Liquid lime: effect on soil chemical properties and wheat grain yield[1]

Amauri Nelson Beutler[2], Giovane Matias Burg[3], Marcelo Raul Schmidt[3], Evandro Ademir Deak[3], Leandro Galon[4]

Abstract – Brazilian soils are usually acid and require correction to provide high yields. To this end, milled lime, in powder form, has been used effectively for decades. Recently, liquid lime was proposed for both acidity correction and supply of Ca^{2+} and Mg^{2+}. The aim of this study was to evaluate the effect of liquid lime on soil chemical properties and wheat grain yield. The experimental design was completely randomized with five treatments and four replications, with 3 × 4 m (12 m²) plots. The treatments were levels of 0, 5, 10, 20 and 40 L ha^{-1} of liquid lime applied to the soil surface in March 2013 with a nozzle array and liquid sprayer rate of 160 L ha^{-1}. Soil chemical properties were evaluated after 30 days. In June, wheat was sown. In harvest were evaluated wheat shoot dry matter, mass of 100 grains and grain yield in 2 m² area. Liquid lime up to a level of 40 L ha^{-1} did not improve soil chemical properties and wheat grain yield.

Key-words: Soil acidity. Liming. *Triticum aestivum* L.

Calcário líquido: efeito nas propriedades químicas do solo e produtividade de grãos de trigo

Resumo – Os solos do Brasil são geralmente ácidos e necessitam da correção da acidez para obtenção de altas produtividades. Para tal, o calcário moído, em pó, tem sido utilizado com eficiência há décadas. Recentemente foi lançado o calcário líquido para a correção da acidez e fornecimento de Ca^{2+} e Mg^{2+}. O objetivo deste trabalho foi avaliar a eficiência do calcário líquido nas propriedades químicas do solo e na produtividade de trigo. O delineamento experimental foi inteiramente casualizado com cinco tratamentos e quatro repetições, constituídas por parcelas de 3 x 4 m (12 m²). Os tratamentos foram as doses de 0, 5, 10, 20 e 40 L ha^{-1} de calcário líquido aplicado na superfície do solo, em março de 2013, via pulverizador com bico leque e vazão de 160 L ha^{-1} de calda. Foram avaliadas as propriedades químicas do solo após 30 dias, na camada de 0-10 cm. Foi semeado trigo, cultivar Quartzo e na colheita foram avaliados a massa seca da parte aérea das plantas, massa de 100 grãos e a produtividade de grãos em área de 2 m². O calcário líquido, até a dose de 40 L ha^{-1}, não melhorou as propriedades químicas do solo e a produtividade de grãos de trigo.

Palavras-chave: Acidez do solo. Calagem. *Triticum aestivum* L.

Introduction

Brazilian soils are usually acid and require correction and fertilization to provide high yields. Acidity is one of the factors which limits crop yield worldwide, because in such conditions Ca^{2+} deficiency and Al^{3+} toxicity usually occur (Fageria e Baligar 2008). The acidification process is continuous and requires periodic correction. In this context liming is the main method used. Lime adds Ca^{2+} and Mg^{2+}, increases the pH and soil basis saturation and neutralizes Al^{3+} toxicity, providing favorable conditions for root system growth, nutrient and water absorption by plants (Ciotta et al. 2004, Caires et al. 2005, Caires et al. 2008, Castro e Crusciol 2013).

Milled limestone is used, in powdered form. However, it is usually necessary to apply it in large quantities and it is difficult homogeneous application on soil surface that increases costs of transportation and application, apart from the generation of dust during application. Furthermore, in no-till systems, which are used for more than 50% of agricultural crops in Brazil, the liming is performed on the surface and splits during the cultivation season (Dalla Nora et al. 2013), without incorporation, promoting only superficial effects because lime has low solubility in soil (Rampim et al. 2011). When lime is applied on the soil surface the effective action usually occurs in a 0-10 cm layer (Amaral et al. 2004). Furthermore, liming with powdered lime must occur at least three months before sowing or planting to allow the soil to react and provide benefits to plants.

