Agronomic Performance of Mineral and Organic Sources of Nutrients for Maize and Wheat Crops

Adilson Luís Bamberg[1]
Carlos Augusto Posser Silveira[1]
Rosane Martinazzo[1]
Magda Bergmann[2]
João Angelo Toniolo[2]
Matheus Farias Grecco[3]
Mariana da Luz Potes[4]
Michelle Ottomann (translator)[5]

Abstract

A combination of mineral and organic source of nutrients was tested in a field experiment, aiming to evaluate its effects on soil chemistry and on maize and wheat productivity. Data showed clearly the potential for the use of shale limestone as a source of Ca, Mg and S, Granodiorite as a source of K and Tung press cake residue as a source of N.

Key words: granodiorite, shale limestone, Tung press cake residue.

Introduction

The use of crushed rocks, which are perceived to release nutrients more slowly when compared to conventional soluble fertilizers, still meets resistance from researchers and farmers, who have as main argument its low agronomic efficacy. However, it is common knowledge that, with the exception of nitrogen, the other required plant nutrients have been or are somehow derived from weathering of primary minerals (Landeweert et al., 2001). Many types

[1] Embrapa Clima Temperado, BR 392 km 78, 96010-971, C.P. 403, Pelotas, RS, Brasil. adilson.bamberg@embrapa.br; augusto.posser@embrapa.br e rosane.martinazzo@embrapa.br; [2] Companhia de Pesquisa em Recursos Minerais - CPRM - Serviço Geológico do Brasil. magda.bergmann@cprm.gov.br; joao.toniolo@cprm.gov.br, [3] Projeto Xisto Agrícola, convênio Embrapa-FAPEG-Petrobras, BR 392 km 78, 96010-971, C.P. 403, Pelotas, RS, Brasil. grecco.eg@hotmail.com; [4] Projeto Agroenergia, convênio Embrapa-FAPEG, BR 392 km 78, 96010-971, C.P. 403, Pelotas, RS, Brasil. marianapotes@ yahoo.com.br; [5] Senior Translator at Remineralize the Earth.

of rocks are multi-element sources of nutrients, especially when applied in the form of matrices of rocks with different compositions. The agronomic efficacy of each rock type depends, among other factors, on the suitability of its particle size, which is in most cases directly related to the release of nutrients. In some cases, the nutrient release can occur very rapidly when the material is finely crushed. This is the case for agricultural limestone, which becomes available in less than a month (Pandolfo & Tedesco, 1996).

Several factors have contributed to the characterization and validation of unconventional sources of nutrients for Brazilian agriculture. The country dependence on imported inputs, the rising costs of fertilizers, the search for diversification of supply inputs for agriculture and for sources with lower risks of environment contamination have spurred the partnership between *Embrapa Clima Temperado* and *Companhia de Pesquisa em Recursos Minerais* – CPRM. These institutions have been conducting studies investigating and evaluating the agronomic performance of agromineral and byproducts of agro-industrial activities in the south of Brazil. Furthermore, the studies take into account the impact of the application of these products on environmental safety and on the quality of the food produced. Among the materials available in the region with potential for agricultural use, it is possible to highlight the byproducts of gravel industries and co-products of agro-industries, such as Granodiorite tailings, which are used for civil construction, and press cake residues of oleaginous plants such as castor and tung.

The study of new sources of nutrients gives the opportunity to formulate and implement multi-element organic mineral matrices with advantages such as the gradual release of nutrients and stimulate the soil microbiota. For this purpose, it becomes crucial to understand the potential release of elements from such matrices for soil solutions. The use of leaching columns assists in determining the potential release and the fraction of the total constitution of rocks available for plants (Bamberg et al., 2011). In order to understand and evaluate the agronomic efficacy of agro-minerals, it is common to use experiments under controlled conditions, in greenhouses and incubation tests, as well as the laboratory use of extracting solutions that correlate with the available fraction and with the productivity of agricultural crops (Pereira et al., 2003). However, the most persuasive way to analyze nutrient sources still seems to be their evaluation through field experiments. Therefore, this study aimed to evaluate the agronomic performance of mineral and organic sources of nutrients for maize and wheat crops in a field experiment in an Albaqualf.

Methodology

A field experiment was installed at *Terras Baixas* Experimental Station belonging to *Embrapa Temperate Agriculture*, Capão do Leão, RS state, Brazil, by using a combination of mineral and organic nutrients. The local soil is classified as an Albaqualf. The soil chemical characterization of the experimental area is presented in Table 1.

