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ROCK POWDER AND ORGANIC FERTILIZATION IN SOIL CULTIVATED WITH BLACK BEAN

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ABSTRACT - The use of rock powder as a source of nutrients to plants can be an alternative or complement to mineral soluble and organic sources. Thus, the aim of this study was to evaluate the potential of different rock powder doses, associated or not with livestock manure, as a source of nutrients for bean and its effect on soil chemical attributes. The treatments consisted of the application of 0, 3, 6, 9 and 12 Mg ha^{-1} of rock powder, associated or not with livestock manure (17 Mg ha^{-1}), applied on the soil surface, without incorporation. The experiment was carried out in completely randomized blocks, with three replicates, and in a factorial arrangement (5x2). The grain yield of bean, height plants and number of plants m^{-2} were not influenced by the treatments. On the other hand, the application of 3 Mg ha^{-1} of rock powder associated with livestock manure resulted in a higher number of grains per pod, and the increase in the rock powder doses affected the number of pods per plant. In the soil, only the manure application, regardless of the rock powder, resulted in effects: reduced potential acidity and potential cation exchange capacity, and increased phosphorus content and base saturation. Thus, rock powder, associated or not with livestock manure, is not effective in improving bean yield and soil chemical attributes after approximately three months of application, and the use of livestock manure, regardless of the rock powder doses, improves some chemical attributes in the soil.
Keywords: alternative fertilization, livestock manure, remineralizer, soil fertility.

PÓ DE ROCHA E ADUBAÇÃO ORGÂNICA EM SOLO CULTIVADO COM FEIJÃO PRETO

RESUMO - O uso de pó de rocha como fonte de nutrientes às plantas pode constituir em alternativa ou complementação às fontes minerais solúveis e orgânicas. Assim, o objetivo deste estudo foi avaliar o potencial de diferentes doses de pó de rocha, associadas ou não ao esterco bovino, como fonte de nutrientes ao feijoeiro e seu efeito nos atributos químicos do solo. Os tratamentos consistiram na aplicação de 0, 3, 6, 9 e 12 Mg ha^{-1} de pó de rocha, associado ou não ao esterco bovino (17 Mg ha^{-1}), aplicados na superfície do solo, sem incorporação. O delineamento experimental foi em blocos casualizados, com três repetições e em esquema fatorial (5x2). A produtividade de grãos do feijoeiro, a altura de plantas e o número de plantas m^{-2} não foram influenciados pelos tratamentos. Por outro lado, a aplicação de 3 Mg ha^{-1} de pó de rocha associado ao esterco bovino resultou em maior número de grãos por vagem, e o aumento das doses de pó de rocha prejudicou o número de vagens por planta. No solo, somente a aplicação de esterco, independente do pó de rocha, resultou em efeitos: redução da acidez potencial e da capacidade de troca de cátions potencial, aumento no teor de fósforo e na saturação por bases. Assim, o pó de rocha, associado ou não ao esterco bovino, não é eficaz em melhorar a produtividade do feijão e os atributos químicos do solo após aproximadamente três meses da aplicação, e o uso de esterco bovino, independente das doses de pó de rocha, melhora alguns atributos químicos do solo.
Palavras-chave: adubação alternativa, esterco bovino, remineralizador, fertilidade do solo.

INTRODUCTION

One of the basic requirements for the crop to manifest its productive potential is the availability of nutrients in the soil in absorbable forms by the plant, because they have specific functions to the metabolism and development of plants (MARSCHNER, 2012). In areas where productive activities are established in Brazil, the common feature is the low availability of nutrients, which implies the adoption of practices to improve soil fertility (LOPES; GUILHERME, 2007). Thus, it is necessary to supplement the supply of nutrients to plants.

In general, soluble mineral fertilizers are used, which quickly releases nutrients and meets the crops requirements. However, there are environmental problems associated with the inappropriate use of these sources, for example, eutrophication. In addition to economic problems due to the dependence of some countries on the soluble mineral fertilizers supply (THEODORO et al., 2012). In the case of Brazil, the import is 60% of the NPK used (ANDA, 2016).

In this context, the number of researches related to the use of rock powder to replace or complement

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soluble and/or organic sources has increased (HANISCH et al., 2013; SOUZA et al., 2013; RAMOS et al., 2017; SOUZA et al., 2018; GOTZ et al., 2019). Souza et al. (2018) observed that rock powder (gneiss) has potential for use in agriculture as nutrients source and can improve the chemical attributes of the soil. Melo et al. (2012) verified that the use of rock powder increased the content of calcium, magnesium, zinc, iron and cooper in the soil, and decreased the potential acidity. On the other hand, Ferreira et al. (2009) and Gotz et al. (2019) did not find a rock powder effect (basalt) on the bean and wheat yield, respectively.

