USE OF ROCK POWDER ASSOCIATED WITH BOVINE MANURE IN LATOSSOLO VERMELHO CULTIVATED WITH WHEAT

Lenir Fátima Gotz[1,2], Alfredo Castamann[3], Felipe Piovesan[3], Bruna Leticia Anzolin[3], Talissa Andressa Herek[3], Willian Miguel Mikoanski[3], Yohanne Larissa Rita[1]

ABSTRACT – The use of rock powders as a source of nutrients aim costs reduction and environmental problems associated with soluble sources. Thus, the aim of this study was to evaluate the use potential of different rock powder doses, associated or not with bovine manure, after two applications in approximately one year, as a source of nutrients for wheat and its effect on soil chemical attributes. The sources were applied, without incorporation, in two successive crops, at the rates of 0, 3, 6, 9 and 12 Mg ha^{-1} of rock powder, isolated or associated to 17 Mg ha^{-1} and 28 Mg ha^{-1} of bovine manure, on first and second applications, respectively. The experiment was carried out in completely randomized blocks, in a 2×5 (bovine manure × rock powder doses) factorial arrangement with three replicates. The use of bovine manure resulted in increments in the following variables: plant height, number of spikelets per spike, number of grain per spike, grain yield, mass of one thousand grains and soil phosphorus and calcium (Ca^{2+}) contents. The association of rock powder, at dose of 3 Mg ha^{-1}, and bovine manure promoted reduction of soil potential acidity (1.54 cmol$_c$ dm^{-3}) and increase soil Mg^{2+} content (0.9 cmol$_c$ dm^{-3}). The application of rock powder doses does not improve wheat yield and soil chemical attributes after two applications in approximately one year. In contrast, the application of bovine manure, independently of the rock powder dose, results in improvements in these variables.

Keywords: alternative fertilization, basalt, organic fertilization, remineralizer, *Triticum aestivum*.

USO DE PÓ DE ROCHA ASSOCIADO A ESTERCO BOVINO EM LATOSSOLO VERMELHO CULTIVADO COM TRIGO

RESUMO – O uso de pós de rocha como fonte de nutrientes visa à redução dos custos e dos problemas ambientais associados às fontes solúveis. Dessa forma, objetivou-se com este estudo avaliar o potencial de utilização de diferentes doses de pó de rocha, associado ou não ao esterco bovino, após duas aplicações em aproximadamente um ano, como fonte de nutrientes ao trigo e seu efeito nos atributos químicos do solo. As fontes foram aplicadas, sem incorporação, em dois cultivos sucessivos, nas doses de 0, 3, 6, 9 e 12 Mg ha^{-1} de pó de rocha, isoladamente ou associado a 17 Mg ha^{-1} e 28 Mg ha^{-1}de esterco bovino, na primeira e segunda aplicação respectivamente. O experimento foi realizado em blocos ao acaso, em arranjo fatorial 2 x 5 (esterco bovino x dose de pó de rocha), com três repetições. O uso de esterco bovino resultou em incrementos nas variáveis: altura de plantas, número de espiguetas por espiga, número de grãos por espiga, produtividade, massa de mil grãos e teores de fósforo e cálcio (Ca^{2+}) no solo. A associação de pó de rocha, na dose de 3 Mg ha^{-1}, e esterco bovino promoveram a redução da acidez potencial (1,54 cmol$_c$ dm^{-3}) e o aumento no teor de Mg^{2+} (0,9 cmol$_c$ dm^{-3}) no solo. A aplicação de pó de rocha não melhora a produtividade do trigo e os atributos químicos do solo após duas aplicações em aproximadamente um ano. Por outro lado, a aplicação de esterco bovino, independente da dose de pó de rocha, resulta em melhorias nestas variáveis.

Palavras chave: adubação alternativa, adubação orgânica, basalto, remineralizador, Triticum aestivum.

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[1] Federal University of Paraná, Rua dos Funcionários, no1540, Juvevê, CEP 80035-050, Curitiba, PR, Brazil.
[2] Contact for correspondence: lenir_gotz@hotmail.com.
[3] Federal University of Fronteira Sul, ERS 135 - Km 72, no 200, CEP 99700-970, Erechim, RS, Brazil.