Table 1. Chemical characterization of 0-20 and 20-40 cm soil layers of an Albaqualf of the experimental area used for this study. Embrapa Clima Temperado, Pelotas-RS, 2013

Depth (cm)	pH Water (1:1)	Index SMP	H+Al	Al	Ca	Mg	Saturation (%)		Clay (%)	MO (%)	P (mg dm^{-3})	K (mg dm^{-3})	CTC (cmol$_c$ dm^{-3})	
			cmol$_c$ dm^{-3}				Al	Bases					efetiva	pH 7
0-20	4,9	5,9	4,7	0,8	2,26	0,74	20,4	40,3	16	1,7	11,4	52	4,0	7,8
20-40	4,9	5,7	5,9	1,2	2,09	0,88	28,2	34,1	17	1,2	3,9	32	4,3	9,0

The experiment was designed as complete randomized blocks with nine treatments and four replicates. The treatments were: T1 - Control (without liming or fertilization); T2 - Liming (1 SMP index by Metamorphic Dolomitic Limestone - DL); T3 - Liming (1 SMP index by Shale Limestone - SL); T4 - Liming (1 SMP index by SL) + 1/2 dose of P2O5 by Arad Rock Phosphate – ARP + 1/2 dose of P2O5 by triple superphosphate (TSP); T5 - Liming (1 SMP index by SL) + 1 dose of ARP; T6 - Liming (1 SMP index by SL) + 1 dose ARP + Granodiorite - Grd; T7 - Liming (1 SMP index by SL) + 1 dose of ARP + Tung cake (TC); T8 - Liming (1 SMP index by SL + Elemental Sulfur) + 1 dose of ARP + Granodiorite + Tung cake (TC); and T9 - Liming (1 SMP index SL) + NPK via soluable fertilizer as recommended for the crop. The doses of Grd and TC were scaled according to the levels of potassium and nitrogen in the source, respectively. The doses of the other sources of nutrients were based on the recommendations of CQFS-RS/SC (2004) (Table 2), with reference to the soil chemical analysis, the total content of nutrients in each source (Table 3) and the expected productivity of 10 t ha-1 for the first maize grain crop. The treatments were incorporated into the arable soil layer (0.0-0.2 m) with a chisel plowing and right after maize seeds were sown in mid-December of 2011 (Figure 1).

Figure 1. Manual application of treatments and shallow incorporation with chisel plow.

Table 2. Doses of N, P_2O_5 and K_2O applied in each treatment from different mineral sources.

Soil	Nitrogen	P_2O_5		K_2O	
	Recommendation (kg ha^{-1})	level in the soil	Recommendation (kg ha^{-1})	level in the soil	Recommendation (kg ha^{-1})
Albaqualf	170	Very Low*	175	medium	120

*in this case, it was also taken into consideration the phosphorus' level of layer 20-40 cm.
Source: CQFS-RS/SC (2004).

In order to evaluate the immediate and residual effects of nutrient sources on the chemical soil parameters, two samples were collected and their respective chemical analyses were carried out. The samples were collected from the top layer of the soil (0.0-0.2m) after the 90th and the 360th day of the original treatment application. An evaluation was carried on the productivity of the maize grain for the harvest of 2011/2012, and on the wheat grain for the harvest of 2012/2012. The dataset was analyzed for the presence of discrepant values, and was submitted to the Shapiro-Wilk test to verify if the variables follow a normal distribution probability.

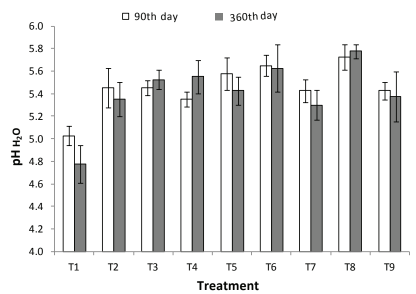
Table 3. Total concentrations of N, P2O5, K2O, CaO, MgO and S of different nutrient sources used in this study. Embrapa Clima Temperado, Pelotas-RS, Brazil 2013

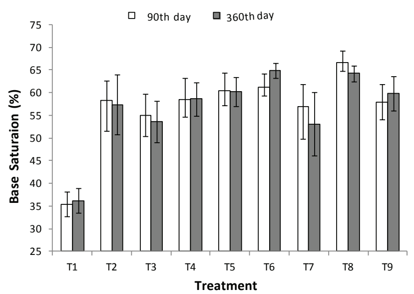
Nutrient Sources	Nutrient Provided (%)					
	N	P_2O_5	K_2O	CaO	MgO	S
Dolomitic Limestone (TNP=60.8%)				20,94	15,82	
Shale Limestone (TNP=60%)		0,20	0,60	20,50	13,60	1,10
Granodiorite		0,15	4,33*	2,42	1,00	
Arad Rock Phosphate ARAD		13,93	0,24	54,00	0,24	1,09
Torta de Tungue	2,7	0,58	3,60	0,35	0,40	
NPK	5,0	20,0	20,0	7,00		4,0
S elementary						99,0

* For the purpose of calculating the application dose, it was considered that 50% of the K2O added can be available for the first two crops.

