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SOIL SCIENCE

Effectiveness of a rapid soil incubation method for determining potential acidity of soils in Rio Grande do Sul, Brazil

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ABSTRACT: *Potential soil acidity can be measured by two methods in the states of Rio Grande do Sul (RS) and Santa Catarina (SC): solution SMP or solution TSM (Buffer Santa Maria). Calibration of these methods is done by incubating soils for long periods (180 days) of $CaCO_3$. The hypothesis of this study is that it is possible to reduce the incubation period in soils by using a soluble base such as calcium hydroxide. The study aimed to estimate potential acidity in a group of soils by moist incubation with $Ca(OH)_2$ (short) as an alternative to the typical method with $CaCO_3$ (long) and relate to the values estimated by the equation used by the Soil Chemistry and Fertility Commission of Rio Grande do Sul and Santa Catarina (CQFS-RS/SC; 2016). Ten soils with sandy texture and low organic matter content were collected at 0-20cm in the Campanha Gaúcha region of the state of RS and incubated for 180 days with doses of $CaCO_3$ equivalent to 0, 25, 50, 75, 100, 125 and 150% of the lime requirement estimated by the solution TSM to raise to pH 6.0. Soils were also incubated for 4 days in an oven at 35ºC with 0.22mol L^{-1} $Ca(OH)_2$ at doses equivalent to $CaCO_3$. Short incubation of the soil with $Ca(OH)_2$ may substitute long incubation with $CaCO_3$. Also, estimating potential acidity using the equation of the CQFS-RS/SC (2016) overestimated potential acidity in soils with solution TSM pH values lower than 6.0 in this study.*
Key words: *sandy soils, lime dose, short incubation, long incubation.*

Eficácia de um método rápido de incubação de solo na determinação da acidez potencial em solos no Rio Grande do Sul, Brasil

RESUMO: *A acidez potencial do solo pode ser medida por dois métodos nos estados do Rio Grande do Sul (RS) e Santa Catarina (SC): índice SMP ou solução TSM (Tampão Santa Maria). A calibração destes métodos é feita pela incubação de solos por longos períodos (180 dias) com quantidades crescentes de $CaCO_3$. A hipótese deste estudo é que é possível reduzir o período de incubação em solos usando uma base solúvel como o hidróxido de cálcio. O trabalho objetivou estimar a acidez potencial em um grupo de solos por meio de incubação úmida com $Ca(OH)_2$ (curta) como alternativa ao método típico com $CaCO_3$ (longa) e relacionar com os valores estimados pela equação utilizada pela CQFS-RS/SC (2016). Dez solos com textura arenosa e baixo conteúdo de matéria orgânica foram coletados a 0-20cm na região da Campanha Gaúcha e incubados por 180 dias com doses de CaCO3 equivalentes a 0, 25, 50, 75, 100, 125 e 150% da exigência de calcário estimada pela solução TSM para elevar o pH a 6,0 (longa). Os solos foram também incubados por 4 dias em estufa a 35ºC com 0,22mol L^{-1} de $Ca(OH)_2$ em doses equivalentes ao $CaCO_3$ (curta). A incubação curta do solo com Ca(OH)2 pode substituir a incubação longa com $CaCO_3$. Além disso, a estimativa da acidez potencial utilizando a equação do CQFS-RS/SC (2016) superestimou a acidez potencial de solos com valores de pH em solução TSM inferiores a 6,0 neste estudo.*
Palavras-chave: *solos arenosos, dose de calcário, incubação curta, incubação longa.*

The solution TSM has been used to replace of the SMP solution in the states of Rio Grande do Sul (RS) and Santa Catarina (SC), because it produces similar results and does not generate wastes, which reduces the potential for contaminating laboratory workers and the environment pollution (TOLEDO et al., 2012; GAMA et al., 2013; GIULIANI, 2015). However, both methods need calibration, which uses the real potential acidity of the soil as a reference, obtained by incubating the soil with lime. Heterogeneous sets of soils are typically used in these calibrations, so that the equations represent the soil diversity of the region in which the method is used. Moreover, the calibration of the SMP solution usually requires an incubation period with lime doses up to 180 days (KAMINSKI et al., 2002), and this period may be longer in certain soils (GIULIANI, 2015). Therefore, there is a need for an alternative, and more rapid method to calibrate solution TSM, with results similar to those obtained by incubation with $CaCO_3$. LIU et al. (2004; 2005) propose a method of soil incubation with $Ca(OH)_2$ for 86 hours, which is longer than that

