Maize yield and nutrition after different application forms of rock powder and manure

Produtividade e nutrição do milho após diferentes formas de aplicação de pó de rocha e esterco

Rendimiento y nutrición del maíz después de diferentes formas de aplicación de polvo de roca y estiércol

Received: 06/16/2021 | Reviewed: 06/25/2021 | Accept: 06/29/2021 | Published: 07/13/2021

Júlia Carolina Ghizzoni
ORCID: https://orcid.org/0000-0001-9070-3604
Federal University of Fronteira Sul, Brazil
E-mail: jullycarolina7@gmail.com
Lenir Fátima Gotz
ORCID: https://orcid.org/0000-0001-6145-4717
University of São Paulo, Brazil
E-mail: lenirgotz@usp.br
Alfredo Castamann
ORCID: https://orcid.org/0000-0002-9478-3549
Federal University of Fronteira Sul, Brazil
E-mail: alfredo.castamann@uffs.edu.br
Juan Cristopher Onesko
ORCID: https://orcid.org/0000-0002-8685-6197
Federal University of Fronteira Sul, Brazil
E-mail: juanonesko@hotmail.com
Ezequiel Bampi
ORCID: https://orcid.org/0000-0001-8219-4918
Federal University of Fronteira Sul, Brazil
E-mail: ezequiel.bampi@gmail.com
Keoma Reis de Sá
ORCID: https://orcid.org/0000-0003-1323-6293
Federal University of Fronteira Sul, Brazil
E-mail: keomareisdesa@gmail.com

Abstract
The aim of this study was to evaluate the efficiency of rock powder applied isolated or associated with egg-laying hen manure as a source of nutrients for maize crop; and to evaluate the effect of application form in the efficiency of this sources in improve crop yield. The experiment was composed by eight treatments, distributed in a randomized block design and in factorial design 4 (A) x 2 (B), with four replicates. In factor A, the different sources of nutrients were allocated: rock powder; rock powder + egg-laying hen manure; egg-laying hen manure; and control; applied on the soil surface or incorporated with harrow. The doses used were 2 and 10 Mg ha^{-1} of rock powder and manure, respectively. Were evaluated: foliar nitrogen (N) and phosphorus (P) contents; extraction of N and P; and maize yield components. There was no interaction between the factors tested. The use of egg-laying hen manure isolated or associated with rock powder resulted in higher foliar P content, higher P extraction and increase in maize yield components, except for the number of plants per linear meter and cobs per plant. The application form did not affect the maize yield components, but when applied on the surface it increased foliar P content and P extraction. Rock powder is efficient in promoting better maize yield only when associated with manure. The incorporation of rock powder does not increase its efficiency in providing nutrients to the plants.
Keywords: Rocking; Organic fertilization; Remineralizer; *Zea mays*; Basalt.

Resumo
O objetivo do trabalho foi avaliar a eficiência do pó de rocha isolado ou associado à cama de poedeiras como fonte de nutrientes ao milho, e avaliar o efeito da forma de aplicação na eficiência dessas fontes em melhorar a produtividade da cultura. O experimento foi composto por oito tratamentos, distribuídos em blocos casualizados, em esquema fatorial 4 (A) x 2 (B), com quatro repetições. No fator A foram alocadas as diferentes fontes de nutrientes: pó de rocha; pó de rocha + cama de poedeiras; cama de poedeiras; e controle; aplicados sobre a superfície do solo ou incorporados com grade. As doses utilizadas foram 2 e 10 Mg ha^{-1} de pó de rocha e esterco, respectivamente. Avaliou-se: teores de nitrogênio (N) e fósforo (P) foliar; extração de N e P; e os componentes de rendimento do milho. Não foi verificado interação entre os fatores testados. O uso de cama de poedeiras isolado ou associado ao pó de rocha

resultou em maior teor de P foliar, maior extração de P e incremento nos componentes de rendimento do milho, exceto para número de plantas por metro linear e espigas por planta. O modo de aplicação não afetou os componentes de rendimento do milho, mas quando aplicado sobre a superfície aumentou o P foliar e a extração de P. O pó de rocha é eficiente em promover melhor produtividade do milho somente quando associado à cama de poedeiras. A incorporação do pó de rocha não aumenta sua eficiência em fornecer nutrientes às plantas.
Palavras-chave: Rochagem; Adubação orgânica; Remineralizador; *Zea mays*; Basalto.