Discussion and Results

After the application of acidity correctives, the chemical attributes of the soil (pHH_2O), base saturation, CEC (cation exchange capacity), and Al3+ saturation were significantly altered by the application of DL and SL, when analyzed at the 90th days after their incorporation into the soil (Figures. 2-A; 2-B; 2-C and 2-D). In the treatment without limestone application (T1) there was an increasing trend of saturation by Al3+ and reduction of soil pH (Figures 2-A and 2-D) at the 360th day after the application of the treatments.





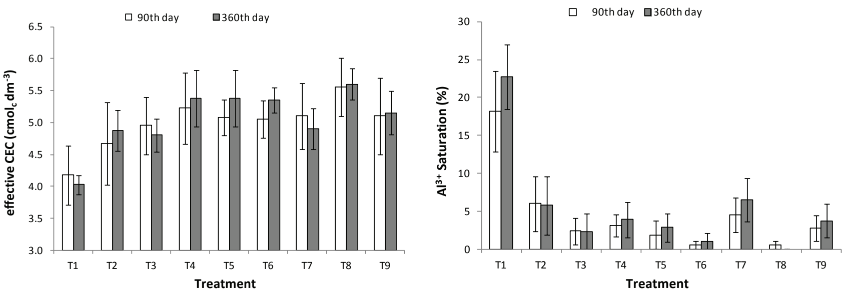


Figure 2

Considering the alternative fertilization mixtures suggested for treatments T7 and T8, it can be inferred that their performance is equal or superior to the conventional soluble fertilization (T9), both for maize and wheat grains yield (Fig. 3). The same was observed for other soil attributes such as base saturation, which indicates the amount of nutrients available to the plants. On the other hand, the association between SL and ARP presented a negative effect on the productivity of maize and wheat grains (Fig. 3).

The treatments that received ARP (Fig. 4-A) did show higher contents of extractable P outlined by Mehlich-1, but, because it is a natural phosphate, plants did not yet have too much access to this nutrient. Thus, the productivity of maize crop was significantly reduced, possibly due to a decrease in ARP solubility, which resulted from an elevation of soil pH and/or from the formation of poorly soluble compounds between ions Ca2+ released by SL and ARP and ions PO4-3 released by ARP. The same effect did not occur for the treatments T4, T7 and T8, because there was a significant input of phosphorus more readily available to plants, provided by TSP in T4 and by TC in T7 and T8- given that TC has additionally provided an amount of circa 20 kg ha-1 of P2O5 for T7 and T8.

Regarding the SL performance compared to the control treatment, it is possible to see that there was a significant effect on maize and wheat grain productivity (Fig. 3) and on soil attributes, such as: increased pH, increased amounts of Ca2+ and Mg2+, increased base saturation and decreased saturation by Al3+. When it was compared to DL, the SL showed similar performance, both for acidity-related variables as well as for the productivity of maize and wheat.

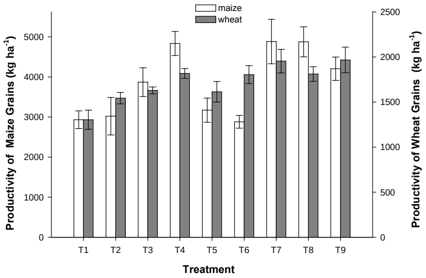


Figure 3. Effect of organic and mineral sources on the productivity of maize and wheat (kg ha-1). Embrapa Temperate Agriculture, Pelotas-RS, Brazil, 2013.