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proposed by THOMPSON et al. (2010) of 48 hours. However, $Ca(OH)_2$ concentration should not exceed 0.025mol L^{-1}, which is enough to neutralize acidity up to 9cmol$_c$ dm^{-3}. For this reason, the addition of solid $Ca(OH)_2$ to supplement the base requirement for soils with potential acidity values greater than 9cmolc dm^{-3} should be tested. Thus, the aim of this study was to estimate potential acidity (H+Al) in a set of soils by moist incubation with $Ca(OH)_2$ (short incubation) as an alternative to the traditional method with $CaCO_3$ (long incubation) and relate to the estimated values of H+Al and lime requirement obtained by the equation proposed by the CQFS-RS/SC (2016).

Soil samples were collected at 0-20cm of 10 soils in natural grassland areas of the Campanha Gaúcha region of RS (Table 1). Soils were air-dried, ground, passed through a 2mm mesh sieve and a portion of the soil was physically and chemically characterized according to the methodology described in TEDESCO et al. (1995) (Table 1). Portions of 1.0kg of soil were placed in 2L polyethylene containers and incubated with $CaCO_3$ at an average temperature of 26°C and relative humidity of 80%. Doses consisted of 25, 50, 75, 100, 125 and 150% of the lime requirement estimated by the SMP solution to raise pH to 6.0, according to the equation proposed by TOLEDO et al. (2012). The experimental design was completely randomized with 4 replicates. Soils were kept at 60% field capacity and every two days the containers were weighed and water was replenished when necessary (GIULIANI, 2015). The soil pH was measured every 30 days. At 180 days of incubation, the soil was air-dried, ground, passed through a 2mm mesh sieve and reserved.

For short incubation, 40g portions of the 10 soils were weighed and placed into 150mL Beckers. Then, 80mL of 0.022mol L^{-1} calcium hydroxide solution $Ca(OH)_2$ was added. In order to prepare the saturated solution of $Ca(OH)_2$, 15g of the solid reactant with a purity of 99% was weighed and added into a 5L Becker. Afterwards, 4.5L of distilled water was added. Soon after, the solution was stirred on magnetic stirrer (Model Te-0851, Tecnal, Brazil) for two days. The solution was then left to stand for three days. Afterwards, the supernatant was transferred to another 5L container and standardized to reach 0.022mol L^{-1} (LIU et al., 2005). Once samples were placed into the containers, a solution of 0.022mol L^{-1} $Ca(OH)_2$ was added to the replicates, according to the value of H+Al, up to a potential acidity limit of 8 cmol$_c$ dm^{-3}. In soils with H+Al greater than 8 cmol$_c$ dm^{-3}, solid $Ca(OH)_2$ was added in amounts corresponding to the potential acidity estimated by solution TSM to raise pH to 6.0, as proposed by LIU et al.(2005). The doses were equivalent to 25, 50, 75, 100, 125 and 150% of the lime requirement estimated by SMP solution to raise pH to 7.0, according to the equation proposed by TOLEDO et al. (2012). The experimental design was completely randomized with 4 replicates. In each replicate, 1mL of chloroform was added to inhibit soil biological activity, not interfering in the correction of the pH. Shortly thereafter, the containers were covered with plastic film to reduce evaporation. Containers of soil were placed in an oven with forced air circulation at a temperature of 35°C. The pH of the solution was measured at 0, 24, 48, 72 and 96 hours.

The values of H+Al obtained in short incubation and by the equation of the CQFS-RS/SC (H+Al=e(10.665- (1.1483*TSM)/10) were correlated with the potential acidity obtained by the long

Table 1 - Geographic coordinates and physical and chemical characteristics of 10 soils collected in the Campanha Gaúcha region of the state of Rio Grande do Sul (RS).