Given the difficulties in relation to powdered lime, liquid lime has been suggested as an alternative. It is easier to obtain and provides uniformity of application with spray equipment or by fertirrigation, improves operating performance, can be applied in small amounts, and has a rapid effect because it is composed of nanoparticles which are smaller than regular particles and therefore react faster in soil. However, more scientific studies are required to assess its effectiveness. According to the manufacturer, liquid lime is a source of Ca^{2+} e Mg^{2+}, increases pH and basic saturation, neutralizes Al^{3+} toxicity, does not require incorporation, and needs rainfall of just 30 mm after its application for product reaction in soil, because it is composed of nanoparticles diluted in water, forming a fluid that is

[1]Manuscrito submetido em 13/03/2015 e aceito para publicação em 09/11/2015
[2]Prof. Associado, Universidade Federal do Pampa (UNIPAMPA), Campus Itaqui, Itaqui, RS, Brasil. E-mail: amaurib@yahoo.com.br
[3]Graduandos em Agronomia, Universidade Federal do Pampa (UNIPAMPA), Campus Itaqui, Itaqui, RS, Brasil. E-mail: gio_burg@hotmail.com, marceloraulschmidt@hotmail.com, evandro.deak@hotmail.com
[4]Prof. Adjunto, Universidade Federal Fronteira Sul (UFFS), Campus Erechim, Erechim, RS, Brasil. E-mail: leandro.galon@uffs.edu.br

easier to add by spraying on the soil surface.

Liquid lime is sold in Brazil, and was particularly popular from the harvest of 2012/13. However, its efficiency still needs investigation in scientific studies involving soil chemical analysis and crop yield, as there are few studies on liquid limestone.

Wheat is one of the most economically important winter crops in the southern Brazilian region and liming is essential to obtain high yield, because this practice enables the neutralization of toxic elements, greater availability of nutrients and improvement of the environment for root growth and plant development. Caires et al. (2006) obtained wheat grain yield 140% higher than without liming using powder lime in an acid soil.

The hypothesis is that liquid lime raises the pH and the content of $Ca^{2}+$ e $Mg^{2}+$ in soil, promoting greater wheat grain yield.

The aim of this study was to evaluate the effect of liquid lime on soil chemical properties and wheat grain yield.

Material and Methods

The experiment was conducted in geographic coordinates of 29° 09′ 09″ S, 56° 33′ 03″ W, 64 m altitude, 0.8% slope, in an Ultissol with 190 g kg^{-1} of clay. According to Köppen-Geiger, the climate type is Cfa, humid subtropical without a dry season, with hot summers (Peel et al. 2007).

The experimental design was completely randomized with five treatments and four replications, with plots of 3 x 4 m. The treatments were levels of 0, 5, 10, 20 and 40 L ha^{-1} of liquid lime applied on soil surface with a nozzle array and liquid sprayer rate of 160 L ha^{-1}.

The liquid lime product was Nyon Solo Cal® with 297.5 e 102.0 g L^{-1} of $Ca^{2}+$ and $Mg^{2}+$, respectively, named by the manufacturer as a source of $Ca^{2}+$ e $Mg^{2}+$ with the characteristics of an acidity corrective. The recommendation is 5 L of the commercial product, on the soil surface, for each ton of powdered lime recommended by soil chemical analysis.

The area was cultivated one year with soybean after natural vegetation, before this experiment. The soil was leveled by disking and on March 26, 2013 liquid lime was applied. After the lime addition, rainfall measuring 60 and 40 mm fell after 6 and 16 days (April 1 and 10) after application, respectively.

Thirty days after lime application, a period in which 100 mm of rain fell, soil chemical properties were evaluated according to Tedesco et al. (1995) in a 0-10 cm soil layer, and 15 subsamples were collected and mixed in order to homogenize the soil and form a full sample per plot.

The wheat, cultivar quartz, medium cycle, was sown on June 12 in lines, with 60 seeds per meter, 17 cm between rows, and 350 plants/m². The fertilization was as recommended by CQFS-RS/SC (2004), with 300 kg ha^{-1} of formulation 5-20-20, N-P-K, and 225 kg ha^{-1} of urea in two surfaces applications: the first applied of 150 kg ha^{-1} in tillering at 30 days, and the second at 75 kg ha^{-1} 75 days after sowing.

