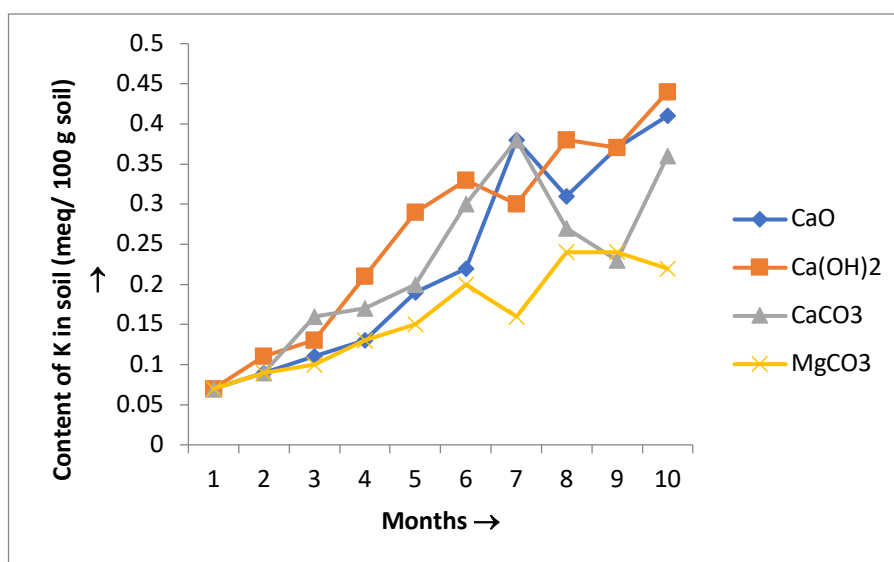


Figure-1: Raising of soil pH with time by different limes

The graph (Figure-1) gives a clear picture in which the curve flattens after some months and the change comes close down.

It should be kept in mind that the effect of lime on soils to be long lasting depends on the buffering capacity of the soil which again, among others, depends on the organic matter though the effect is not permanent (Fageria et al., 2008). Liming should be repeated, more frequently than every 3 years (Caudle, 1991), when the values of exchangeable Ca^{2+} , Mg^{2+} and pH fall below the expected level for a certain crop (Athanas, 2013).

The soil content of available Na and K, before and after liming of the soil, was determined to compare the effects of the limes on availability of the content of K and Na in the soil. The initial content of K was 0.17 meq/100g soil and Na was 0.011 meq/100g soil.

During the liming treatment with the above mentioned limes, soil K content was found to be increased. Addition of limes in soils imposed a positive impact on the K content of the soils. All the limes helped to increase soil K level, however, better impact was noted for Ca(OH)_2 . The order of the limes, as far as the K content of soil is concerned, can be presented as $\text{Ca(OH)}_2 > \text{CaO} > \text{CaCO}_3 > \text{MgCO}_3$.

The pattern and extent of increase in soil K content during liming operations with different limes are presented in Figure-2.

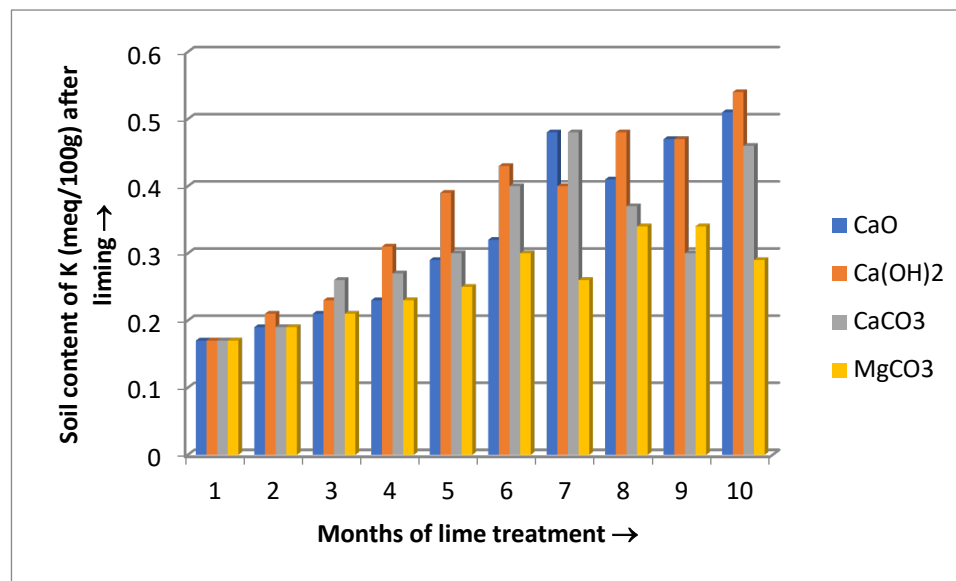


Figure-2: Increases in the content of soil K after liming with different liming materials or 10 months