The main limitation of the rock powder use in agriculture is associated with the slow solubilization and release of nutrients to plants (COLA; SIMÃO, 2012). This solubilization involves a process associated with biological activities. Then, due to the microorganisms present in the manure, this, when associated with rock powder, can accelerate the solubilization and the availability of nutrients for plants. Based on this, the aim of this study was to evaluate the potential of different rock powder doses, associated or not with livestock manure, as a source of nutrients for bean and its effect on soil chemical attributes.

MATERIAL AND METHODS

The experiment was conducted at experimental area of Federal University of Fronteira Sul in Erechim City, in Rio Grande do Sul State. According to Köppen classification, the climate of the region is fundamental type C, subtype fa (*Cfa*), characterized as humid subtropical, without defined dry season, with the temperature of the hottest month exceeding 22ºC, average annual temperature of 18.2ºC and average annual precipitation of 1,869 mm (MATZENAUER et al., 2011).

The soil of the experimental area is classified as Latossolo Vermelho Aluminoférrico típico, according to the Brazilian Soil Classification System (EMBRAPA, 2018; STRECK et al., 2018). The area has been fallowing since 2010 and previously the nutrient sources application, soil samples were collected in the 0-10 cm layer, to determine chemical attributes and clay content (Table 1). Rainfall during the crop cycle was 503 mm and the average temperature was 23ºC (Figure 1).

TABLE 1 - Clay content and chemical attributes of a Latossolo Vermelho Aluminoférrico típico previous the implantation of the experiment, in the 0-10 cm layer.

Clay	pH	P	K	Al	Ca	Mg	H + Al	$CEC_{pH7,0}$
(g kg^{-1})	(H_2O)	-------- mg dm^{-3}	---------	--------------------------------		cm$_c$ dm^{-3}	--------------------------------	
>600	5.6	4.5	155	0.0	6.4	3.0	4.4	14.2
Sat. of CEC (%)		S	Zn	Cu	B	Mn	OM	SMP
Bases	Al	------------------------------		mg dm^{-3}	----------------------------		%	index
69	0.0	10	2.0	3.8	0.7	50	3.8	6.0

*CEC: cation exchange capacity, Sat. of CEC: saturation of CEC, OM: organic matter.

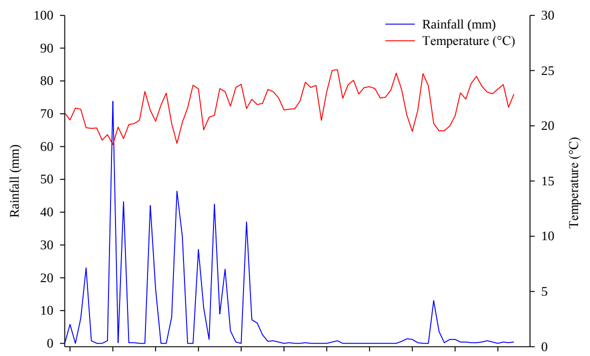

FIGURE 1 - Rainfall and temperature during the bean crop cycle (November 23, 2015 to February 15, 2016).

The experiment was carried out in a randomized complete block design, with treatments factorial design 5 (A) x 2 (B). 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 livestock manure, totaling ten treatments, with three replicates. 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, totaling 13.6 m^2. The sources application was carried out in November 2015, before bean sowing.

The rock powder doses were established considering some generic indications of technical assistants who work with agroecology. The dose reference used was 6 Mg ha^{-1} and was evaluated lower (3 Mg ha^{-1}) and higher (9 and 12 Mg ha^{-1}) doses to try to establish which dose is more appropriate for the conditions evaluated. The dose of livestock manure used was established from the soil analysis result (Table 1), based on indications to bean crop, according to recommendations of CQFS (2004). The dose was calculated to meet N, P and K bean demand, and was defined according to the highest nutritional requirement, in this case P.

The rock powder applied was obtained in an extrusive igneous rock miner of Serra Geral formation, located in the municipality of São Domingos do Sul (Rio Grande do Sul State) 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%, S: <0.01%, Cu: 59 mg kg^{-1}, Zn: 66 mg kg^{-1}, Fe: 2.2 mg kg^{-1}, Mn: 466 mg kg^{-1} and B: 2 mg kg^{1}. The livestock manure applied had the following composition: 0.35% of P_2O_5, 0.35% of K_2O and 0.77% of Ca.