Resumen
El objetivo de este estudio fue evaluar la eficiencia del polvo de roca aplicado aislado o asociado a estiércol de gallina ponedora como fuente de nutrientes para el cultivo de maíz; y evaluar el efecto de la forma de aplicación en la eficiencia de estas fuentes para mejorar el rendimiento del cultura. El experimento estuvo compuesto por ocho tratamientos, distribuidos en un diseño de bloques al azar y en diseño factorial 4 (A) x 2 (B), con cuatro repeticiones. En el factor A se asignaron las diferentes fuentes de nutrientes: polvo de roca; polvo de roca + estiércol de gallina ponedora; estiércol de gallina ponedora; y control; aplicado en la superficie del suelo o incorporado con rastra. Las dosis utilizadas fueron 2 y 10 Mg ha^{-1} de polvo de roca y estiércol, respectivamente. Se evaluaron: contenido foliar de nitrógeno (N) y fósforo (P); extracción de N y P; y componentes del rendimiento del maíz. No hubo interacción entre los factores probados. El uso de estiércol de gallina ponedora aislado o asociado con polvo de roca resultó en un mayor contenido de P foliar, una mayor extracción de P y un aumento en los componentes del rendimiento del maíz, excepto por el número de plantas por metro lineal y mazorcas por planta. La forma de aplicación no afectó los componentes del rendimiento del maíz, pero cuando se aplicó en la superficie aumentó el contenido de P foliar y la extracción de P. El polvo de roca es eficaz para promover un mejor rendimiento solo cuando se asocia con estiércol. La incorporación de polvo de roca no aumenta su eficiencia a la hora de aportar nutrientes a las plantas.
Palabras clave: Fertilizar con roca; Fertilización orgânica; Remineralizante, *Zea mays*; Basalto.

1. Introduction

Brazil has a large territorial magnitude and presents constant evolution of agriculture; but is a great consumer of agricultural fertilizers, mainly because the soils have low natural fertility. In general, soluble mineral fertilizer are used, which quickly release nutrients and meets the crops requirements, being that in case of Brazil, 70% of the NPK used is imported (ANDA, 2016). This dependence of fertilizers importation creates economic problems, which associated to the environmental problems with inappropriate use of these sources of nutrients (Theodoro et al., 2012) resulted in increased research from alternative sources, such as rock powder, regionally source of nutrients.

Among the available rocks for use in agriculture, it can be mentioned the basalt, which is a basic and extrusive igneous rock, with a wide geographic distribution. This rock is composed by minerals such as of aluminosilicates from the group of pyroxenes and plagioclase, important sources of Ca^{2+}, Mg^{2+}, K^{+}, and micronutrients (Ferreira, Almeida & Mafra, 2009). It stands out that mining industry sometimes found is more populated areas or near cities, faces the challenges of avoiding landscape damage and properly disposing the processing tailings (Ramos et al., 2021). Therefore, it is evident the importance of using this mining waste for agricultural use.

In this context, a greater number of research related to the use of rock powders has been realized, with the objective to evaluate the ability of these sources to substitute or complement other soluble and/or organic sources. According to Theodoro et al. (2012) and Alovisi et al. (2020), the rock powder application can be easily adopted by family farmers, due to its simplicity, low cost of use and positive results in terms of grain yield. However, the main limitation is the slow solubilization and release of nutrients to the plants, with a source being less responsive when compared to short-term soluble mineral sources (Ferreira, Almeida, Mafra & 2009; Hanish et al., 2013; Gotz et al., 2019; Gotz, Piovesan & Castamann, 2020; Alovisi et al, 2020).

The solubilization of rock powders is a process associated to biological activities. Therefore, the characteristic of slow solubilization of the nutrients present in the rock powder makes it necessary for this process a more intense edaphic biological activity. In this context, studies have sought to associate rock powder with organic fertilization, to accelerate the dissolution of minerals present in the constitution of rock powder (Ferreira, Almeida & Mafra, 2019; Gotz et al., 2019; Gotz, Piovesan &

Castamann, 2020); and thus reduce the socioeconomic and environmental problems triggered by the indiscriminate use of soluble mineral fertilizers. In addition, another aspect that should be considered is the application form of sources of nutrients, because the adoption of the no-tillage system brought important changes in the management of organic fertilization. These, which were previously applied on the surface and immediately incorporated into the soil, are now applied on soil surface without incorporation (Scherer & Nesi, 2009), what can result and differences in behavior when associated with rock powder. Gotz et al. (2019) highlighted that the product incorporation in soil may increase the solubility and therefore the nutrients availability to the plants, and that complementary studies are necessary to elucidate such hypothesis.

