SOUTH AMERICA

Liming Tropical Soils – A Management Challenge

By José Espinosa

Soils that are dominated by 2:1 clays (montmorillonite, vermiculite, illite) are usually found in temperate zones of the globe. However, they also occur in tropical and subtropical areas. These soils behave differently than the typical tropical red soils (Ultisols and Oxisols) which are dominated by kaolinite and by iron (Fe) and aluminum (Al) oxides and hydroxides. And they are not the same as soils developed from volcanic ash (Andisols) that are widely spread over the world. These important differences determine the approach used to evaluate lime requirements.

> Research in several South American countries has emphasized the importance of lowering exchangeable aluminum (Al) through liming. Objectives of lime applications for temperate and tropical or ash derived soils are quite different.

In soils dominated by 2:1 clays, the reduction in base saturation from loss of potassium (K), calcium (Ca), and magnesium (Mg) leads to increasing acidity. This increased acidity in turn leads to the subsequent breakdown of the clay material and to the release of structural Al, which occupies the exchange sites left by the lost bases. This is the reason why these soils can be easily limed to a pH of near 7.0, which is optimal for the production of many crops. During the liming process there is little change in cation exchange capacity (CEC)...soils of permanent charge.

Determining Lime Needs — Temperate Soils

Common methods for determining lime needs in soils dominated by permanent charge clays are based on buffered solutions. The most popular of these methods is the SMP method developed to determine lime needs in acid soils of the temperate zones of the U.S. The equilibrium pH value of a suspension made of soil – water - buffer solution is correlated with the amount of lime needed to increase soil pH to a certain value, using a $CaCO_3$ incubation procedure, in the same soil sample. In this way, recommendations can be developed to indicate the amount of time required to bring soil pH to a particular value. **Table 1** presents an example of liming recommendations based on calibration of a SMP buffer solution.

Liming Tropical and Ash Soils

However, the approach for liming tropical red soils and soils derived from volcanic ash is quite different. In Ultisols and Oxisols, Al and Fe are present in mineral clays that are stable at pH values as low as 5.0. In this case, Al is buried in the clay particle. It is not a threat to plant growth until soil pH reaches a value where the oxides and kaolinite dissolve, bringing Al...sometimes in toxic quantities...into the soil solution. When this situation arises it is advisable to raise soil pH to about 5.5. This will allow Al precipitation and appreciable increase in CEC (soils of variable charge), **Table 2.** In this pH range, crop growth and yield

TABLE 1. Liming rates determined using SMP buffer solutions.

SMP Index[1]	5.5	6.0	6.5
	Desired pH after liming		
	Lime rate, t/ha		
4.4	15.0	21.0	29.0
4.6	10.9	15.1	20.0
4.8	8.5	11.9	15.7
5.0	6.9	9.7	12.9
5.2	5.5	8.0	10.6
5.4	4.4	6.5	8.7
5.6	3.3	5.1	7.0
5.8	2.3	3.9	5.5
6.0	1.4	2.8	4.1
6.2	0.6	1.7	2.7
6.4	0.0	0.0	1.5

[1]pH of the suspension soil–water–buffer solution.

are excellent, **Table 3.**

In tropical soils, the determination of lime requirements using buffered solutions does not work adequately. Using this approach, large amounts of lime are recommended to force soil pH to values in the 6.0 to 7.0 range. However, only a moderate amount of lime is needed to raise soil pH to values high enough to precipitate Al in the top layer in this type of soil (around pH 5.5). A better approach to develop liming recommendations is to take into account the amount of exchangeable Al present in the topsoil. Following this concept, lime requirements for most tropical soils can be predicted applying the following equation:

$$CaCO_3 \text{ (t/ha)} = \text{Factor x cmol Al/kg soil}$$

The factor used can vary from 1.5 to 3.0 depending on the crop characteristics and the soil type and can be fine tuned by the agronomist or farmer working at any specific site.

The primary goal of this approach is to neutralize all Al, but there are Al-tolerant crops that can grow and yield satisfactorily at moderate to high Al saturation of the exchange complex. Since not all Al needs to be precipitated, a lower amount of lime can be used...to reduce Al saturation to the desired level. In most of these cases, the lime applied is used to overcome Ca and Mg deficiencies which can be limiting to plant growth in weathered soils of low CEC. Coffee, banana, oil palm, pineapple, and a number of tropical grasses and legumes are among the crops that tolerate high Al saturation.

Plant breeding has developed cultivars of certain crops that are also tolerant of high soil Al saturation. Examples are Orizyca sabana 6 (upland rice) and Sorghica real 60 (sorghum) developed for Oxisols from the eastern savannas of Colombia. Lime recommendations for Orizyca sabana 6 upland rice range from 250 to 500 kg/ha of dolomite, with the only purpose of providing Ca and Mg to the crop.

TABLE 2. Effect of lime application to a red Ultisol from Panama.