INTRODUCTION

The wheat (*Triticum aestivum* L.) stands out for being one of the main food of humanity, besides being used in animal food. The relevance of this crop extrapolate the social aspect, because it represents approximately 30% of world grain production (Bona et al., 2016).

Although the good potential, the production of wheat in Brazil has not been enough to meet internal demand, which results in the importation of this cereal. This fact may be attributed to the high cost of the production, to the low price paid for the product and to climatic instability, which demotivated their cultivation, primarily in Rio Grande do Sul State (Georgin et al., 2014). Thus, the achievement of studies with alternative practices that search the reduction of the costs justifies it, especially in relation to soluble fertilizers, because those are responsible for 24,8% of production cost (Bona et al., 2016).

Some nutrients available from soluble sources may be leaching and, therefore, contaminate the surface and groundwater resources (Cola & Simão, 2012). Furthermore, the use of soluble sources may result in economic problems, because Brazil imports approximately 70% of used NPK, and, due to the high acquisition cost, increase the indebtedness of farmers (ANDA, 2016).

In this context, it has been observed a greater number of research related to the use of rock powders (remineralizers), with the objective to evaluate the ability of these sources to substitute or complement other soluble and/or organic sources (Hanisch et al., 2013). Among the advantages of the use of rock powder, the improvement of soil quality and the prolonged residual effect has been emphasized (Ramos et al., 2014). However, the slow solubilization and liberation of nutrients to plants constitutes a challenge to be overcame, because, in the short term, this source is less responsive, when compared to soluble mineral sources (Cola & Simão, 2012).

The solubilization of rock powders is a process associated to biological activities, which may result in lower efficiency if its use is not associated to cultural practices that stimulate the soil microbiota (Brugnera, 2012). Ferreira et al. (2009) observed increase potential of bean productivity with the association of manure and basalt powder, in relation to the use of the basalt powder isolated. Therefore, the use of rock powder, associated to animal manures, is able to accelerate the solubilization and the availability of the nutrients for plants.

Thus, the aim of this study was to evaluate the potential of use of different rock powder doses, associated or not to bovine manure, after two applications in approximately one year, as a source of nutrients for wheat and its effect on soil chemical attributes.

MATERIAL AND METHODS

The experiment was conducted at Federal University of Fronteira Sul in Erechim City, in Rio Grande do Sul State. The soil of the experimental area is classified as Latossolo Vermelho Aluminoférrico húmico, according to the Brazilian Soil Classification System (SiBCS) (Embrapa, 2018), which corresponds to Oxisol, in American Soil Taxonomy System (Soil Survey Staff, 2014). According to Köppen classification, the climate of the region is fundamental type C, subtype fa, characterized as humid subtropical, without defined dry season, with the temperature of the hottest month exceeding 22°C, average annual temperature of 18.2ºC and average annual precipitation of 1,869 mm (Matzenauer et al., 2011).

Previously the nutrient sources application, soil samples were collected in the 0-10 cm layer, to determine soil chemical attributes and clay content (Table 1).

The experiment was carried out in completely randomized blocks, in a factorial arrangement 5 (A) x 2 (B), with three replicates. Rock powder doses were allocated (0, 3, 6, 9 and 12 Mg ha^{-1}) in factor A, and in factor B applying or not the bovine manure, totaling ten treatments. The treatments were applied in two consecutive crops, November 2015 and June 2016. One fact that stands out is that the experimental units received the same treatments in both moments.