Thus, the aim of this study was to evaluate the efficiency of rock powder applied isolated or associated with egg-laying hen manure as an alternative source of nutrients for maize crop; and to evaluate the effect of application form in the efficiency of this sources in improve maize yield.

2. Methodology

The type of our research was experimental field research, where the problem was analyzed, the hypotheses were constructed and the possible factors (variables) were manipulated; in order to find answers proof or even new phenomena in relation to the problem questioned (Koche, 2011).

The experiment was conducted at experimental area of Federal University of Fronteira Sul in Erechim City, in Rio Grande do Sul State (27.728681° S; 52.285852° W) in an area located at an altitude of 770 m. The soil of the experimental area is classified as Latossolo Vermelho Aluminoférrico típico (Streck et al., 2018; Santos et al., 2018). According to Köppen classification, the climate of the region is fundamental type C, subtype fa (Cfa), characterized as humid subtropical, without dry season, with the temperature of the hottest month exceeding 22 ºC, average annual temperature of 18,2 ºC and average annual precipitation of 1,869 mm (Matzenauer et al., 2011). Soil characterization at the establishment of the experiment is presented on Table 1 (Gotz et al., 2019).

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	SMP	P	K	O.M.	Al^{3+}	Ca^{2+}	Mg^{2+}	$Al^{3+} + H^+$	CTC $_{(pH7,0)}$	V
(%)	(H_2O)	index	(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

*CEC: cation exchange capacity; O.M: organic matter; V: base saturation.
Source: Gotz et al. (2019).

The experiment was composed by eight treatments, distributed in a randomized block design and in factorial design 4 (A) x 2 (B), with four replicates. In factor A, the different sources of nutrients were allocated: only rock powder (2 Mg ha^{-1}); rock powder (2 Mg ha^{-1}) + egg-laying hen manure (10 Mg ha^{-1}); only egg-laying hen manure (10 Mg ha^{-1}); and control (without application), and in factor B two application forms: on the soil surface or incorporated with harrow. Each experimental unit presented 5 m long by 3.5 m wide, totaling 17.5 m^2. The sources application was carried out on October 4, 2019, manually, in the useful area of each plot (12 m^2); and incorporation with harrow was carried out in the treatments with this management.

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: SiO_2: 51.6%; Fe_2O_3: 15.9%; CaO: 8.8%; MgO: 4.4%; P_2O_5: 0.2%; K_2O: 1.22%; MnO: 0.24%; Na_2O: 2.55%; S:1 mg kg^{-1}; Zn: 68 mg kg^{-1}; Cu: 224 mg kg^{-1}; B: 10 mg kg^{-1}; Co: 21.9 mg kg^{-1}; Mo: 1.0 mg kg^{-1}; Ni: 17.8 mg kg^{-1}. The egg-laying hen manure applied had the following composition: N: 0.82%; P_2O_5: 2.44%; K_2O: 1.67%; C: 6.77%: Mg: 0.66%; S: 0.30%; Mn: 363.5 mg kg^{-1}; Cu: 57.02 mg kg^{-1}; Zn: 269.36 mg kg^{-1}; Fe: 3,525.7 mg kg^{-1}; B: 73.74; pH: 9.8; organic carbon: 27.22%; C/N relation: 20.16.

The maize sowing was carried out on Oct 11, 2019, using the cultivar VT PRO 3® - Dekalb, with 0.5 m spacing and 60,000 plants per hectare. All treatments received a total of 110 kg of N ha^{-1}. The experimental units with application of egg-laying hen manure received N from the organic source before implantation of experiment (25 kg ha^{-1} of N) and mineral (85 kg ha^{-1} of N) in two times, at V4 and V8 stages. Already, the treatments without egg-laying hen manure, also received 110 kg of N ha^{-1} distributed among three applications, 25 kg ha^{-1} at sowing, and 85 kg ha^{-1} of N in two applications: V4 and V8 stages. Mineral source used was urea with 45% of N. The control of insect pests and diseases was performed out using biological products.

