Acta Scientiarum 21(3):479-482, 1999.
ISSN 1415-6814.

Correction of an acid soil using the base saturation method and influence on chemical parameters

José Carlos Pintro* and Maicon Dieison Tescaro

Departamento de Agronomia, Universidade Estadual de Maringá, Av. Colombo, 5790, 87020-900, Maringá-Paraná, Brazil.
**Author for correspondence.*

ABSTRACT. The efficiency of base saturation (V%) method to correct an acid soil with high buffer chemical characteristic was studied under controlled conditions. Calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) were used as lime at ratio of 3:1. Theoretical calculations were made to increase the values of V% to 40%, 60%, 80% and 100%. With the increasing values of V% there was an exponential reduction of Al saturation values. On the other hand, the pH values in H_2O and in $CaCl_2$ increased. The rates of $CaCO_3$ and $MgCO_3$ were enough and efficient to elevate the values of V% up to 60%. Over this V% value the rates were not efficient.

Key words: acidity, allic, liming, correction, base saturation method, efficiency.

RESUMO. Correção de um solo ácido usando o método de saturação por bases e influência sobre os parâmetros químicos. A eficiência do método de saturação por bases (V%) na correção de um solo ácido com alto poder de tamponamento foi estudada sob condições controladas. Sais de carbonato de cálcio e carbonato de magnésio, p.a., foram usados como corretivos na relação 3:1. Os cálculos teóricos foram feitos no sentido de elevar os valores de V% para 40%, 60%, 80% e 100%. Com o aumento dos valores de V% houve uma redução exponencial dos valores de saturação de Al. Por outro lado, os valores de pH em H_2O e $CaCl_2$ aumentaram. As quantidades de $CaCO_3$ e $MgCO_3$ foram suficientes e eficientes para elevar os valores de V% até 60%. Acima destes valores de V% as quantidades não foram eficientes.

Palavras-chave: acidez, álico, corretivo, correção, método de saturação por bases, eficiência.

The soil acidity and the aluminum (Al) toxicity are the main factors that limit the expression of the productivity potential of the species cultivated in the tropical areas (Taylor, 1988) and Al is the most important metallic element of the soil mineral fraction (Lindsay, 1979). As the acidification process is intensified, the stability of Al minerals is reduced, the Al solubilization increases and it is released into the soil solution (Kinraide and Parker, 1989).

In the acidity situation, the nutrient availability to plants (Ca, Mg, K, P,...) in the soil is reduced and the concentration of the nutrients in the plants is usually low (Clark, 1977; Pavan and Bingham, 1982). The main Al toxic effect is manifested by the reduction of the root growth/development (Horst, 1987). As a consequence, the soil volume to be explored by the roots is reduced and the efficiency on the water and nutrients absorption processes is affected, mainly in periods without rain (Wright, 1989).

Approximately 61% of the soils of the state of Paraná in Brazil are acids and the aluminum saturation of the effective cation exchange capacity (ECEC) is higher than 50% (Embrapa, 1984). In this environment condition there is an agreement that the increase in productivity is achieved if the soil acidity is corrected by liming (Vitti, 1987).

There are different methods for calculating the lime requirement, as follows: (a) method of incubation, (b) method based on the potential acidity, (c) method based on the elevation of the concentration of $Ca^{2+}+Mg^{2+}$, (d) method of exchangeable Al, (e) method of SMP (Shoemaker, McLean, Pratt) buffer solution, and (f) method based on the increase of base saturation (V) of the cation exchange capacity (CEC) of the soil at pH 7 (Raij *et al.* 1983; Mello, 1985). In the state of Paraná, the method commonly used is the increase of V% (Emater, 1995).

Under field conditions and using commercial lime, the method of the V% was not efficient to correct the acidity of different soils in order to elevate the values of V% to desired levels (Raij *et al.*, 1983; Caires and Rosolem, 1993; Oliveira *et al.*, 1997, besides others). The objective of this study was to evaluate the efficiency of the V% method to correct the acidity of an acid soil with high buffer chemical characteristics using calcium carbonate and magnesium carbonate under controlled conditions.