In 2015, the dose of bovine manure was 17 Mg ha^{-1}, while in 2016, it was 28 Mg ha^{-1}. The difference on doses of bovine manure used was established from the soil analysis result, based on indications to crops – beans in the first cultivation and wheat in the second cultivation, respectively – according to recommendations of CQFS – RS/SC (2004). The doses were calculated to meet N, P and K crop demands, and were defined

Table 1 - Clay content and chemical attributes of a Latossolo Vermelho previous the implementation of the experiment, in the 0-10 cm layer

0-10 cm layer											
Clay	pH	pH	P	K	O.M.	Al^{3+}	Ca^{2+}	Mg^{2+}	$Al^{3+} + H^{+}$	CTC $_{(pH7,0)}$	V
(%)	$_{(H2O)}$	SMP		(mg dm^{-3})	(%)	(cmol$_c$ dm^{-3})					%
> 60	5.6	6.0	4.5	155.0	3.8	0.0	6.4	3.0	4.4	14.2	69.0

according to the highest nutritional requirement, P in the first one and N in the second one, respectively.

The rock powder applied in November 2015, before bean sowing, was obtained in an extrusive igneous rock miner of Serra Geral formation, located in the municipality of São Domingos do Sul (RS) and had the following composition: pH: 7.90; N: 0.04%; total P: 0.10%; K_2O: 0.38%; CaO: 0.38%; MgO: 0.21% and; S: <0.01%. The bovine manure applied in November 2015 had the following composition: 0.35% of P_2O_5; 0.35% of K_2O and; 0.77% of Ca. The rock powder applied in June 2016, before sowing the wheat, had the following composition: SiO: 51.13%; Al_2O_3: 13.99%; CaO: 19.79%; MgO: 6.70%; K_2O: 0.41%; Na_2O: 2.10%; MnO: 0.19% and; P_2O_5: 0.12%. The bovine manure applied in June 2016 had the following contents: 1.2% of N; 0.41% of P_2O_5 and; 0.46% of K_2O.

The sources were distributed on the soil surface in isolation, manually, in the useful area of each plot (3 m x 2 m), without incorporation, due to the management of the soil in no-tillage system. Each experimental unit presented 5 m long by 2.72 m wide, totalling 13.6 m^2. The wheat sowing was carried out on Jun 28th 2016, using the cultivar TBIO Sinuelo, with 0.17 m spacing, 16 lines per experimental unit and aimed a final population of 310 m^{-2} plants.

The wheat harvesting was carried out on June 20th, 2016. The following variables were evaluated: plants height, number of tillers per plant, number of spikelets per spike and number of grain per spike were determined in five plants in the useful area of each plot, randomly defined; grain yield (Mg ha^{-1}), through manual harvesting of eight central lines in 3 m length, totalling 4.08 m^2, which the obtained value was corrected to 13% moisture; mass of one thousand grains from each experimental unit, verified according with the methodology indicated by Brasil (2009) and corrected to 13% moisture and; number of spikes per area, obtaneid from the counting of spikes in 1 m^2. The determination of grain moisture followed the methodology indicated by Brasil (2009).

To evaluate the variation of chemical atributes, soil samples were collected with the aid of an auger sampler, at 0-10 cm soil depth, in the useful area of each experimental unit, in December 12th 2016 (390 days after the first application of nutrient sources and 171 days after second application). The sampling procedure followed the methodology indicated by CQFS-RS/SC (2004) for systems without soil stirring (no-tillage system). Each sample was composed by 8 subsamples. Samples were air-dried, sieved (0.02 mm) and the following chemical analyzes were carried out: active acidity by pH (H_2O) in relation 1:1 v/v soil/water (Tedesco et al., 1995) and by pH ($CaCl_2$), determined in a 0.01 mol L^{-1} $CaCl_2$ suspension (1:2.5 v/v soil/solution) (Embrapa, 2009); potential acidity ($H+Al^{3+}$), extracted with calcium acetate solution 0,5 mol L^{-1}, pH 7,1-7,2 and determined by titulometry (Embrapa. 2009); available soil P content was extracted by Mehlich-1 and determined by UV spectrophotometry; available soil Ca^{2+} and Mg^{2+} contents were extracted by the solution 1 mol L^{-1} KCl and determined by atomic absorption spectrometry (Tedesco et al., 1995).

The results were submitted to analysis of variance, the means were compared by the Tukey test at 5% probability (qualitative variable) and regression with evaluation of the predictive capacity of the proposed model (quantitative variable). All analyzes were performed using the statistical software SISVAR version 5.6 (Ferreira, 2014). Results of soil Ca^{2+} content were transformed ($\sqrt{(y+0,5)}$), due to the high coefficient of variation.