The bean sowing was carried out on Nov 23th 2015, using the cultivar BRS Campeiro, with 0.5 m spacing. The seeds were inoculated with *Rhizobium tropici*. The bean harvesting was carried out on Fev 15th, 2016 and the following variables were evaluated: the number of pods per plant, the number of grains per pod and the average plant height, determined in four plants of the useful area of each plot, randomly defined. After, the pods were removed from the plants and dried in an oven with forced air circulation, at temperature of 60ºC, to facilitate the opening of the pods and to the dry grain mass, and after determining the dry grain mass yield. In addition, the final population was obtained by counting the three central lines, in three linear meters, totaling 4.5 m^2 of useful area.

Ten days after the bean harvesting, 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. Each sample was composed by eight subsamples. The sampling procedure followed the methodology indicated by CQFS (2004) for no-tillage system. Samples were dried in an oven with forced air circulation at 50ºC, sieved (0.02 mm) and the following chemical analysis were carried out: pH in water in relation 1:1, potential acidity (H + Al), extraction of Ca and Mg with KCl 1 mol L^{-1}; determination of K and P by the Mehlich^{-1} method; organic matter by moist digestion. In addition, the cation exchange capacity and base saturation were determined. The methodology used was that indicated by 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) and SigmaPlot Version 11 (SYSTAT SOFTWARE, 2010).

RESULTS AND DISCUSSION

Bean yield components

Relative to number of pods per plant was verified effect only for the rock powder doses (Figure 2). This result indicated that the use of rock powder harmed this variable and it is possible that this result was influenced by the water stress in January (Figure 1). It should be noted that this effect did not result in a change in bean yield, because probably the reduction in the number of pods per plant with the application of increasing rock powder doses was compensated by the increase in the mass of grains.

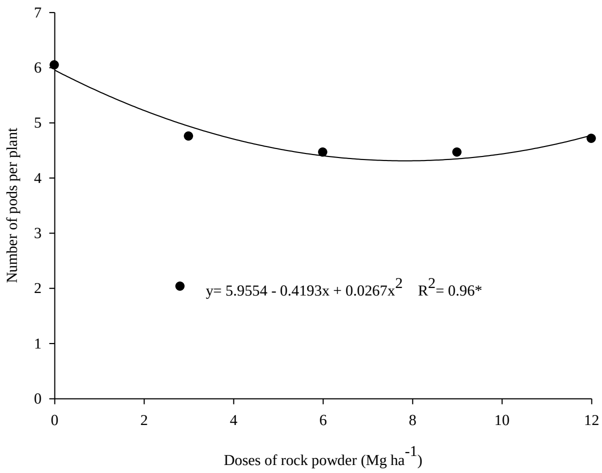

FIGURE 2 - Number of pods per bean plant in function on the rock powder doses in the absence of livestock manure.

In relation to the number of grains per pod, the analysis of variance indicated that there was interaction between the factors tested (Table 2). Within each dose it was observed that only at the dose of 3 Mg ha^{-1} there was a difference between the presence and absence of livestock manure, since the association with livestock manure resulted in a greater number of grains per pod (Table 3). This result indicates that there may have been an effect of the application of rock powder when associated with the use of livestock manure.

As the solubilization of rock powder involves a process strongly associated with biological activities, possibly the microorganisms present in the manure and the effects of manure on soil microbiota contributed to the solubilization and, consequently, release of the mineral elements present in the rock, resulting in benefits for the crop.

TABLE 2 - Number of grains per pod due the interaction of rock powder doses and livestock manure in a Latossolo Vermelho Aluminoférrico típico.

Treatments	Rock powder doses (Mg ha^{-1})				
	0	3	6	9	12
	Number of grains per pod				
Without manure	3.65 a*	3.25 b	4.07 a	4.26 a	3.52 a
With manure	3.87 a	4.12 a	4.25 a	3.73 a	3.80 a

*Means followed by distinct letters in the column differ by the Tukey's test ($p<0.05$), comparing the use or not of livestock manure within each rock powder dose.

The rock powder application associated or not with livestock manure did not influenced the plant height (Table 3). Kosera et al. (2009) observed a lower capacity of rock powder to provide a higher height compared to mineral fertilization. Similarly, there was no effect on grain yield of bean (Table 3), corroborating with Plewka et al. (2009), Ferreira et al. (2009) and Silva et al. (2012).