Materials and methods

The soil, derived from volcanic rocks, was collected at the depth of 0-20cm in the municipality of Mangueirinha, southwestern region of the state of Paraná. The soil was dried at room temperature and sifted in a 2mm-mesh. After being homogenized, samples were collected for physic and chemical analyses (Embrapa, 1979). The concentration values of clay, loam and sand were of 580, 320 and 100gkg^{1-}, respectively. The results of the chemical analysis were: pH (H_2O 1:2.5) = 3.9; $CaCl_2$ 0.01 mol L^{1-} 1:2.5 = 3.7); [H^{+}+Al^{3+} = 18.15; Al^{3+} = 9.3; Ca^{2+}+Mg^{2+} = 0.94; Ca^{2+} = 0.56; K^{+} = 0.32; sum of bases (SB = Ca^{2+}+Mg^{2+}+K^{+}) was 1.27; cation exchange capacity (CEC = SB+H^{+}+Al^{3+}) was 19.83 (cmol$_c$dm^{-3})], base saturation of CEC (V = SB x100/CEC) was 6.0%, aluminum saturation (m = Al^{3+}x100/SB+Al^{3+}) was 88%; P was 4 mg dm^{-3} and organic carbon (OC) was 32.3 gdm^{-3}. The effective cation exchange capacity (ECEC) was calculated by: SB+Al^{3+}(Curi *et al.*, 1993) and the CEC of organic carbon (CECOC) was calculated as follows: %OCx4.5 (Camargo *et al.*, 1987).

Theoretical calculations were made to increase the values of V% from 6% to 40%, 60%, 80%, and 100%, considered the treatments. Calcium carbonate ($CaCO_3$) p.a. and magnesium carbonate ($MgCO_3$) p.a. were used as lime source at a ratio of 3:1 (Table 1).

Table 1. Quantities of calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) used per 50kg of soil to increase V% to different calculated values

V%	$CaCO_3$ (g)	$MgCO_3$ (g)	Total (g)	Total (t ha^{-1})
Control	0.000	0.000	0.000	0.0
40	124.929	34.980	159.909	6.4
60	199.290	55.801	255.093	10.2
80	273.654	76.623	350.277	14.0
100	348.016	97.445	445.461	17.8

In each treatment, after incorporation of the reagents, the soils were transferred to a waterproof polystyrene black bag, then they were wetted to increase the moisture content near to field capacity. The incubation period of 30 days (from September 07 to October 06, 1997) was achieved at the environmental conditions where the average of maximum temperature was 28.8ºC and the average of minimum temperature was 17.6ºC. After this period, the samples were collected and the chemical analyses were carried out.

Results and discussion

The results of the soil chemical analyses after the incubation period are presented in Table 2. With the increase values of V% from 6% to 80% there was an exponential reduction of the Al saturation values from 88% to 1% (Figure 1). As the V% values increased, the pH values in H_2O and in $CaCl_2$ increased from 3.9 to 6.2 and from 3.7 to 5.6, respectively (Table 2), establishing a linear regression between the values of V% and the pH in H_2O and an exponential regression between values of V% and the pH in $CaCl_2$ (Figure 2). The results of this study confirmed the effects of liming on the elevation of pH values, on the V% values, and on the reduction of exchangeable Al (Raij *et al.*, 1983; Caires and Rosolem, 1993, besides others). It is important to state that liming did not linearly increase the availability of K and P. No variations in the availability of K by liming were verified in *Terra Roxa estruturada*, dystrophic, in the state of São Paulo by Caires and Rosolem (1993).

With the incorporation of lime in the soils, the values of ECEC changed from 10.56 to 18.02 cmol$_C$dm^{3-} (an increase of 71%), while the values of CEC changed from 19.41 to 22.46 cmol$_C$dm^{3-} (an increase of 16%). These results support the idea that liming increases the values of ECEC higher than the values of CEC (Raij, 1981; McBride, 1994). The OC contents were responsible for more than 50% of the CEC values, except for the V60% treatment (Table 3). Raij (1981) also noticed, independently of the mineralogy of different soils, that the soil OC was the main component to determine the CEC values. The contribution of OC changed from 56% to 82% of the total electric negative charges in the studied soils. The reduction of the OC values noticed in the V60% treatment (Table 2), despite not having influenced negatively the values of ECEC and CEC (Table 3), seems be due to better soil conditions for bacteria activity in the OC mineralization process (Selbach, 1989).

Table 2. Results of chemical analyses of the soil incubated during 30 days with different rates of $CaCO_3$ and $MgCO_3$

Treatments	pH		Al^{3+}	$H^{+}+Al^{3+}$	$Ca^{2+}+Mg^{2+}$	Ca^{2+}	K^{+}	P	OC
Calculated V% values	$CaCl_2$	H_2O			$cmol_c dm^{3-}$			$mg\ dm^{3-}$	$g\ dm^{3-}$
Control	3.7	3.9	9.30	18.15	0.94	0.56	0.32	4	32.30
40	4.3	5.2	2.20	11.35	7.60	5.63	0.38	2	26.60
60	4.8	5.5	0.50	8.41	12.56	10.29	0.38	4	18.88
80	5.2	5.8	0.20	6.67	14.86	11.97	0.35	2	28.12
100	5.6	6.2	0.10	4.54	17.56	14.47	0.36	2	29.26