RESULTS AND DISCUSSION

Wheat yield components

The application of increasing rock powder doses did not influence the variables: plants height, number of tillers per plant, number of spikelets per spike, number of grain per spike, grain yield, mass of one thousand grains and number of spikes per area (Table 2). Similarly, there was no interaction between the factors tested (rock powder doses x bovine manure) on these variables (Table 2). Such behavior may be attributed to the slow solubilization of the nutrients present in the rock powder and the consequent slow liberation to the plants (Hanisch et al., 2013). Hanisch et al. (2013) did not observe effect of rock powder doses (0, 2, 4, 8 and 12 Mg ha^{-1}), with incorporation (plowing and harrowing), on the yield of maize and soybean crops grown in a Latossolo Vermelho, in Santa Catarina State.

The application of bovine manure, independent of the presence or not of rock powder, influenced positively the variables: plants height, number of spikelets per spike, number of grain per spike, grain yield, and mass of one thousand grains (Table 3). This result may be explained by immediate availability of nutrients provided by bovine manure, emphasizing the Nitrogen (N), because this is the most demanded nutrient by wheat plants, and their availability is considered as a determinant factor of yield potential of the crop (Malavolta, 2006; Bona et al., 2016). In addition, one of the effects of N deficiency is the reduction of plant growth and, when severe, it causes a general yellowing on the plant, starting from the older leaves (Põtfker & Roman, 1998).

According to Bredemeier & Mundstocko (2001), the intense demand of N by wheat plants occurs preferentially between the emergence and the emission of the seventh leaf of the main stem, because in this period, there is the establishment of the number of differentiated spikelets and, in consequence, of the number of grain per spike, which is directly related to crop productivity. Thus, the largest number of spikelets and grains per spike obtained with the application of bovine manure (Table 3), independent of the rock powder dose, may be attributed to the supply of N demand by the crop at the time of establishment of these components, which was not verified with the application of increasing rock powder doses and without the addition of bovine manure.

Table 2 - Plants height (Height), number of tillers per plant (Tillers/plant), number of spikelets per spike (Spikelets/plant), number of grain per spike (Grain/spike), grain yield, mass of one thousand grains (Mass 1000 grains) and number of spikes per area (Spikes /area) of wheat plants (cultivar TBIO Sinuelo) subjected to the application of rock powder doses (Mg ha^{-1}) in the presence (P) and absence (A) of bovine manure, in a Latossolo Vermelho

Doses	Height (m)		Tillers/ plant		Spikelets/ spike		Grain/ spike		Grain Yield (Mg ha^{-1})		Mass 1000 grains (g)		Spikes/ area	
	A	P	A	P	A	P	A	P	A	P	A	P	A	P
0.0	1.0	1.1	1.6	1.7	13.2	13.5	24.1	28.8	1494.1	2283.4	33.8	38.6	252.0	289.3
3.0	0.9	1.1	1.7	1.5	11.2	14.1	15.7	28.2	1128.7	2260.7	32.1	36.0	272.0	294.7
6.0	0.9	1.0	1.4	1.7	11.8	14.8	21.4	28.4	1210.0	2118.2	32.7	34.9	308.0	273.3
9.0	1.0	1.0	1.7	1.7	13.2	13.8	25.2	27.0	1380.3	1931.0	33.7	38.1	256.0	297.3
12.0	1.0	1.1	1.7	2.0	10.9	13.6	18.9	29.1	1737.9	2255.2	34.2	36.2	304.0	297.3

Data presented do not differ by the Tukey test at 5% of error probability.

Table 3 - Effect of the presence or absence of bovine manure, independent of rock powder dose, on the plants height, on the number of spikelets per spike, on the number of grain per spike, on the mass of one thousand grain and on the grain yield, TBIO Sinuelo wheat cultivar cultivated on a Latossolo Vermelho(1)

Bovine manure	Plants height (m)	Number of spikelets per spike	Number of grain per spike	Mass of one thousand grain (g)	Grain yield (Mg ha^{-1})
With	1.06 a	13.97 a	28.31 a	36.73 a	2.169,70 a
Without	0.98 b	12.02 b	21.05 b	33.30 b	1.390,20 b
C.V. (%)	7.44	12.71	18.60	6.27	20.72

(1) Means followed by distinct letters in the column differ by the Tukey test (P<0.05).