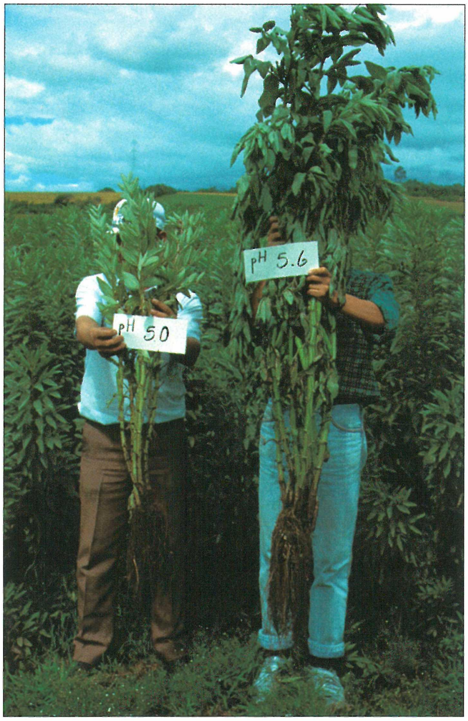
Treatment	pH	Ca	Mg	K	Al	Effective CEC
		cmol/kg				
No lime	4.9	1.79	1.11	0.11	2.15	5.18
Lime (4 t/ha)	5.8	7.90	6.73	0.14	0.09	14.85

Another common method used to calculate lime requirements, related to Al saturation, is based on soil base saturation. Though it has been determined that base saturation does not influence yield in soils dominated by 2:1 clays, this parameter is very important in highly weathered soil (Ultisols and Oxisols) of low CEC and low Ca and Mg content. As indicated above, lime is used not only as an amendment in these types of soils, but also as a source of Ca and Mg. Research has demonstrated that, within certain limits, higher base saturation in weathered soils improves fertility and increases crop yields.

A method for determining lime requirement was developed taking into account a targeted soil base saturation which is attained by lime application. Brazilian experience indicates, for example, that the best coffee yields are obtained at 60 percent saturation. In other words, coffee can grow satisfactorily in a soil with up to 40 percent Al saturation. According to these criteria, lime requirements can be calculated using the following equation:

$$CaCO_3\ (t/ha) = \frac{(BS_2 - BS_1) \times CEC}{100}$$

BS_1 = Initial base saturation
BS_2 = Required base saturation



THE EFFECT of soil pH on growth of faba bean plants is shown in this comparison on an Andisol in Ecuador.

The liming approach for soils derived from volcanic ash (Andisols) is somewhat different. The high buffering capacity (resistance to pH change) of Andisols complicates lime requirement evaluation. The intensity of the buffering capacity varies from one place to another according to altitude, rainfall and temperature, which are factors that control volcanic ash weathering. For this reason, there is no simple rule to evaluate lime requirement in these soils. The use of the exchangeable Al criterion, in certain cases, underestimates lime needed, as illustrated by the data presented in **Table 4.**

Clay particles resulting from volcanic ash weathering (allophane, imogolite, humus-Al complexes, etc.) have very

TABLE 3. Liming effects on soil pH and the yield of various crops in Oxisols from Brazil.

Corn			Wheat			Soybeans		
$CaCO_3$, t/ha	Soil pH	Yield, kg/ha	$CaCO_3$, t/ha	Soil pH	Yield, kg/ha	$CaCO_3$, t/ha	Soil pH	Yield, kg/ha
0	3.9	1,150	0	4.7	1,320	0	4.6	1,943
2	4.5	4,090	3.5	5.0	2,364	3.5	4.9	2,514
4	4.7	4,420	7.0	5.2	3,031			
6	5.3	5,340						

TABLE 4. Effect of lime application on soil chemical properties and crop yield in an Andisol of the highlands of Ecuador.

Lime, t/ha	Soil pH	Ca	Mg	K	Al	CEC	Faba beans	Barley	Oats
		cmol (+)/kg					Yield, t/ha		
0	4.9	2.54	0.36	0.30	2.1	6.0	13.9	2.2	3.6
3	5.2	3.30	0.39	0.29	1.6	6.6	17.1	2.9	4.3
6	5.3	4.69	0.40	0.28	0.6	7.2	19.2	3.9	4.7
12	5.4	5.59	0.40	0.30	0.2	8.4	21.6	4.1	4.8
15	5.8	8.60	0.42	0.29	0.1	10.4	21.0	4.3	4.7

reactive surfaces. When lime is applied to these soils it reacts with the clay surfaces, creating charge (increase in CEC) while failing to increase pH or to precipitate Al. The amount of lime needed to precipitate Al varies with the age and weathering of the volcanic ash. For this reason, it is necessary to conduct simple field trails which can indicate precisely the amount of lime needed at a specific site.

Regardless of the method used to determine lime requirement in tropical soils, it is advisable to avoid excessive lime applications. Usually this happens when such soils are limed to neutrality. Tropical soils should only be limed to neutralize exchangeable Al, which generally brings soil pH to values in the 5.5 to 6.0 range. Overliming leads to soil structure deterioration, reduced boron (B), zinc (Zn) and manganese (Mn) availability, and lower yields. BC

Dr. Espinosa is Director of INPOFOS, the PPI/PPIC program in northern Latin America. He is located in Quito, Ecuador.

Dr. R.L. Yadav Receives 1995 PPIC-FAI Award for Research

The 1995 award for best research on Management and Balanced Use of Inputs in Achieving Maximum Yield went to Dr. R.L. Yadav, Project Directorate for Cropping Systems Research, Modipuram, Uttar Pradesh, India. The award is presented annually by the PPIC-India Programme and The Fertiliser Association of India (FAI).

Dr. Yadav obtained his Ph.D. degree from GBPUA&T, Pantnagar and started his research career as Sr. Scientist at IISR, Lucknow, where he worked for about 18 years. He has 276 papers to his credit and nine awards, including the FAI Silver Jubilee Award in 1988. His main research interests are integrated use of chemical fertilizers and organic manures, particularly recycling of organic farm wastes. BC