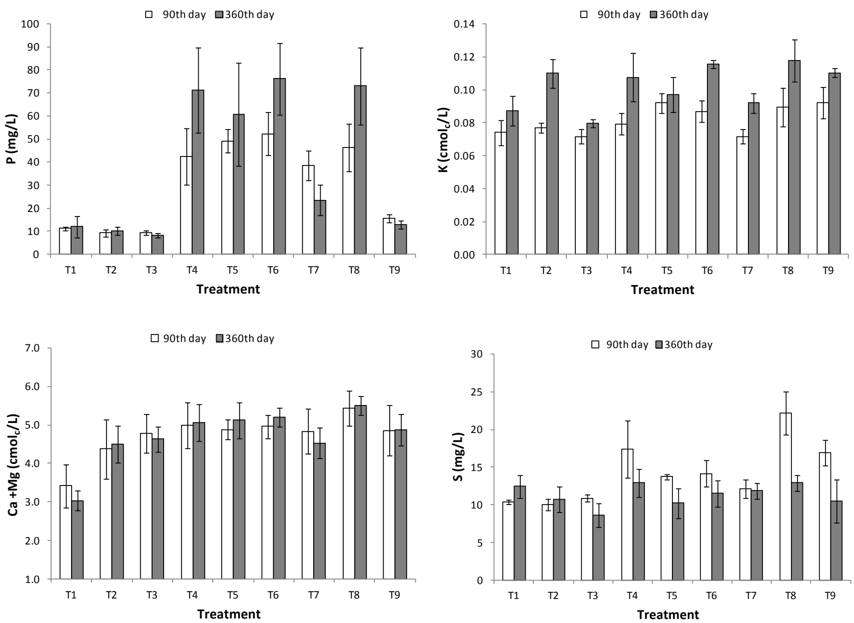


Figure 4. Effect of organic and mineral sources on chemical soil attributes at the 90th and 360th days of application and superficial incorporation of the treatments: a) extractable P by Mehlich-1 (mg L-1); b) exchangeable K+ (cmolc L-1); c) Ca2+ + Mg2 (cmolc L-1); and S (mgL-1). Embrapa Temperate Agriculture, Pelotas-RS, Brazil, 2013.

Final considerations and Recommendations

This study shows that certain organic and mineral sources may have immediate effect on the nutrient supply for crops, resulting in grain productivity that resembles those obtained with high solubility fertilizers. However, despite already being common knowledge, it is important to emphasize the negative effect on grain productivity of concomitant applications of limestone and natural phosphates. Such problem can be easily solved with the application of P2O5 combined with an organic or mineral source of greater solubility.

The Granodiorite tailings obtained at Pedreira Silveira de Pelotas (RS) quarry and used as a source of potassium and other nutrients in agriculture proved itself a viable alternative at a regional level. Even though it might need larger doses when compared to high solubility sources, it has a clear potential for releasing K to plants, even for short term crops as maize and wheat. The dose required for the total correction and for the maintenance of crops such as maize can be high (around 7 t ha-1), especially when it is desired to immediately correct low or medium levels of K, as it is the case for the Albaqualf of this study. In this condition, there is the option of gradual correction of fertility level, applying annual doses of 3 t ha-1 , which would provide approximately 65 kg ha-1 of K2O, considering the content of 4.33 % of K2O and a release efficiency of 50% of K2O added annually.

References

BAMBERG, A.L., SILVEIRA, C.A.P., POTES, M.L., PILLON, C.N., LOUZADA, R.M., CAMPOS, A.A. Dinâmica de liberação de nutrientes disponibilizados por diferentes tipos de rochas em colunas de lixiviação. In: CONGRESSO BRASILEIRO DE CIÊNCIA DO SOLO, 33. 2011. In: Anais.Uberlândia, MG, 2011.

COMISSÃO DE QUÍMICA E FERTILIDADE DO SOLO – CQFS-RS/SC. Manual de adubação e de calagem para os Estados do Rio Grande do Sul e de Santa Catarina. 10.ed. Porto Alegre: Sociedade Brasileira de Ciência do Solo / Comissão de Química e Fertilidade do Solo, 2004. 400p.

LANDEWEERT R., HOFFLUND E., FINLAY R.D., VAN BREEMEN N. Linking plants to rocks: Ectomycorrhizal fungi mobilize nutrients from minerals. Trends in Ecology and Evolution. v.16, p.248-254, 2001.

PANDOLFO, C.M.; TEDESCO, M.J. Eficiência relativa de frações granulométricas de calcário na correção da acidez do solo. Pesquisa Agropecuária Brasileira, Brasília, v. 31, n. 10, p. 753-758, 1996.

PEREIRA, H.S.; KORNDÖRFER, G.H.; MOURA, W.F.; CORREA, G.F. Extratores de silício disponível em escórias e fertilizantes. Revista Brasileira de Ciência do Solo, v.27, p.265-274, 2003.

TEDESCO, M.J., GIANELLO, C., BISSANI, C.A., BOHNEN, H. & VOLKWEISS, S.J. Análises de solo, plantas e outros materiais. 2. ed. Porto Alegre, Universidade Federal do Rio Grande do Sul, 1995. 174p. (Boletim técnico, 5).