The availability of N through the addition of bovine manure may also have contributed to the increase of the leaf area index of the plant. In turn, influenced the interception of solar radiation, promoting increases in wheat productivity components (number of spikelets per spike, number of grains per spike and mass of one thousand grains) and, consequently, in grain yield. This performance was observed by Melero et al. (2013), when the authors evaluated the influence of plant cover residues and doses of N in wheat. However, this data was not evaluated in this research.

Pauletti et al. (2008), with increase of the bovine liquid manure dose (0, 15, 30 and 45 m^3 ha^{-1}), verified a linear increment in wheat grain yield. The authors emphasized that this results were, possibly, because the organic fertilization contributed completely to meet the nutritional needs of the crop.

Considering that the number of tillers per plant was not modified with the treatments (Table 2), consequently, the treatments did not influence the number of spikes per area (square meter) (Table 2), because this variable is dependent on the number of fertile tillers emitted by the plant. However, these results were compensated by the change on the other productivity components (number of spikelets per spike, number of grains per spike and mass of one thousand grains). Valério et al. (2009) emphasized that there are genotypes that presented reduced tillering potential, because presented a greater relation of compensatory effect with the other components.

Soil chemical attributes

The active acidity, evaluated by $pH_{(H2O)}$ and by $pH_{(CaCl2)}$, was not influenced by the treatments tested (Table 4). Although rock powder, derived from basalt, presents relatively high CaO and MgO contents (above 10% and 6%, respectively), their probable non-solubilization or their slow solubilization resulted in maintaining the pH value of the soil. Such performance can also be explained by buffering capacity of soil.

Similarly, Hanisch et al. (2013) did not observe difference in soil pH after 42 months of application of basalt powder (0, 2, 4, 8 and 12 t ha^{-1}) in Latossolo Vermelho. It stands out that in an experiment conducted by Hanisch et al. (2013) the basalt powder were incorporated in soil with plowing and harrowing. In contrast, Inocêncio et al. (2009) verified influence of application of the basalt ground doses (0.00, 12.50, 25.00, 37.50, 50.00 and 62.50 g dm^{-3}) on soil pH, both in H_2O, and in $CaCl_2$ solution, after 90 days of incubation, but with differences between soil types, due the different buffering capacity of soil. The soil with higher clay and organic matter content was less influenced due to its higher buffering power, while the soil with lower clay and organic matter content was more influenced due to its lower buffering power.

In relation to the potential soil acidity ($H^+ + Al^{3+}$), the analysis of variance indicated that there was interaction between the treatments tested (Table 5). Effect of rock powder doses was observed, associated or not to the use of bovine manure. It can be observed that the application of 3 Mg ha^{-1} of rock powder associated with bovine manure resulted in lower potential acidity, compared to non-association. The bovine manure utilized presented pH close to neutrality (6.6), which indicates that the application of this source may have contributed with the reduction of potential acidity. Araujo et al. (2011) verified a 6% reduction in potential soil acidity with application of manure (pH 7.3), pointing that this performance resulted on the addition of basic organic material and considerable quantity of Ca^{2+} in its composition.

Table 4 - Active acidity (pH(H_2O) and pH ($CaCl_2$)), soil P and Ca^{2+} content, after application of rock powder doses (Mg ha^{-1}) in the presence (P) and absence (A) of bovine manure in a Latossolo Vermelho

Dose (Mg ha^{-1})	pH (H_2O)		pH ($CaCl_2$)		P (mg dm^{-3})		Ca^{2+} ($cmol_c$ dm^{-3})	
	A	P	A	P	A	P	A	P
0.0	5,23	5.18	4.67	4.65	9.41	24.49	3.35	4.70
3.0	5.12	5.35	4.65	4.70	7.88	25.43	3.66	7.27
6.0	4.98	5.15	4.69	4.70	10.42	26.70	3.57	3.23
9.0	5.18	5.33	4.72	4.67	14.41	21.36	1.38	4.44
12.0	5.49	5.17	4.72	4.67	8.39	38.73	2.83	3.66

Data presented do not differ by the Tukey test at 5% of error probability.