To evaluate nitrogen (N) and phosphorus (P) contents, maize leaves were collected in two planting lines in useful area of each experimental unit, removing the leaf below and opposite the cob when 50% (+1) of the plants were in the phonological stage of tasseling; and only the middle third of each leaf was used (CQFS RS/SC, 2016). After collection, the leaves were dried at 65 ºC, ground, and after analyzed by methodology established by Tedesco et al. (1995). In addition, the N and P extractions were calculated by quantifying these nutrients and dry mass of the leaves.

The maize harvesting was carried out on March 16, 2020, in two central lines in each experimental unit in three linear meters, totaling 3 m^3. The following variables were evaluated: number of plants per linear meter, number of cobs per plant, number of grains per cob, determined in four plants of each plot, randomly defined; mass of one thousand grains from each experimental unit; and grain yield (Mg ha^{-1}) which the obtained value was corrected to 13% moisture.

The results were submitted to analysis of variance, and when a significant effect was observed ($p < 0.05$) the averages were compared using the Tukey test at 5 % probability All analyzes were performed using the statistical software Sisvar version 5.6 (Ferreira, 2019).

3. Results and Discussion

3.1 Nutritional composition of maize

On Table 2 and Table 3 is possible to observe the effect of nutrient sources and application form on the foliar nitrogen (N) and phosphorus (P) content and extraction. Thus, the treatments did not influence the N foliar content (Table 2, Table 3). Similarly, there was no interaction between the factors tested. It stands out that the contents can be interpreted as adequate, since they are within the sufficiency range indicated for the crop (2.7 to 3.5%) (CQFS RS/SC, 2016). This result is probably due to the supply of the N plant's demand via mineral fertilization, being that the N amounts applied were equivalent in all treatments because the capacity of the egg-laying hen manure to supply this nutrient was also considered.

Table 2. Effect of nutrient sources on the foliar nitrogen content (foliar N content), foliar phosphorus contents (foliar P content), N extraction and P extraction, regardless of the application form (on the soil surface or incorporated).

Source	Foliar N content	Foliar P content	N extraction	P extraction
	%		mg kg^{-1}	
M[(1)]	3.20 [ns]	0.17 a*	1,384 [ns]	73.98 a
M + RP	3.29	0.17 a	1,386	72.10 ab
RP	3.09	0.15 b	1,198	58.80 c
C	3.20	0.16 b	1,281	62.49 bc
C.V.[(2)]	8.36	6.42	10.98	11.43

[(1)] M: Egg-laying hen manure; RP: rock powder; C: control [(2)] C.V.: coefficient of variation (%); * Means followed by different letters differ by Tukey test at 5% probability; [ns]: not significant.
Source: Authors (2021).

Table 3. Effect of application form on the foliar nitrogen content (foliar N content), foliar phosphorus contents (foliar P content), N extraction and P extraction.

Application form	Foliar N content	Foliar P content	N extraction	P extraction
	%		mg kg^{-1}	
Soil surface	3.21 [ns]	0.17 a*	1,367 a	72.21 a
Incorporated	3.18	0.15 b	1,257 b	61.47 b
C.V.[(1)]	8.36	6.42	10,98	11.43

[(1)]C.V.: coefficient of variation; * Means followed by different letters differ by Tukey test at 5% probability.
Source: Authors (2021).

Similarly, the effect of nutrient sources was not verified on the N extraction (Table 2). Already, the application forms modified this variable, being the N extraction was higher when the sources were applied on the soil surface (Table 3). It stands out that the cover crops prior to maize were oats, vetch, and turnip; it is a consortium in which two of these species have a low C/N ratio. So, when on the surface, they release N more slowly, which may favor the N absorption by the crop throughout the cycle and may have contributed to the increase in extraction. However, when these cover crops are incorporated, they are quickly decomposed, as they are more accessible to the soil microbiota; and the N is more susceptible to leaching losses, reducing its absorption by plants, as well as immobilization by microorganisms. Mundus et al. (2008) pointed that the application of fertilizers (*Gliricidia* and cattle manure) on the soil surface, instead of incorporating it, may be management options to delay N release and provide this nutrient in a more synchronized pattern for the maize demand.