At harvest, the shoot dry matter was evaluated in 0.25 m² area with two replicates per plot, and mass of 100 grains and grain yield in 2m² area, and corrected to 13% moisture.

Data were subjected to analysis of variance performed at 5% level of probability. When results were significant regression equations were adjusted.

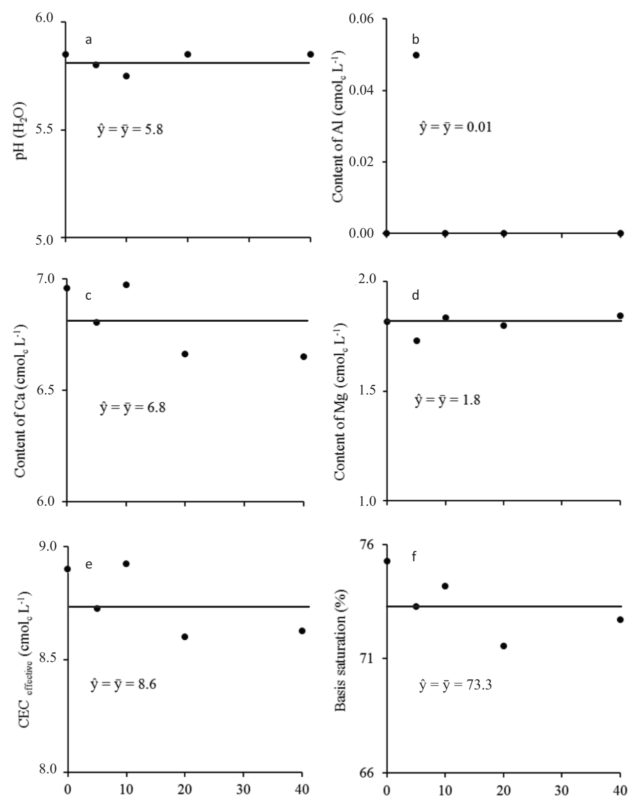

Figure 1 - Soil chemical properties in layers of 0 - 10 cm, 30 days after surface liquid lime application and 100 mm of rainfall. CEC: cation exchange capacity.

Results and Discussion

The chemical soil properties did not change with the application of up to 40 L ha^{-1} of liquid lime (Figure 1a, b, c, d, e, f). This is a high amount, as the manufacturer's recommendation is 5 L ha^{-1} for each ton of powdered lime recommended by the soil chemical analysis. Thus, 40 L ha^{-1} is considered equivalent to 8 t ha^{-1} of powdered lime. Similar results were obtained by Carmo et al. (2013), who found that application of 14.5 L ha^{-1} of liquid lime did not improve soil chemical properties 87 days after application. According to these researchers, in soil water content at field capacity, 10 days after the application of powdered lime with a power relative neutralization total of 85%, at 1.41 t ha^{-1}, soil pH increases, although liquid lime applied did not change soil pH.

So the conditions after application of liquid lime on soil surface were appropriate and the time was sufficient for reaction of the nanoparticles of Ca^{2+} and Mg^{2+} contained in the product, since two rainfalls occurred, one of 60 mm and another of 40 mm, at 6 and 16 days after surface liming, respectively, providing water soil saturation and water content close to field capacity for several days, suitable for lime reaction (Carmo et al. 2013) and conduction of Ca^{2+} and Mg^{2+} in depth (Alcarde & Rodella 2003). Rainfall is essential, because it increases soil water content and accelerates lime reaction, allowing entrainment of Ca^{2+} and Mg^{2+} in depth (Alcarde & Rodella 2003).

In relation to reaction time, the samples were collected 30 days after surface application of liquid lime and total rainfall of 100 mm, necessary and sufficient conditions for the reaction of lime nanoparticles in soil. According to MAPA (2006) and Carmo et al. (2013), finer particles react faster in soil, suggesting that the liquid lime applied in this study had sufficient time and moisture conditions for reaction in soil.