Table 5 - Potential soil acidity (|$H+Al^{3+}$|) due the interaction of rock powder doses and bovine manure in a Latossolo Vermelho[1]

Treatments	Rock powder doses (Mg ha^{-1})				
	0	3	6	9	12
	$H+Al^{3+}$ (cmol$_c$ dm^{-3})				
With manure	3.36 a	2.48 b	2.94 a	3.36 a	2.64 a
Without manure	2.64 a	4.02 a	3.52 a	2.32 b	2.26 a
C.V. (%)			18.48		

[1] Means followed by distinct letters in the column differ by the Tukey test ($P<0.05$), comparing the use or not of bovine manure within each rock powder dose.

When rock powder was not associated with bovine manure, there was an increase in potential acidity with the application of lower dose (3 Mg ha^{-1}) and decrease with the higher dose (9 Mg ha^{-1}). Such performance was also observed by Melo et al. (2012), evaluating eight basalt powder doses (0, 2, 4, 8, 12, 24, 48 and 96 Mg ha^{-1}) and attributed the increment in this variable due to the increase of Al^{3+}, resultant of weathering of silicates, at the start of the rock powder reaction with the soil solution. In the case of the reduction of potential acidity with higher doses, it may have been promoted by the reaction of calcium and magnesium carbonates with the soil hydrogen, liberating water and carbon dioxide, precipitating Al^{3+} in the hydroxide form (Melo et al., 2012). It is emphasized that the rock basalt powder used by these authors was incubated and humus of organic compost was added to the dose equivalent to 3% of organic matter (0.3 g kg^{-1} of soil).

No differences were observed in soil P content with application of increasing rock powder doses (Table 4). The basalt powder utilized in this research presented on average 0.11% of P_2O_5, which can also explain the non-increase on the content of this nutrient with the application of the product, further of the slow solubilization attributed to this source. Erhart (2009) evaluated the application of basalt powder doses (0, 10, 20 and 50 Mg ha^{-1}), with 0.45% de P_2O_5, and verified increase of soil P content (Mehlich-1) until the dose 20 Mg ha^{-1}, one year after application, in a Neossolo Litólico, in Santa Catarina State.

In contrast, there was a significant effect on this variable in treatments that received the bovine manure application, independent of the dose of rock powder (Table 6). The interpretation of soil P contents based on the parameters indicated in CQFS-RS/SC (2004) resulted in contents considered high and very high, without and with manure, respectively (Table 6). The increase in soil P content was also observed in studies with the application of bovine manure conducted by Caetano & Carvalho (2006). Such performance can be explained by the presence of this nutrient in manure and their immediate availability, compared to rock powder.

The application of increasing rock powder doses did not result in changes on soil Ca^{2+} content (Table 4). Similarly, there was no interaction between the evaluated factors (Table 4). In contrast, the application of bovine manure, independent of rock powder dose, modified the soil Ca^{2+} content (Table 5). The Ca^{2+} content previous the instalation of experiment was interpreted as high (CQFS-RS/SC, 2004). With the application of bovine manure the content maintained as high. In contrast, without the application of manure, the content of this nutrient was interpreted as medium (CQFS-RS/SC, 2004). Such performance demonstrate that the rock powder did not provide Ca^{2+}, due its slow solubilization, while the application of manure, due to the presence of Ca^{2+} in its composition and its immediate availability, maintained a high content of this nutrient in soil.

Araujo et al. (2011) evaluated five proportions of bovine manure in association with urea (0, 25, 50, 75 and 100%) and observed increase of soil Ca^{2+} content with the application of the manure, at 0-10 cm and 10-20 cm soil depths. The higher contribution of the Ca^{2+}, in the experiment conducted by theses authors, resulted with 100% of bovine manure treatment.