Relative to the P, the treatments influenced the foliar P contents; an isolated effect of the factors was observed (Table 2, Table 3). However, the contents are below the lower limit of the sufficiency range indicated for the crop (0.2 to 0.4%) (CQFS RS/SC, 2016). It is possible to observe on Table 2 that the treatments with application of egg-laying hen manure isolated or associated with rock powder resulted in higher foliar P content and higher P extraction in maize; that is, the use of rock powder alone did not result in an increase in these variables. This result is due to the low P content present in rock powder, and slow solubilization of the rock powder, according highlighted by Gotz et al. (2019); requiring more time to dissolve minerals and release nutrients to crops. It stands out that the P content was 0.10% in their study, and 0.2% of P_2O_5 in our study. On the other hand, the P_2O_5 present in egg-laying hen manure was 2.44%, associated to your immediate availability, increasing the P extraction by plants.

About the application forms, when the sources were applied on the soil surface resulted in higher P content and higher P extraction (Table 3). The incorporation of sources results in rapid decomposition due to the increase in the microbial attack surface, as conditions are favorable for the rapid growth of the population of microorganisms, accelerating the decomposition processes. However, the P that is released faster is subject to reactions in the soil. Scherer and Nesi (2009) found higher contents of soil available P in the treatment without incorporation of poultry house litter and pig slurry, highlighting that soil turning provides greater contact of fertilizers with soil colloids and, consequently, greater P adsorption and fixation, reducing available P to plants.

3.2 Maize yield components

On Table 4 and Table 5 is possible to observe the effect of nutrient sources and application form on maize yield components. So, the treatments (nutrients sources x application form) did not influence the variables: number of plants per linear meter, and number of cobs per plant (Table 4, Table 5). Gotz, Piovesan and Castamann (2020) studying in the same area of our study verified that rock powder application isolated or associated with manure did not promote differences in number of plants m^{-2} of black bean; indicating that the treatments did not affect the plant emergence. In addition, the response of other variables was not affected by the plant stand. According to Vieria et al. (2010) the number of cobs per plant is affected by plant population and plant density, explaining the lack of effect in our work.

Table 4. Effect of nutrient sources on the variables: number of plants per linear meter (plants m^{-1}), number of cobs per plant (cobs $plant^{-1}$), number of grains per cob (grains cob^{-1}), mass of one thousand grains (1,000 grains), and grain yield (grain yield), regardless of the application form (on the soil surface or incorporated).

Source	Plants m^{-1}	Cobs $plant^{-1}$	Grains cob^{-1}	1,000 grains	Grain yield
				g	Mg ha^{-1}
M[(1)]	3.41 ^{ns}	0.91 ^{ns}	444.6 a*	265.7 a	6,650 a
M + RP	3.35	0.94	403.3 ab	261.6 ab	6,407 a
RP	3.18	0.91	398.0 ab	239.2 bc	4,642 b
C	3.33	0.90	372.6 b	234.2 c	4,585 b
C.V.[(2)]	13.01	10.54	11.57	7.12	15.53

[(1)] M: Egg-laying hen manure; RP: rock powder; C: control [(2)] C.V.: coefficient of variation (%); * Means followed by different letters differ by Tukey test at 5% probability; ^{ns}: not significant.
Source: Authors (2021).

Relative to the number of grains per cob, the effect only of nutrient sources was observed (Table 4, Table 5). The use of egg-laying hen manure to increase the number of grains per cob is the most appropriate option in conditions like our experiment, because this treatment applied in isolation resulted in higher number of grains per cob, however it differed only to the control treatment; and the other treatments did not differ to control (Table 4). Similarly, Gotz et al. (2019) verified that only the application of bovine manure, independent of the presence or not of rock powder, influenced positively the number of grains per spike in wheat, possibly because of the immediate availability of nutrients provided by bovine manure.

Table 5. Effect of application form on the number of plants per linear meter (plants m^{-1}), number of cobs per plant (cobs $plant^{-1}$), number of grains per cob (grains cob^{-1}), mass of one thousand grains (1,000 grains), and grain yield (grain yield).

