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RESEARCH ARTICLE

EVALUATION OF METHODS FOR SOIL LIMING REQUIREMENT TO SUGAR CANE REGION OF PARAIBA STATE

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ABSTRACT

Considering soil acidity importance under Paraiba State conditions and the existence of several liming requirement evaluation methods, this laboratory experiment was carried out to compare different liming methods for the sugar cane region soils of Paraiba State. Thus, one experiment involving Ultisol and Entisol soils incubation was conducted in laboratory, during 42 days. The treatments consisted of five increasing doses of calcium carbonate corresponding to the quantities necessary to increase the saturation of soil. The amount of calcium carbonate to achieve the treatments was calculated based on 100% of relative power of total neutralization (RPTN). After stabilizing the pH samples were collected and subsequently analyzed pH, calcium (Ca), hydrogen (H) and aluminum (Al). It was determined the liming requirement by the method of aluminum, by method using calcium and magnesium, by the base saturation method to increase saturation of 60% according to sugar cane culture and by method related to amount of limestone to reach pH 6.0 and pH 6.5. For ease of liming recommendation, methods of base saturation and neutralization of aluminum levels were the most suitable for the soils of sugar cane region of Paraiba State.

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INTRODUCTION

The soil may be naturally acid by reason of the poverty of bases of the source material or by forming processes which promote the removal of basic elements such as potassium, calcium, magnesium and sodium, in the use of most chemical fertilizers. Excessive acidity directly affects the availability of elements essential to plant, reducing the activity of microorganisms and the solubility of elements that may be toxic to the plant (Meurer, 2007). Among the soil environmental factors related to fertility and agricultural production, the acidity is what most affects productivity, especially in tropical regions. So it is important that soil acidity correction is made by liming which raises the pH; provides nutrients such as calcium and magnesium; reduces or eliminates toxic effects of aluminum, manganese and iron; reduces the "fixation" of phosphorus; increases the availability of nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron and molybdenum into the soil; increases fertilizer efficiency; improves the physical properties of the soil, such as aeration and circulation water; increasing amounts of base saturation and the sum of exchangeable cations or the capacity to exchange cations. The need for liming, ie, the amount of lime to neutralize the acidity of the soil, can be estimated by methods such as, for example, aluminum neutralization and / or elevated levels of calcium and magnesium method, the method of base saturation, the liming method to achieve a certain pH of the soil and the soil incubation with $CaCO_3$ method (Campanharo *et al.*, 2007). Incubating soils with $CaCO_3$, resulting in the neutralization curve, it is the standard method for determining the need for liming, and serves for calibration of other methods, ensuring more efficiency and accuracy in the amount of lime to be applied (Melem JR *et al*, 2008). The first and simplest method to obtain the need for liming is one based on aluminum neutralization, since this element is considered a major component related to the acidity of soil and is obtained by chemical analysis of the soil. Whereas the acidic soils have low levels of calcium and magnesium, aluminum method has been improved and calculated together with the elevation of calcium and magnesium (Bastos, 1999). Another method is to use the base saturation which is regarded as the most usual and recommended until now, because it increases the elevation of base saturation (V%) at predetermined values as the crop to be

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installed (Raij *et al*., 1983), for example, 60% for sugar cane (Oliveira *et al*., 2007). The determination of the amount of lime applied to soil to achieve the appropriate pH for a given culture, it is quick and easy, if known soil neutralization curve.
The sugar cane is a crop of great social, economic and energy to Brazil, occupying an estimated area of 8,091 million hectares in the 2010/2011 season, where 14.3% of the entire crop is in North / Northeast (Conab, 2010). The sugarcane area of Paraiba State occurs in soils with low fertility and the presence of exchangeable aluminum, preventing a good crop development if the acidity of the soil is not corrected. The liming, in this case, provides gains in agricultural crop yield of sugar cane, when the pH reaches values between 5.5 to 6.5 (Malavolta, 1989) and due to the supply of calcium and magnesium, aluminum neutralization and increasing the availability of other nutrients (Rossetto *et al*., 2004). Despite the different methods used to calculate the need for liming, there is no consensus on which is the most appropriate method for the state of Paraiba. So it is important to study and select methods in this region that can determine more accurately the amount of limestone required for these soil acidity correction.
This study aimed to compare different liming methods for the sugar cane region soils of Paraiba State.

MATERIALS AND METHODS

The experiment was carried in Irrigation and Salinity Laboratory of the Department of Agricultural Engineering, UFCG, from November to December 2015, using the incubation method in pots for 42 days. To evaluate the behavior of calcium carbonate on the rise in saturation land bases, and thus neutralize the acidity of the soil, samples of Ultisol and Entisol, were collected in the municipalities Santa Rita (Japungu Farm situated at 07°04'51''S and 34°54'05''O) and Mamanguape (Experimental Station of Camaratuba situated at 06°33' 36''S and 35°08'07''O), respectively, in State of Paraiba, Brazil, whose chemical characteristics according to the methodology of Embrapa (1997) are in Table 1. These soils are being used for sugarcane cultivation.