Soil	Coordinates		OM	Clay	Sand	Silt	pH in H_2O	pH in TSM	P	K	Ca	Mg	Al	H+Al
	Latitude	Longitude	%	-------g kg^{-1} ------			1:1 ratio	1:1.5 ratio	--mg dm^{-3}--		-------cmol$_c$ dm^{-3}-------			
1	30°9'2.92"S	55°13'20.85"W	1.5	207	736	57	4.7	5.48	2.8	96	1.6	0.8	0.7	7.9
2	30°10'16.52"S	56°12'21.02"W	1.2	157	757	86	4.3	5.32	9.7	52	1.8	0.4	0.9	9.4
3	30°10.2'16"S	55°12'16.73"W	1.2	204	731	66	4.6	5.44	16.2	80	3	0.7	0.5	8.2
4	30°6'56.88"S	54°43'18.04"W	1.2	207	684	109	4.7	5.42	3.1	44	1.3	0.6	1.3	8.4
5	30°5'36.48"S	54°42'39.95"W	1.3	73	817	109	4.4	5.14	4.8	44	1.1	0.4	1.6	11.7
6	30°15'16.93"S	54°58'32.87"W	1.4	363	526	111	4.4	4.66	3.4	116	2.1	0.9	2.0	20.3
7	30°15'32.04"S	54°58'35.21"W	0.9	58	885	58	5.1	6.11	4.4	32	0.9	0.4	0.2	3.8
8	30°15'23.18"S	54°58'41.99"W	1.3	84	852	64	4.9	5.77	6.2	56	1.6	0.5	0.6	5.7
9	30°47'25."3S	55°22'05.6"W	0.8	64	878	58	5.4	6.20	2.7	40	1	0.3	0.1	3.5
10	30°48'41.6"S	55°26'17.0"W	1.2	88	837	74	5.1	5.99	3.2	100	1.2	0.5	0.2	4.4

OM= Organic matter.

incubation of soils with $CaCO_3$. We correlated the values of solution TSM pH and H+Al to the respective reference pH through regression analysis to obtain the mathematical model to estimate potential acidity or lime requirement to best fit the data. Results were compared statistically using confidence intervals (95%) for the equation coefficients. To adjust the relationship between the potential acidity of the soil and the solution TSM pH values, H+Al values were used at pH 6.0; 6.5 and 7.0 for samples with $CaCO_3$ and $Ca(OH)_2$.

Organic matter contents ranged from 8.0 to 15.0g kg^{-1} in the 10 soils (Table 1). Clay values ranged from 58 to 363g kg^{-1}. The pH values in water ranged from 4.3 to 5.4; in TSM from 4.6 to 6.2; and real H+Al at pH 7.0 from 3.5 to 20.3cmolc kg^{-1}, which shows a considerable variation in soil potential acidity.

The values of H+Al estimated by the equation proposed by the CQFS-RS/SC (2016) were overestimated in relation to short incubation with $Ca(OH)_2$ and long incubation with $CaCO_3$ in any buffer range evaluated in this study (Figure 1A). The estimated H+Al values obtained by the equations of short incubation ($H+Al=908.83e^{-0.983TSM}$) and long incubation ($H+Al=454.85e^{-0.816TSM}$) were lower than the values obtained by the equation proposed by the CQFS-RS/SC(2016) ($H+Al=4283e^{-1.14TSM}$) at solution TSM pH values lower than 6.0 (Figure 1B). This is because the equation proposed by the CQFS-RS/SC (2016) was obtained by incubating a greater diversity of soil types, with a significant presence of soils with higher organic matter and clay contents (FOX, 1980; SSALI & NUWAMANYA, 1982; KAMINSKI et al., 2002).