Moreover, the soil was leveled by disking which made it more porous and allowed greater water infiltration and movement of the nanoparticles contained in the liquid lime applied to the soil surface, facilitating the lime reaction and expression of its benefits in soil chemical properties. According to Amaral et al. (2004), lime has an effective action in layers 0-10 cm in depth, so the samples were collected from this layer for better assessment of the liquid lime effect.

Despite that all the assumptions in the experiment were attended, as ideal conditions after application, use of high doses and sampling in surface layer, there was no increase in soil pH, level of Ca^{2+}, Mg^{2+} or soil basis saturation. Therefore, there was no soil acidity correction or Ca^{2+} and Mg^{2+} addition. This was possibly because of the low amounts of Ca^{2+} and Mg^{2+} and low neutralization power, in doses recommended by the manufacturer, compared with levels of Ca^{2+} and Mg^{2+} much highest in powder lime (Alcarde 2005, MAPA 2006), why was not verified response to liquid lime application until 40 L ha^{-1}.

In relation to Ca^{2+} and Mg^{2+}, when was applied the high dose, 40 L ha^{-1} of liquid lime, equivalent to 8 t ha^{-1} of powder lime according manufacturer's recommendation, was added in soil 11.9 kg ha^{-1} of Ca^{2+} and 4.08 kg ha^{-1} of Mg^{2+}, very small amounts, compared to added with powder lime according to MAPA (2006). These amounts do not satisfy current wheat plant requirements, and those of subsequent crops, leading to reduced soil fertility over the years, because the addition is smaller than the crop requires and the amounts exported in wheat grain in a single crop cultivation. Analysis of the wheat production in this experiment of 2,983 kg ha^{-1} (Figure 2c), showed that approximately 9.2 kg ha^{-1} of Ca^{2+} were exported, considering that Ca^{2+} content in wheat grains is on average 3.10 mg g^{-1} (Gargantini & Blanco 1973).

Wheat shoot dry matter contains approximately 2.96 mg g^{-1} of Ca^{+2}, according to Raza et al. (2013), which, multiplied by the 5,954 kg ha^{-1} of wheat shoot dry matter

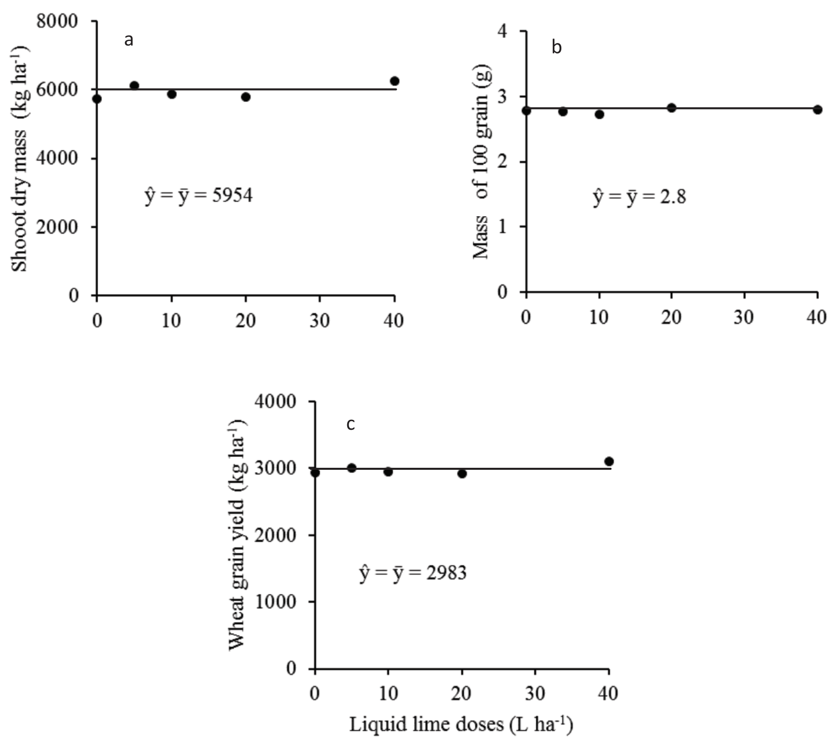

Figure 2 - Wheat shoot dry mass, mass of 100 grains and grain yield in liquid lime, harvest 2013.