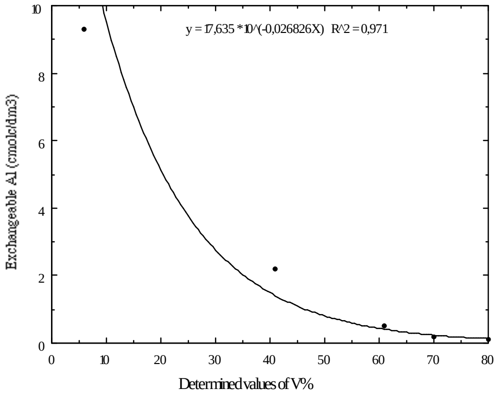

Figure 1. Relation between determined values of V% and exchangeable Al in the soil

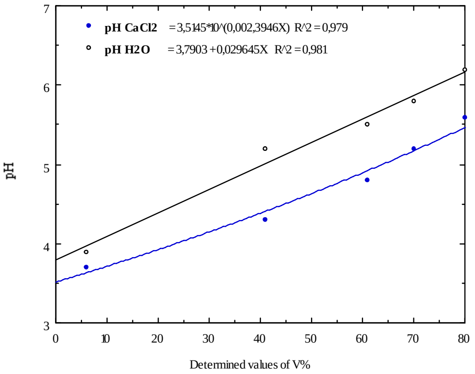

Figure 2. The effect of increased V% values on the pH values in H_2O and $CaCl_2$

Table 3. Soil chemical parameters after incubation with different rates of $CaCO_3$ e $MgCO_3$ during 30 days

Calculated V% values	SB	ECEC	CEC	Determined V% values	CECOC	% of CEC due to OC
		$cmol_c dm^{3-}$			$cmol_c dm^{3-}$	
Control	1.26	10.56	19.41	06	14.53	75
40	7.98	10.18	19.33	41	11.97	62
60	12.94	13.44	21.35	61	8.46	40
80	15.21	15.41	21.88	70	12.64	58
100	17.92	18.02	22.46	80	13.17	59

The rates of $CaCO_3$ and $MgCO_3$, calculated by the method of base saturation, were enough and efficient to elevate the values of V% up to 60%. Over this value they were not efficient (Caires and Rosolem, 1993). The relationship between the lime rates incorporated into the soil and the theoretical values of V% was linear. On the other hand, the relationship between the lime rates and the real values of V% was quadratic (Figure 3). The same tendency was verified by Caires and Rosolem (1993), Oliveira *et al.* (1997), besides others. In the theoretical calculations the values of V% should be of 80% and 100%. In fact, the real values were of 70% and 80% respectively.

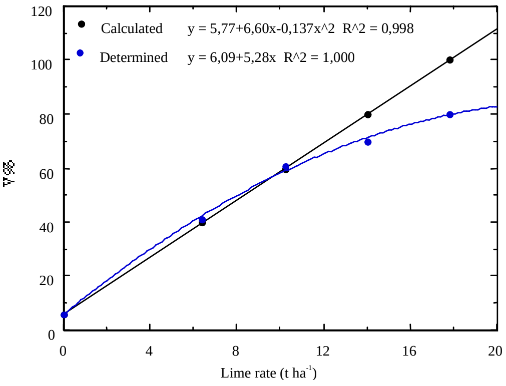

Figure 3. Relation between lime rates and V% values of the soil

The inefficiency correction process over 60% by the V% method based on the hypothesis that texture of lime could hamper its solubilization (Quaggio *et al.*, 1982; Caires and Rosolem, 1993 and Oliveira *et al.*, 1997) should not be considered, at least under the conditions of this study. The incubation period, over 30 days, did not affect the variation of V% values. Caires and Rosolem (1993) also verified that periods of 90, 120 and 240 days after lime application to the soil did not influence the V% values. The inefficiency of the bases saturation method to reach the theoretical V% values could be justified by the following hypotheses: a) the high rates of lime used, due to the high soil buffer power, could have affected its solubility and/or the equilibrium reaction (Oliveira *et al.*, 1997); b) with the increase of the pH, part of Ca and Mg could be used to neutralize the negative charges resultant from the deprotonization process of the OH of inorganic colloids and/or carboxylic/phenolic acids of organic colloids. The deprotonization process of OH would be originated from covalent bonding between oxygen and hydrogen. On the other hand, the efficiency of the reaction to move hydrogen from the ionic bonding would be harmed. In this work, the deprotonization process would be due, mainly, to the high OC in the soil, that presents the high pH-dependent charges (Brady and Weil, 1996). In the studies carried out by Raij *et al.* (1983), Caires and Rosolem (1993) and Oliveira *et al.* (1997), the deprotonization process would probably be due to the presence of the clay minerals and oxides, because the soils studied were highly weathered, presenting high pH-dependent charges as well (Brady and Weil, 1996); c) at last, there was a possibility of a mineral neoformation with the participation of Ca, Mg, Al, ... under hydroxides forms that present low solubility.