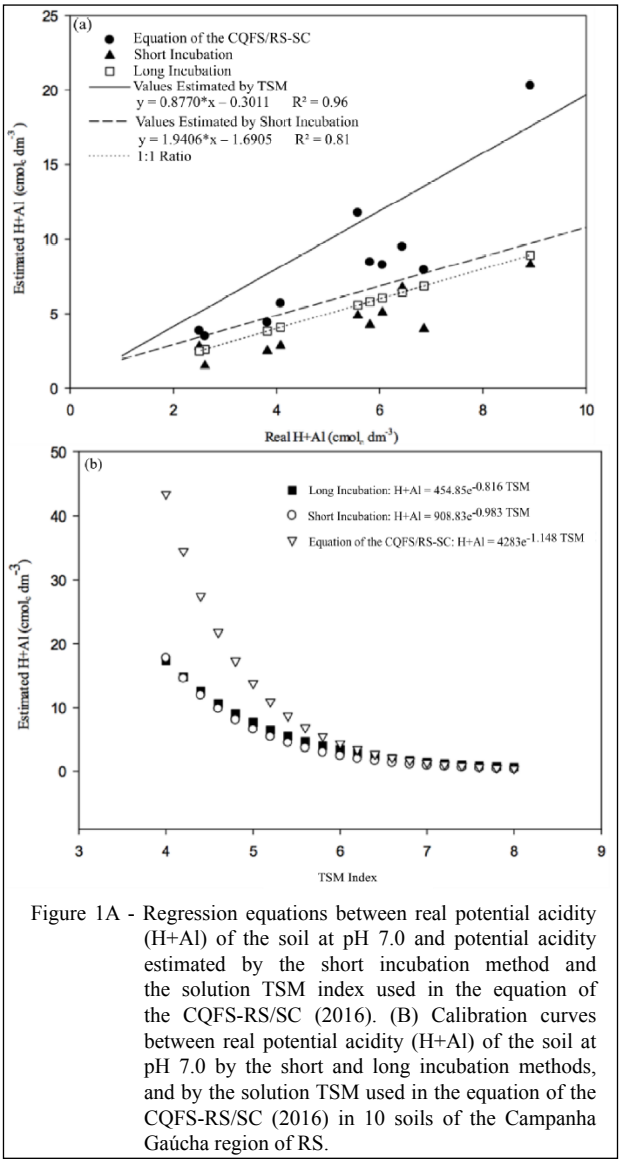

Figure 1A - Regression equations between real potential acidity (H+Al) of the soil at pH 7.0 and potential acidity estimated by the short incubation method and the solution TSM index used in the equation of the CQFS-RS/SC (2016). (B) Calibration curves between real potential acidity (H+Al) of the soil at pH 7.0 by the short and long incubation methods, and by the solution TSM used in the equation of the CQFS-RS/SC (2016) in 10 soils of the Campanha Gaúcha region of RS.

Conversely, the long and short incubation equations were similar to each other over a wide range of solution TSM pH. This showed that incubation by both methods was equally efficient in correcting acidity, which corroborates with the results obtained by GIULIANI (2015). It should be noted that the values of H+Al estimated by the long and short incubation equations at solution TSM pH values <6.0 were the same, even with the addition of solid $Ca(OH)_2$ to complete the need to neutralize potential acidity (LIU et al., 2004; LIU et al., 2005), but with an incubation period of more than 48 hours, as advised by THOMPSON et al. (2010). These results are important as they differ from what was obtained by THOMPSON et al. (2010), who emphasized that soils submitted to long incubation overestimate the values of H+Al in comparison to short incubation.

Conversely, at solution TSM pH higher than 6.0, the values of H+Al estimated by the long and short incubation equations and obtained by the equation proposed by the CQFS-RS/SC (2016) were similar (Figure 1B). This is most likely due to the fact that soils with low potential acidity have low buffering, since they are typically soils with low organic matter and clay contents. For this reason, the estimation methods for these soils tend to be similar (LANA et al., 2013). Figure 1B clearly shows that for soils with a solution TSM pH lower than 6.0, the equations obtained by long or short incubation can be used to estimate H+Al and; consequently, the lime dose. Lime doses estimated by short and long incubation below solution TSM pH 6.0 were lower than those estimated by the equation of the CQFS-RS/SC (2016) to raise the pH in water to 6.0 and 6.5 (Table 2). Conversely, at solution TSM

Table 2 - Estimation of the lime requirement to raise soil pH to 6.0 and 6.5 by long incubation, short incubation and by the solution TSM used in the equation of the CQFS-RS/SC (2016) in 10 soils of the Campanha Gaúcha region of RS.