Application form	Plants m^{-1}	Cobs $plant^{-1}$	Grains cob^{-1}	1,000 grains	Grain yield
				g	Mg ha^{-1}
Soil surface	3.27 ^{ns}	0.91 ^{ns}	409.67 ^{ns}	255.42 ^{ns}	5,585 ^{ns}
Incorporated	3.37	0.92	399.58	244.93	5,558
C.V.[(1)]	13.01	10.54	11.57	7.12	15.53

[(1)] C.V.: coefficient of variation (%); * Means followed by different letters differ by Tukey test at 5% probability; ^{ns}: not significant.
Source: Authors (2021).

The use of organic fertilization isolated or associated with rock powder resulted in higher mass of one thousand grains in maize (Table 4). The application form did not modify this variable; and it was not found interaction between source and application form (Table 5). The grain yield presented similar behavior (Table 4). Similarly, Writzl et al. (2019) observed favorable effects to the use of the association of organic fertilizers with rock powder. These authors verified that the grain yield in the treatments rock powder + chicken fertilizer and only rock powder presented results equal to mineral fertilization, showing the potential of alternative fertilization in high fertility soil in popcorn crop. Gotz et al. (2019) verified that the application of bovine manure, independently of the rock powder dose (0, 3, 6, 9 and 12 Mg ha^{-1}), resulted in improvements in wheat yield after two applications in approximately one year.

On the other hand, Plewka et al. (2009) and Gotz, Piovesan and Castamann (2019) did not verify the effect of the doses of rock powder, associated or not with manure, on bean production. Hanish et al. (2013), in three years of the experiment, did not verify an increase in soybean and maize grain yield with application of basalt powder (0, 2, 4, 8, and 12 Mg ha^{-1}), observing the effect only of mineral fertilizers. In addition, Alovisi et al. (2021) did not observe promising results in the soybean crop, noting that the small release of nutrients from the basalt powder indicates that this material cannot be used as the main source of nutrients for the plants.

It should be noted that the application form of sources of nutrients did not influence the maize yield components (Table 4, Table 5). Gotz et al. (2019) had as a hypothesis that the incorporation may increase the solubility and therefore the nutrients availability to the plants, mainly in rock powder case. However, this performance did not observe in our study.

4. Conclusion

The use of rock powder isolated cannot be used as an alternative source of nutrients to maize. On the other hand, when associated with egg-laying hen manure, it improves maize yield components and maize nutrition. The incorporation of rock powder does not increase maize yield components, and results in lower foliar phosphorus content, and nitrogen and phosphorus extraction. Thus, the use of rock powder associated with manure is indicated.

In our study, it was evident that the main limitation of the use of rock powder isolated as a source of nutrients is its slow solubilization; requiring that studies in this area to be continued. In addition, 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. Complementary studies are necessary to elucidate such hypothesis.

(CC BY 4.0) | ISSN 2525-3409 | DOI: http://dx.doi.org/10.33448/rsd-v10i8.17285

References

Alovisi, A. M. T., Rodrigues, R. B., Alovisi, A. A., Tear, M. M., Villalba, L. A., Muglia, G. R. P., Soares, M. S. P., Tokura, L. K., Cassol, C. J., Silva R. S, Tokura, W. I., Gning, A. & Kai, P. M. (2021). Uso de pó de rocha basáltica como fertilizante alternativo na cultura da soja. *Research, Society and Development*, 10 (6), 1-12.

Alovisi, A. M. T., Taques, M. M., Alovisi, A. A., Tokura, L. K., Silva, J. A. M. & Cassol, C. J. (2020). Rochagem como alternativa sustentável para a fertilização de solos. *Revista gestão e sustentabilidade ambiental*, 9, 918-932.

ANDA - Associação Nacional para Difusão de Adubos. (2016). *Anuário estatístico do setor de fertilizantes*. ANDA.

CQFS RS/SC– Comissão de Química e Fertilidade do Solo. (2016). *Manual de adubação e calagem para os Estados do Rio Grande do Sul e de Santa Catarina*. Sociedade Brasileira de Ciência do Solo.

Ferreira, E. R. N. C., Almeida, J. A. & Mafra, A. L. (2009). Pó de basalto, desenvolvimento e nutrição do feijão comum (*Phaseolus vulgaris*) e propriedades químicas de um Cambissolo Húmico. *Revista de Ciências Agroveterinárias*, 8 (2), 111-121.