produced in this experiment (Figure 2a), means 17.6 kg ha^{-1} of Ca^{+2} is necessary for complete wheat growth and development. This without considering the amount of Mg^{2+} which is applied in three times smaller levels. In this context, calculation was accomplished with reference to the amounts of Ca^{2+} in wheat grain and shoot dry matter described in the literature. It should be noted that these amounts may be slightly more or less depending on the cultivar and growing conditions. There is little variation in the levels of Ca^{2+} in wheat in this study and the work of Espindula et al. (2010). However, the above calculations are useful because they emphasize that doses of Ca^{2+} applied by liquid lime are lower than those necessary for wheat crops.

On the other hand, when 10 L ha^{-1} of liquid lime was applied, equivalent to the dose of powdered lime of 2.0 t ha^{-1} recommended for this soil (CQFS-RS/SC, 2004), 2.97 kg ha^{-1} of Ca^{2+}were added, a value less than that required by the wheat crop, without considering that subsequent crops will be conducted, indicating a lower dose of Ca^{2+}. For the Mg^{2+}, doses are still lower than the wheat's requirement, as verified by Gargantini & Blanco (1973). According to MAPA (2006), is considered an acidity corrective a product that promotes the soil acidity correction, besides provide Ca^{+2}, Mg^{+2} or both, condition not attended by liquid lime, in doses recommended by manufacturer, according the results obtained in this study and of Carmo et al. (2013). In this context, this product could not be considered an acidity corrective.

The production of wheat shoot dry matter, mass of 100 grains and grain yield does not increase with liquid lime application up to 40 L ha^{-1} (Table 1, Figure 2a, b, c).

According to Caires et al. (2006), wheat culture responds to liming and, in acid soils, increased until 140% grain yield. Therefore, the lack of wheat response to liquid lime application is possibly related to the lack of improvement in soil chemical properties such as increased pH, Ca^{2+}, Mg^{2+} and soil basis saturation. On the other hand, it appears that the soil already had satisfactory chemical properties for wheat development; however, liquid lime application did not improve soil fertility, which could have increased wheat yield.

The results obtained in this study suggest that there was no effect of liquid lime in doses up to 40 L ha^{-1} in terms of amelioration of soil chemical properties and wheat grain yield. Therefore, because liquid lime application is easier, there are required more studies on acidic soils with higher product doses; however, it is important to highlight that high doses of the product result in higher liquid lime costs.

Table 1 - Analysis of variance for shoot dry mass, mass of 100 grains and wheat grain yield, cultivar quartz, after liquid lime doses.

Causes of variation	Degree of free	Mean square	F test
		Shoot dry weight (kg ha^{-1})	
Treatment	4	193095.9	0.1549^{ns}
Residue	15	1246728.8	-
Total	19	-	-
CV (%)		18.7	
		Mass of 100 grain (g)	
Treatment	4	0.0048	0.2019^{ns}
Residue	15	0.0235	-
Total	19	-	-
CV (%)		5.5	
		Wheat grain yield (kg ha^{-1})	
Treatment	4	19965.9	0.1530^{ns}
Residue	15	130481.0	-
Total	19	-	-
CV (%)		12.1	

^{ns} Not significant. CV: coefficient of variation.

Conclusions

1. Surface application of liquid lime up to 40 L ha^{-1} did not affect the soil chemical properties at 0 -10 cm depth.
2. Surface liquid lime application up to 40 L ha^{-1} does not increase wheat grain yield.

Acknowledgments

The third author thanks CNPq and the fourth Fapergs for their scholarship. The 2B representations by the financial support.

References

ALCARDE, J. A.; RODELLA, A. A. **Qualidade e legislação de fertilizantes e corretivos**. In: CURI, N. et al. Tópicos em Ciência do Solo. Viçosa: Sociedade brasileira de Ciência do Solo, 2003. v. 3. p. 291-334.

ALCARDE, J. C. **Corretivos da acidez dos solos:** características e interpretações técnicas. São Paulo: ANDA, 2005. 24 p. (Boletim técnico, 6).