Table 1. Chemical characterization of soil samples used for the tests

Attributes Chemical	Ultisol	Entisol
Calcium ($cmol_c\ kg^{-1}$)	1.78	0.42
Magnesium ($cmol_c\ kg^{-1}$)	0.74	0.31
Sodium ($cmol_c\ kg^{-1}$)	0.06	0.02
Potassium ($cmol_c\ kg^{-1}$)	0.04	0.02
Sum of bases ($cmol_c\ kg^{-1}$)	2.57	0.77
Hydrogen ($cmol_c\ kg^{-1}$)	1.74	0.75
Aluminum ($cmol_c\ kg^{-1}$)	0.20	0.20
CEC ($cmol_c\ kg^{-1}$)	4.51	1.72
Organic matter ($g\ kg^{-1}$)	16.40	3.10
Comparable phosphorus ($mg\ kg^{-1}$)	15.80	24.30
pH H_2O (1:2.5)	5.39	5.02
V%	56.98	44.77

Treatments for Ultisol and Entisol consisted of five increasing doses of calcium carbonate corresponding to the quantities necessary to increase the saturation of soil according to Table 2, with three replicates. The amount of calcium carbonate to achieve the treatments was calculated based on 100% of relative power of total neutralization (RPTN).

Table 2. Quantity of calcium carbonate ($CaCO_3$) used to achieve different soil base saturation percentages

Ultisol		Entisol	
Base saturation percentages (%)	$CaCO_3$ used (g) to kg of soil	Base saturation percentages (%)	$CaCO_3$ used (g) to kg of soil
56	0	45	0
66	0,15	55	0,057
76	0,30	65	0,115
86	0,45	75	0,172
96	0,60	85	0,229

Incubation experiments were conducted to evaluate the effects of calcium carbonate in increasing base saturation of soil. Thousand grams samples of the study soils were placed in plastic pots (experimental units) and then mixed with calcium carbonate according to the treatments (Table 2). Soil and calcium carbonate were mixed thoroughly, and then wetted with deionized water to approximately 80% water content (i.e., the field water capacity of the soil). The incubated pots were placed in a room at 28 °C and weighed every 7 d to maintain constant moisture content. After stabilizing the pH (42 days) samples were collected and allowed to air dry and were subsequently analyzed calcium (Ca), hydrogen (H) and aluminum (Al) according to the methodology of Embrapa (1997). The evaluation of the pH was performed using 10g of soil from each experimental unit with 25 mL of water.
It was determined the need for liming of the method by aluminum (Morh, 1960; Cate, 1965) ($Al^{3+} \times 1.5 = t\ ha^{-1}$ of $CaCO_3$), of the method using calcium and magnesium ($2.0 - cmol_c\ Ca^{2+} + Mg^{2+}\ kg^{-1} = t\ ha^{-1}$ of $CaCO_3$ or $3.0 - cmol_c\ Ca^{2+} + Mg^{2+}\ kg^{-1} = t\ ha^{-1}$ of $CaCO_3$ in areas with irrigated crops), the base saturation method to increase saturation of 60% according to sugar cane culture (Quaggio, 1983) and method related to amount of limestone to reach pH 6.0 and pH 6.5 (optimal pH to sugar cane culture) (Marin, 2016).

RESULTS AND DISCUSSION

The incubation of soil samples with calcium carbonate, increased pH, neutralizing the acidity of the soil according to Frade Junior *et al*. (2013). The highest amount of calcium carbonate corresponding to 96% and 85% saturation bases in Ultisol and Entisol soils, has reached the pH around 6 to 7 (Figure 1). According to the chemical and physical characteristics of soils, the liming requirement varied according to the methods used (Table 3).

Table 3. Recommendation of limestone for Ultisol and Entisol soils as a function of different methods

Method	Need for limestone, $t\ ha^{-1}$	
	Ultisol	Entisol
Aluminum exchangeable	0.30	0.30
$2.0 - Ca^{2+} + Mg^{2+}$	0.0	1.27
$3.0 - Ca^{2+} + Mg^{2+}$	0.48	2.27
Base saturation (60%)	0.14	0.26
Lime to reach pH 6.0	0.73	0.25
Lime to reach pH 6.5	1.46	0.60

In the two studied soils it is necessary to apply limestone to eliminate or reduce the exchangeable aluminum to levels not toxic to plants. However, according to the neutralization equation (Figure 1), the amount of limestone 0.3 t ha^{-1} would reach pH 5.6 in Ultisol, ie, a value less than optimal pH (6.0 to 6.5) for sugar cane culture.