TSM	Long Incubation		Short Incubation		Equation of the CQFS	
	6.0	6.5	6.0	6.5	6.0	6.5
	$NL=87.051e^{-0.61}$ TSM	$NL=454.85e^{-0.816}$ TSM	$NL=813.3e^{-1.42}$ TSM	$NL=903.98e^{-0.983}$ TSM	$NL=7692e^{-1.326}$ TSM	$NL=4283e^{-1.148}$ TSM
	t/ha[(1)]					
4.4	5.9	12.5	8.3	12.0	22.5	27.4
4.5	5.6	11.6	7.5	10.8	19.7	24.4
4.6	5.3	10.7	6.7	9.8	17.3	21.8
4.7	5.0	9.8	6.1	8.9	15.1	19.4
4.8	4.7	9.1	5.5	8.1	13.2	17.3
4.9	4.4	8.3	4.9	7.3	11.6	15.4
5.0	4.1	7.7	4.4	6.6	10.2	13.8
5.1	3.9	7.1	4.0	6.0	8.9	12.3
5.2	3.6	6.5	3.6	5.4	7.8	10.9
5.3	3.4	6.0	3.2	4.9	6.8	9.8
5.4	3.2	5.5	2.9	4.5	6.0	8.7
5.5	3.0	5.1	2.6	4.1	5.2	7.8
5.6	2.9	4.7	2.4	3.7	4.6	6.9
5.7	2.7	4.3	2.1	3.3	4.0	6.2
5.8	2.5	4.0	1.9	3.0	3.5	5.5
5.9	2.4	3.7	1.7	2.7	3.1	4.9
6.0	2.2	3.4	1.6	2.5	2.7	4.4
6.1	2.1	3.1	1.4	2.2	2.4	3.9
6.2	2.0	2.9	1.3	2.0	2.1	3.5
6.3	1.9	2.7	1.1	1.8	1.8	3.1
6.4	1.8	2.5	1.0	1.7	1.6	2.8
6.5	1.7	2.3	0.9	1.5	1.4	2.5
6.6	1.6	2.1	0.8	1.4	1.2	2.2
6.7	1.5	1.9	0.8	1.2	1.1	2.0
6.8	1.4	1.8	0.7	1.1	0.9	1.7
6.9	1.3	1.6	0.6	1.0	0.8	1.6
7.0	1.2	1.5	0.6	0.9	0.7	1.4

[(1)]Limestone with Relative Total Neutralization Power (RTNP 100%). NL=Need for limestone.

pH higher than 6.0, the lime doses estimated by the three methods were similar.

The results showed that short incubation of the soil with $Ca(OH)_2$ is a viable alternative to long incubation with $CaCO_3$ to estimate H+Al of soils with low organic matter and clay contents. Moreover, the estimation method of the equation proposed by the CQFS-RS/SC overestimated H+Al and the lime doses when solution TSM pH values were lower than 6.0 for the soils evaluated in this study.

DECLARATION OF CONFLICTING INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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AUTHORS' CONTRIBUTIONS

The graduation students Rodrigo Otávio Schneider Souza, Roque Junior Sartori Bellinaso, Rodrigo Krammes and Jacson Hindersmann were responsible for the collection of soil samples, incubations and laboratory analyzes. The postgraduate students Rogério Piccin and Lincon Stefanello were responsible for tabulation of the data, statistical analysis, confection of the figures, tables, and writing of the manuscript. Professors Gustavo Brunetto, João Kaminski, Carlos Alberto Ceretta and Luciano Colpo Gatiboni were responsible for planning the study, coordinating the activities, as well as writing and correcting the manuscript. All authors critically revised the manuscript and approved of the final version.

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