In relation to the soil Mg^{2+} content, the analysis of variance indicated that there was interaction between the factors tested (Table 7). Within each dose, it was observed that only at the dose 3 Mg ha^{-1} there was a difference between the presence and absence of bovine

Table 6 - Soil P and Ca^{2+} contents as a function of the presence and absence of bovine manure, independent of the dose of rock powder in a Latossolo Vermelho[1]

Treatments	P(mg dm^{-3})	Ca^{2+}($cmol_c$ dm^{-3})
With manure	29.34 a	4.36 a
Without manure	10.10 b	3.01 b
C.V. (%)	37.30	23.86

[1] Means followed by distinct letters in the column differ by the Tukey test (P<0.05).

Table 7 - Soil Mg^{2+} content obtained due the application of rock powder doses, associated or not to bovine manure in a Latossolo Vermelho[1]

Treatments	Rock powder doses (Mg ha^{-1})				
	0	3	6	9	12
	H+Al^{3+} ($cmol_c$ dm^{-3})				
Without manure	1.57 a	0.93 b	1.63 a	1.87 a	1.93 a
With manure	1.30 a	1.83 a	1.97 a	1.80 a	1.80 a
C.V. (%)			13.64		

[1] Means followed by distinct letters in the column differ by the Tukey test (P<0.05), comparing the use or not of bovine manure within each rock powder dose.

manure. With the application of the other rock powder doses, the use of manure did not produce differences in the values of this analyzed variable. The utilization of 3 Mg ha^{-1} of rock powder in the presence of bovine manure presented higher soil Mg^{2+} content, compared to the content obtaneid with the utilization only for rock powder (Table 7).

On the other hand, applying 3 Mg ha^{-1} of rock powder, without bovine manure, caused a decrease in the Mg^{2+} content (Table 7), which may be related to the occurrence of isomorphic substitutions, as highlighted by Hanish et al. (2013). In addition, in the dissolution reactions the released elements are not always kept in solution in the same stoichiometric proportion of the mineral composition. In natural environments, precipitation and formation of secondary phases due to supersaturation is the dominant mechanism in silicates incongruent dissolution, which is more common than the congruent one (Kämpf et al., 2009). However, even though the dissolution was incongruent in the larger doses, there was an increase in the contents. Since added amounts were expressive, it was not possible to state the manure contribution.

The Mg^{2+} content resulted in a tendency of increasing values as a function of the rock powder doses, both in isolation and in association with the use of manure. It should be noted that in these cases a linear and growing trend is expected, however the mathematical models obtained with low predictive capacity (R^2 = 35.7% and R^2 = 52.25%, respectively), which is why the figures with these values are not shown.

Ferreira et al. (2009) did not verified differences in the soil Mg^{2+} content with the application of 2.5 and 5 Mg ha^{-1} of basalt powder, associated with manure, or in isolation (incorporated with rotatory hoe), in a Cambissolo Húmico, in Santa Catarina State. Hanisch et al. (2013) observed reduction of soil Mg^{2+} content, with the increase of basalt powder doses (0, 2, 4, 8 and 12 Mg ha^{-1}), in 14 months and in 21 months after application. In 9 months and in 42 months after application, they did not verify significant results for this variable. These authors, working in a Latossolo Vermelho, incorporated basalt powder in soil with plowing and harrowing.

CONCLUSIONS

Rock powder is not effective in improving wheat yield and soil chemical atributes after two applications in approximately one year.

The use of bovine manure increases the wheat yield and improves the soil chemical attributes.

The rock powder, although its initial non-effectiveness, can bring contributions over successive crops, due to its residual effect, thus requiring studies in this area to be continued.

Although the possible advantages of using rock powder as nutrients source, results obtained in this present study indicate that one of the main limitations of this product in agriculture is its slow solubilization. However, the use of lower particle sized rock powder, as well as the use of microorganisms and the product incorporation in soil may increase the solubility and therefore the nutrients availability to the plants. Complementary studies are necessary to elucidate such hypothesis.

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