References

Brady, N.C.; Weil, R.R. The nature and properties of soils. New Jersey: Prentice-Hall, 1996.

Caires, E.F.; Rosolem, C.A. Calagem em genótipos de amendoim. *Rev. Brasil. Cienc. Solo, 17*:193-202, 1993.

Camargo, M.N.; Klamt, E.; Kauffman, J.H. Classificação de solos usada em levantamentos pedológicos no Brasil. *Rev. Brasil. Cienc. Solo, 12*(1):11-33, 1987.

Clark, R.B. Effect of aluminum on growth and mineral elements of Al-tolerant and Al-intolerant corn. *Plant Soil., 47*:653-662, 1977.

Curi, N.; Larach, J.O.I.; Kämp, N.; Moniz, A.C.; Fontes, L.E.F. *Vocabulário de ciência do solo*. Campinas: Sociedade Brasileira de Ciência do Solo, 1993.

Emater. Análises de solo: tabelas para transformação de resultados analíticos e interpretação de resultados. Curitiba, 1995. (Informação Técnica, 31).

Embrapa. Levantamento de reconhecimento dos solos do Estado do Paraná. Curitiba, Embrapa/SNLCS/Sudesul/Iapar, 1984. (Boletim técnico, 57).

Embrapa. Serviço Nacional de Levantamento e Conservação de Solos. Manual de métodos de análises de solos. Rio de Janeiro, 1979.

Horst, W.J. Aluminium tolerance and calcium efficiency of cowpea genotypes. *J. Plant Nutr., 10*:1121-1129, 1987

Kinraide T.B.; Parker D.R. Assessing the phytotoxicity of mononuclear hydroxy-aluminum. *Plant Cell Environ., 12*:479-487, 1989.

Lindsay W.L. Chemical equilibria in soils. New York: John Wiley & Sons, 1979.

McBride, M.B. Environmental chemistry of soils. New York: Oxoford University Press Inc., 1994.

Mello, F.A.F. de. Origem, natureza e componentes da acidez do solo: critérios para calagem. In: Malavolta, E. (ed.). Seminário sobre corretivos agrícolas. Campinas: Fundação Cargill, 1985. p.65-93.

Oliveira, E.L.; Parra, M.S.; Costa, A. Resposta da cultura do milho, em um latossolo vermelho escuro álico, à calagem. *Rev. Brasil. Cienc. Solo, 21*:65-70, 1997.

Pavan, M.A.; Bingham, F.T. Toxicity of aluminum to coffee seedlings grown in nutrient solution. *Soil Sci. Soc. Am. J., 46*:993-997, 1982.

Quaggio, J.A.; Dechen, A.R.; Raij, B. van. Efeitos da aplicação de calcário e gesso sobre a produção de amendoim e lixiviação de bases no solo. *Rev. Brasil. Cienc. Solo, 6*:189-194, 1982.

Raij, B. van. Avaliação da fertilidade do solo. Piracicaba: Instituto da Potassa & Fosfato, Instituto Internacional da Potassa, 1981.

Raij. B. van; Camargo, A.P. de; Cantarella, H.; Silva, N.M. Alumínio trocável e saturação em bases como critérios para recomendação de calagem. *Bragantia, 42*(13):149-156, 1983.

Selbach, P.A. Acidez dos solos e atividade microbiana. In: Kaminski, J.; Volkweiss, S.J.; Becker, F.C. (eds.). *Corretivos da acidez do solo*. Santa Maria: Imprensa Universitária, 1989. p. 62-73.

Taylor, G.J. The physiology of aluminum tolerance in higher plants. Commun. *Soil Sci. Plant Anal., 19*:1179-1197, 1988.

Vitti, G.C. Acidez do solo, calagem e gessagem. In: Fernandes, F.M.; Nascimento, V.M. (ed.) *Curso de atualização em fertilidade do solo*. Campinas: Fundação Cargill, 1987. p. 303-319.

Wright, R.J. Soil aluminum toxicity and plant growth. Commun. *Soil Sci. Plant Anal., 20*:1479-1497, 1989.

Received on May 03, 1999.
Accepted on August 31, 1999.