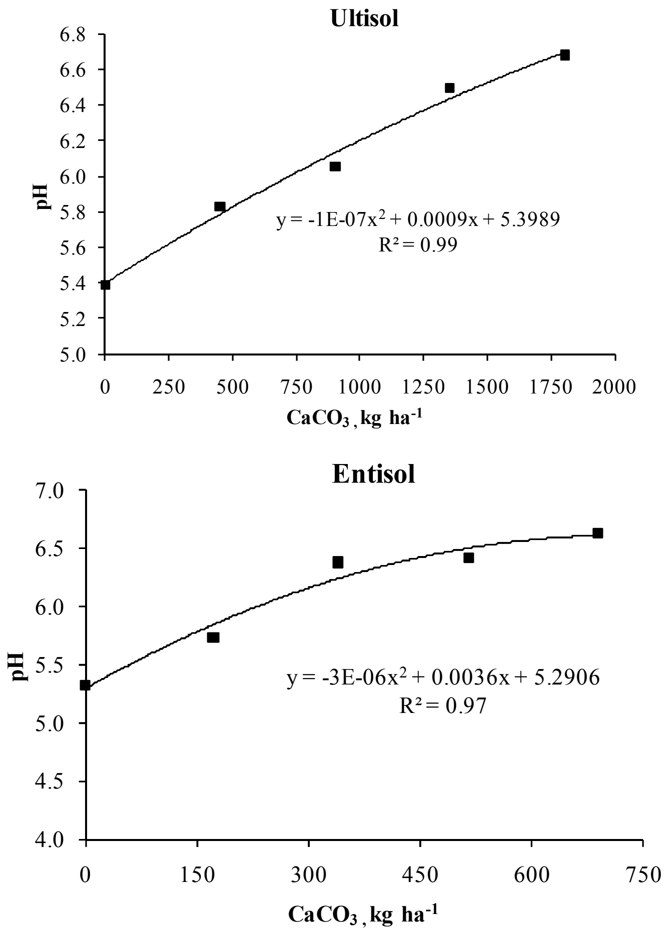

Figure 1. Neutralizing curves of Ultisol and Entisol

According to the method of calcium + magnesium to crops without irrigation in Ultisol soil not need liming, however, with irrigation, it is necessary to apply 0.48 t ha^{-1} of calcareous in soil to neutralize the acidity. Similarly, this amount of limestone, which reached pH 5.8, according Figure 1, do not reach the ideal pH. To reach the maximum limit of saturation of bases for the culture of sugar cane, or 60%, the liming requirement in Ultisol soil (0.14 t ha^{-1}) was lower than the amounts by previous methods despite the soil having reached pH 5.5. To achieve the optimal values of soil pH, 6.0 to 6.5, for the sugar cane culture, it was necessary to apply in Ultisol much larger amounts of calcareous than those determined by other methods, according to Table 3. However, the recommendation of this first method was half of the amount to reach pH 6.5. In theory, this method would be best for the liming requirement of this soil. With exception of the methods of liming to achieve pH 6.0 and pH 6.5, the liming requirement by other methods, despite being different, reached similar pH values. To reduce the exchangeable aluminum of Entisol is necessary 0.3 t ha^{-1}; in the two conditions, without and with irrigation, also, it is necessary to apply calcareous, ie, 1.27 and 2.25 t ha^{-1}, respectively. To achieve 60% of base saturation, it is necessary to apply 0.26 t ha^{-1} of limestone, similar to the amount necessary to reach pH 6, ie, 0.25 t ha^{-1}. This was the lowest recommendation liming for Entisol soil. Apparently, this soil, as the formation of this soil, the content of organic matter and its texture, has a low buffering capacity, so with the application of low amounts of limestone reduced the exchangeable aluminum, reached 60% of base saturation and pH 6.0. If applied greater amounts of limestone, presented in Table 3, not reach the ideal pH and would overestimate the base saturation. Analyzing the data in Table 3, it is observed that all the methods to Entisol soil, with exception of those calculating calcium + magnesium, have been adequate to correct soil acidity. Economically, method of limestone for achieving pH 6.0 was the best, since it requires less amount of limestone for the best answer, reaching pH 6 and 60% saturation bases. For both soils, liming method to reach pH 6 or 6.5, was apparently better and / or more economical, however, this method is impracticable in routine work of a laboratory, since it is necessary to know in advance the soil neutralization curve. Therefore, for ease of work, the liming requirement to soils of occurrence in the sugar cane region of the Paraiba State can be estimated by methods of exchangeable aluminum and/or 60% saturation bases, faster and simple in determination. Chemical changes after incubation of soils afforded increases in calcium and decrease of exchangeable aluminum Al as a function of their treatment, as shown in Table 4 and according to Santos (2010). The calcium from calcium carbonate applied to the soil, displaces the hydrogen and the aluminum of surface colloid to solution soil in which the aluminum is precipitated and hydrogen, after various reactions, form water.

Table 4. Calcium, hydrogen and aluminum values after incubation of soils according treatments

Treatments	Attributes Chemical		
$CaCO_3$ g to kg of soil	Calcium $cmol_c\ kg^{-1}$	Hydrogen	Aluminum
	Ultisol		
0	1.78	1.74	0.20
0.15	1.75	1.50	0.10
0.30	2.29	1.35	0.10
0.45	2.26	1.28	0.00
0.60	3.05	1.20	0.00
	Entisol		
0	0.42	0.75	0.20
0.057	0.44	0.48	0.10
0.115	1.09	0.32	0.10
0.172	1.03	0.28	0.00
0.229	0.91	0.26	0.00

Conclusion

For ease of liming recommendation, methods of base saturation and neutralization of aluminum levels were the most suitable for the soils of sugar cane region of Paraiba State.

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