AMARAL, A. S.; ANGHINONI, I.; DESCHAMPS, F. C. Resíduos de plantas de cobertura e mobilidade dos produtos da dissolução do calcário aplicado na superfície do solo. **Revista Brasileira de Ciência do Solo,** Viçosa, v. 28, n. 1, p. 115-123, 2004.

CAIRES, E. F. et al. Surface application of lime for crop grain production under a no-till system. **Agronomy Journal,** Madison, v. 97, n. 3, p. 791-798, 2005.

CAIRES, E. F. et al. Surface application of lime ameliorates subsoil acidity and improves root growth and yield of wheat in an acid soil under no-till system. **Scientia Agricola**, Piracicaba, v. 63, n. 5, p. 502-509, 2006.

CAIRES, E. F. et al. Effects of soil acidity amelioration by surface liming on no-till corn, soybean, and wheat root growth and yield. **European Journal of Agronomy,** Amsterdam, v. 28, n. 1, p. 57-64, 2008.

CARMO, L. D.; FIGUEIREDO, F. C.; BOTREL, P. P. Efeito do calcário líquido, cal virgem dolomítica e calcário comum na correção do solo. In: Congresso brasileiro de pesquisas cafeeiras, 39., 2013, Poços de Caldas. **Anais...** Poços de Caldas: MAPA/Procafé, 2013. p. 175-177.

CASTRO, G. S. A.; CRUSCIOL, C. A. C. Yield and mineral nutrition of soybean, maize, and Congo signal grass as affected by limestone and slag. **Pesquisa Agropecuária Brasileira**, Brasília, v. 48, n. 6, p. 673-681, 2013.

CIOTTA, M. N. et al. Manejo da calagem e os componentes da acidez de Latossolo Bruno em plantio direto. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 28, n. 2, p. 317-326, 2004.

COMISSÃO DE QUÍMICA E FERTILIDADE DO SOLO - RS/SC (CQFS-RS/SC). **Manual de adubação e calagem para os Estados do Rio Grande do Sul e de Santa Catarina.** 10. ed. Porto Alegre: SBCS/UFRGS, 2004. 400p.

DALLA NORA, D. D. et al. Gesso: alternativa para redistribuir verticalmente nutrientes no perfil do solo sob sistema plantio direto. **Revista Plantio Direto**, Passo fundo, v. 133, n. 1, p. 8-20, 2013.

ESPINDULA, M. C. et al. Composição mineral de grãos de trigo submetidos a doses de sulfato de amônio e trinexapac-etil. **Pesquisa Agropecuária Tropical**, Goiânia, v. 40, n. 4, p. 513-520, 2010.

FAGERIA, N. K.; BALIGAR, V. C. Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production. **Advances in Agronomy**, San Diego, v. 99, n. 2, p. 345-399, 2008.

GARGANTINI, H.; BLANCO, H. G. Absorção de nutrientes pelo trigo. **Bragantia**, Campinas, v. 32, n. 1, p. 285-307, 1973.

MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO - MAPA**. Normas sobre especificações e garantias, tolerâncias, registro, embalagem e rotulagem dos corretivos de acidez, de alcalinidade, de sodicidade e dos condicionadores de solo, destinados à agricultura** (Instrução normativa, 35, 4 jul. 2006). Available at: <>. Accessed: fev. 04, 2015.

PEEL, M. C.; FINLAYSON, B. L.; MCMAHON, T. A. Updated world map of the Köppen-Geiger climate classification. **Hydrology Earth System Science**, v. 11, n. 5, p. 1633-1644, 2007.

RAMPIM, L. et al. Chemical attributes of a soil and response of wheat and soybean to gypsum in no-tillage system. **Revista Brasileira de Ciência do Solo**, Viçosa, v. 35, n. 5, p. 1687-1698, 2011.

RAZA, M. A. S. et al. Potassium applied under drought improves physiological and nutrient uptake performances of wheat *(Triticum aestivun* L.). **Journal of Soil Science and Plant Nutrition**, Temuco, v. 13, n. 1, p. 175-185, 2013.

TEDESCO, J. M. et al. **Análise de solo, plantas e outros materiais**. 2. ed. Porto Alegre: UFRGS, 1995. 174 p. (Boletim técnico de solos, 5).