Ferreira, D. F. (2019). Sisvar: um sistema de análise de computador para efeitos fixos projetos de tipo de partida dividida. *Revista Brasileira de Biometria*, 37 (4), 529-535.

Gotz, L. F., Castamann, A., Piovesan, F., Anzolin, B. L., Herek, T. L. Mikoanski, W. M. & Rita. Y. L. (2019) Use of rock powder associated with bovine manure in LAtossolo Vermelho cultivated with wheat. *Revista Brasileira de Agropecúaria Sustentável*, 9 (2), 131-139.

Gotz, L. F., Piovesan, F. & Castamann, A. (2020). Rock powder and organic fertilization in soil cultivated with black bean. *Scientia Agraria Paranaensis*, 19 (3), 296-301.

Hanish, A. L., Fonseca, J. A., Balbinot Junior, A. A. & Spagnollo, E. (2013). Efeito de pó de basalto no solo e em culturas anuais durante quatro safras, em sistema de plantio direto. *Revista Brasileira de Agropecuária Sustentável*, 3(2), 100-107.

Koche, J. C. (2011). *Fundamentos de metodologia científica:* teorias da ciência e iniciação científica. Vozes.

Matzenauer, R., Radin, B. & Almeida, I. R. (2011). *Atlas climático: Rio Grande do Sul.* Secretaria da Agricultura Pecuária e Agronegócio, Fundação Estadual de Pesquisa Agropecuária.

Mundus, S., Menezes, R. S. C., Neergaard, A. & Garrido, M. S. (2008). Maize growth and soil nitrogen availability after fertilization with cattle manure and/or gliricidia in semi-arid NE Brazil. *Nutrient Cycling in Agroecosystems*, 82, 61-73.

Plewka, R. G., Zamulak, J. R., Venancio, J. A., Marques, A. C. & Oliveira, C. D. (2009). *Revista Brasileira de Agroecologia*, 4 (2), 4397-4400.

Ramos, C. G., Dalmora, A. C., Kautzmann, R. M., Howver, J., Dotto, G. L. & Oliveira, L. F. S. (2021). Sustainable release of macronutrients to black oat and maize crops from organically-altered dacite rock powder. *Natural Resources Research*, 30(3).

Santos, H. G., Jacomine, P. K. T., Anjos, L. H. C., Oliveira, V. A., Lumbreras, J. F., Coelho, M. R., Almeida, J. A., Araújo Filho, J. C., Oliveira, J. B. & Cunha, T. J. F. (2018). *Sistema Brasileiro de Classificação de Solos*. Embrapa.

Scherer, E. E. & Nesi, C. N. (2009). Características químicas de um Latossolo sob diferentes sistemas de preparo e adubação orgânica. *Bragantia*, 68 (3), 715-721.

Streck, E. V., Kämpf, N., Dalmolin, R. S. D., Klamt, E., Nascimento, P. C., Giasson, E. & Pinto, L. F. S. (2018). *Solos do Rio Grande do Sul*. EMATER/RS-ASCAR.

Tedesco, M. J., Gianello, C., Bissani, C. A., Bohnen, H. & Volkweiss, S.J. (1995). *Análise de solo, plantas e outros materiais*. Departamento de Solos.

Theodoro, S. H., Tchouankoue, J. P., Gonçalvez, A. O., Leonardos, O. & Harper, J. (2012). A Importância de uma rede tecnológica de rochagem para a sustentabilidade em países tropicais. *Revista Brasileira de Geografia Física*, 6, 1390-1407.

Viera, M. A., Camargo, M. K., Daros, E., Zagonel, J. & Koehler, H. S. (2010). Cultivares de milho e população de plantas que afetam produtividade de espigas verdes. *Acta Scientiarum*, 32 (1), 81-86.

Writzl, T. C., Canepelle, E., Stein, J. E. S., Kerkhoff, J. T., Steffler, A. D., Silva, D. W. & Redin, M. (2019). Produção de milho pipoca com uso do pó de rocha de basalto associado à cama de frango em Latossolo. *Revista Brasileira de Agropecuária Sustentável*, 9 (2), 101-109.