This performance can be explained by the fact that there was not enough time for the adequate solubilization of rock powder in the soil, because bean are a short cycle crop and rock powder releases nutrients gradually. In addition, these and other assessment parameters may have been affected by water stress in January (Figure 1), precisely in the flowering period and formation of bean pods, which are the most critical for the crop and can cause a reduction in yield, fact only observed by Ferreira et al. (2009).

TABLE 3 - Dry grain yield of bean (Yield), plant height (Height) and number of plants m^{-2} (number of plants) of bean plants (cultivar BRS Campeiro) subjected to the application of rock powder doses (Mg ha^{-1}) in the presence (P) or absence (A) of livestock manure, in a Latossolo Vermelho Aluminoférrico típico.

Rock powder doses (Mg ha^{-1})	Yield (kg ha^{-1})		Height (cm)		Number of plants	
	P	A	P	A	P	A
0	542.1*	387.0	38.7	39.1	23.2	20.5
3	413.1	295.0	39.1	37.4	22.9	19.7
6	428.3	375.1	37.9	38.0	24.0	22.8
9	511.6	410.8	41.0	39.7	21.7	23.2
12	498.4	389.1	41.6	38.0	21.8	24.2

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

Relative to number of plants m^{-2}, the rock powder application isolated or associated with livestock manure did not promote differences in this variable (Table 3). Such performance was already expected because it did not affect the plants emergence, considering that the compounds were applied on the surface and the manure was already tanned. It stands out that the fact of plants population is not different, indicates that the other response variables were not affected by the plant stand.

Soil chemical attributes

The active acidity, evaluated by $pH_{(H2O)}$, was not influenced by the treatments tested (Table 4). Such performance can be attributed to the buffering capacity of the soil, associated the slow solubilization of rock powder. This result corroborates those found by Ferreira et al. (2009) in a Cambissolo Húmico, Silva et al. (2012) in a Nitossolo Bruno, Hanish et al. (2013) and Gotz et al. (2019) in a Latossolo Vermelho. Similarly, no differences were observed in potential acidity with application of increasing rock powder doses (Table 4). It stands out that positive result was observed by Melo et al. (2012) with the addition of basalt doses (in an incubation experiment) in the pH values (increase) and H + Al (reduce). However, the doses used were much higher than in the present experiment (up to 96 Mg ha^{-1}).

On the other hand, a reduction in potential acidity (H + Al) was observed with the application of livestock manure, regardless of the rock powder dose (Table 5). The livestock manure can be presented pH close to neutrality (GOTZ et al., 2019), which indicates that the application of this may have contributed to the reduction of potential acidity. In addition, the considerable presence of calcium (0.77 m m^{-1}) in its composition must also be considerable. Also, in an experiment conducted by Araujo et al. (2011) the manure application (pH 7.3) reduced the 6% of potential acidity in the 10 to 20 cm layer.

Calcium (Ca) and magnesium (Mg) contents were not influenced by the treatments tested (Table 4). Similar results were observed by Silva et al. (2012). Such performance demonstrates that the rock powder did not provide Ca and Mg content, due its slow solubilization. Melo et al. (2012) verified that relatively low increments in Ca and Mg contents, indicating that these elements must be present in minerals with low solubility and slow change, being that the doses tested by this authors were much higher (up to 96 Mg ha^{-1}).

Similarly, the treatments tested did not influence the potassium content (K) in the soil (Table 4). Ferreira et al. (2009) and Silva et al. (2012) also did not verify K increments with rock powder application. According to Ferreira et al. (2009) this was due to the short period of conduction of the experiment and the slow dissolution of nutrients by natural weathering reactions. In addition, the low K content of the rock powder used (0.38% of K_2O).

No differences were observed in phosphorus (P) content with application of increasing rock powder doses (Table 4). This result may be associated with the low P content present in rock powder (0.10% total P) and slow solubilization of the product. Similarly, Gotz et al. (2019) verified no increase in P content in the soil with increasing rock powder doses (0.11% of P). On the other hand, the manure application, regardless of the rock powder dose, increased the P content in the soil (Table 5), due presence of this nutrient in manure (0.35% of P_2O_5) and release to the plant during cultivation. The P content previous the installation of experiment was interpreted as low (CQFS, 2004). With the application of livestock manure the content was interpreted as medium (CQFS, 2004), demonstrating the importance of manure in the availability of P in the soil. These data corroborate those found by Caetano and Carvalho (2006), Araujo et al. (2011) and Gotz et al. (2019) with livestock manure application.