Addition of lime increases K (primary macronutrient) availability in soils possibly through the K displacement by secondary macronutrients like Ca^{++} and Mg^{++} . Calcium and magnesium ions present in the limes released with time, increase soil pH and substitute K^+ ions from the exchange sites of both the organic and inorganic sources. Mainly, the availability of K is associated with the release of K from the interlayer spaces of silicate clays due to the marked changes in pH. Supporting this hypothesis, liming the tidal lands was also found to increase available K in soils both by surface application and by incorporating within 20cm top soils (Wijanarko & Taufiq, 2016). Another important macronutrient for plant growth, S, was also found to become more available in the form of SO_4^{2-} due to liming (Bolan et al., 2003). However, a contradictory assessment was conducted by Magdoff & Bartlett (1980). On their experiment, soil K content was found to be decreased with liming operations. Potassium concentration in soil solutions was also found to decrease in a liming experiment both in laboratory and field conditions as per Curtin & Smillie (1986). Potassium ions in greater quantity can restrict magnesium and calcium uptake by plants through precipitation (Resh, 2004).

In case of Na, it is prominently observed that the amount of soil available Na was decreased than the initial content in all four cases of liming. The Na content was decreased promptly for CaO lime, whereas pH was increased markedly for the same lime. The more the liming effect detected, the less the Na content determined. That means, the lime which possesses greater effect on increasing soil pH, affects Na availability adversely. Unpredictably, Na content was found to show little increase due to the application of MgCO_3 as lime, although the increase is statistically not significant (P value 0.973). The decrease in the Na content due to liming is presented below in figure-3:

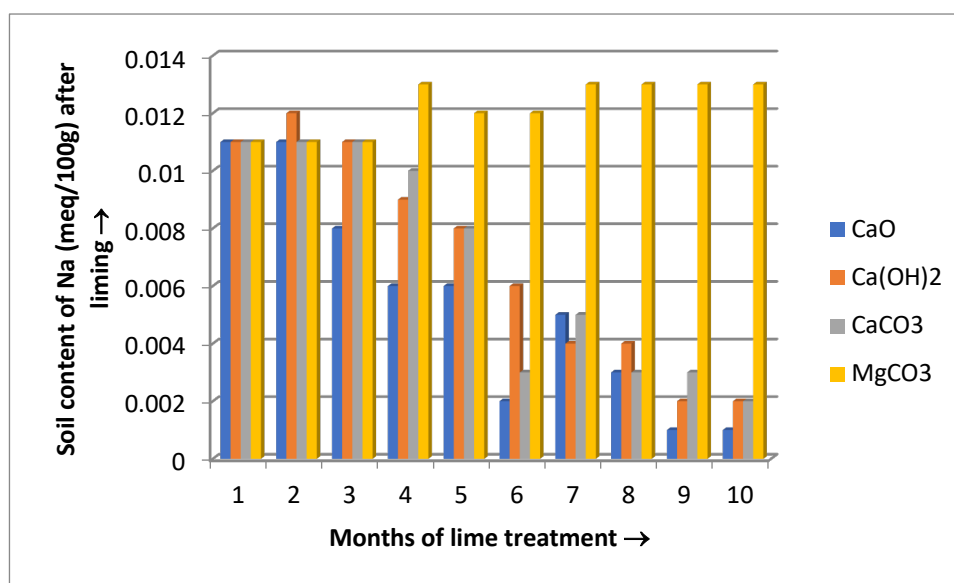


Figure-3: Changes in the content of soil Na after liming with different liming materials or 10 months

Liming compounds increase soil pH making soils more alkaline and less acidic which inhibit Na release and availability in soils. Incorporation of calcium in soils replaces the sodium ions on clay particles, causing the sodium to leach away and restoring in the structure of the soil. As Mg^{2+} ions are comparatively less effective than Ca^{2+} ions in replacing H^+ ions from the acid soils, they show least or negative impact on the decrease in Na content in soils. Similarly, more Ca^{2+} and Mg^{2+} ions present in increased soil pH condition the availability of some other ions like phosphate (Viade et al., 2011), Zn, Ni (Hooda & Alloway, 1996), Mn, Pb, Al (Bolan et al., 2003) etc either by adsorption or precipitation or leaching loss from the soil profile. However, different combinations of sodium metasilicates and various limes were found to be very good stabilizers of soils (Ellis, 1963).

CONCLUSION

It is apparent from this experiment that among the above mentioned limes, CaO is found to be more competent in raising soil pH in a shorter period regardless of the cost and availability. On the other hand $MgCO_3$ performs feebly in reducing soil acidity. But it is mentionable that considering the buying cost and availability as well as the pH raising capability, $Ca(OH)_2$ is better recommended lime in Bangladesh.

The limes also cause some changes in the release of K and Na content of the soils. The availability of K was found to increase with liming whereas the content of Na was decreased except for $MgCO_3$. Longer periods of liming with different doses of each lime in field trials may bring a clearer pattern of K and Na release from the soils which will require more budget. Moreover, to make an overall inference on the impact of liming the availability of all the important soil nutrients such as N, P, K and S should be taken into account. Crop quality and crop disease status evaluation due to liming operations also require attention. Further research is needed to evaluate the exact efficacy of these limes considering the relative agronomic efficiency as well as relative economic efficiency.

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