The organic matter (OM) content was not modified with the application of treatments, even with manure use (Table 4). Similar results were observed by Ferreira et al. (2009). This performance may be associated with the need for very high amounts of organic manure to increase the organic matter content in the soil, because 2/3 of the C added is lost in the form of CO_2. The increasing of rock powder doses did not increase the potential cation exchange capacity ($CEC_{pH7.0}$) of the soil (Table 4), due the short period of conduction of the experiment, since the rock powder presents slow solubilization. In contrast, the treatments without manure application showed higher potential CEC (Table 5) and this fact can be explained by the reduction of potential acidity with manure application (Table 5) because this is part of CEC calculation.

TABLE 4 - pH in water (pH $_{(H2O)}$), potential acidity (H + Al), calcium (Ca), magnesium (Mg), potassium (K), phosphorus (P) and organic matter (OM) contents, cation exchange capacity (CEC) and base saturation (V%) ninety-six days after application of rock powder doses (Mg ha^{-1}) in the presence (P) and absence (A) of livestock manure in a Latossolo Vermelho Aluminoférrico típico.

Rock powder doses (Mg ha^{-1})	pH $_{(H2O)}$		H + Al ------------------ ($cmol_c\,dm^{-3}$) ------------------		Ca		Mg		V (%)	
	P	A	P	A	P	A	P	A	P	A
0	5.2*	5.3	4.4	5.2	4.8	5.3	2.4	2.5	71.0	61.0
3	5.2	5.0	3.3	7.0	4.8	3.7	2.4	1.9	70.0	44.7
6	5.2	5.1	3.7	15.8	4.1	3.6	2.1	2.2	67.0	31.0
9	5.2	5.3	2.6	9.5	4.3	4.7	2.2	2.7	71.3	47.0
12	5.1	5.4	2.4	11.3	4.6	4.8	2.3	2.4	83.7	44.0

Rock powder doses (Mg ha^{-1})	K ------------------------ ($mg\,dm^{-3}$) ------------------------		P		OM (%)		$CEC_{(pH7.0)}$ ($cmol_c\,dm^{-3}$)	
	P	A	P	A	P	A	P	A
0	99.0	117.3	8.7	7.0	4.0	4.1	11.9	13.4
3	114.7	87.7	7.4	5.9	4.0	3.5	11.0	13.0
6	83.3	116.7	8.8	5.3	3.7	3.5	10.3	21.7
9	107.3	67.7	7.3	4.5	3.6	3.7	9.5	17.0
12	107.0	101.7	9.9	4.7	4.2	3.6	9.6	19.0

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

TABLE 5 - Potential acidity (H + Al), phosphorus (P) content, cation exchange capacity (CEC) and base saturation (V%) as a function of the presence and absence of livestock manure, independent of the dose of rock powder, in a Latossolo Vermelho Aluminoférrico típico.

Treatments	H + Al ($cmol_c\,dm^{-3}$)	P ($mg\,dm^{-3}$)	$CEC_{(pH7.0)}$ ($cmol_c\,dm^{-3}$)	V (%)
With manure	3.10 b*	8.43 a	10.26 b	72.60 a
Without manure	9.77 a	5.49 b	16.82 a	45.53 b

*Means followed by distinct letters in the column differ by the Tukey's test ($p<0.05$).

Relative to soil base saturation, this variable was not influenced by the application of increasing rock powder doses (Table 4), which was expected, because its use did not influence the sum of bases (Ca, Mg and K) and the potential CEC. On the other hand, the manure application increased this variable (Table 5). It should be noted that the increase in base saturation occurred with the reduction in potential CEC, as a result of the reduction in potential acidity, without reducing the sum of bases. Even though the increase in base saturation has not been matched by the increase in the sum of bases, there is an increase in the availability of exchangeable cations, which translates into greater capacity to supply them to plants, in other words, greater fertility.

CONCLUSIONS

Rock powder, associated or not with livestock manure, is not effective in improving bean yield and soil chemical attributes after approximately three months of application.

The use of livestock manure, regardless of the rock powder dose, improves some chemical attributes in the soil.

Thus, the results obtained indicate that the main limitation of the rock powder use as a source of nutrients is its slow solubilization. Therefore, future studies are necessary in order to seek ways to improve its solubilization and, consequently, the availability of nutrients to plants, such as the microorganisms use.

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