Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online
DOI: https://doi.org/10.18188/sap.v20i3.27429

BASALT ROCK POWDER AND ORGANIC COMPOUNDS IN CORN CROPS

Edleusa Pereira Seidel[1*], Letícia Gabriela Ertel[2], Renan Pan[3],
José Alessandro da Silva Franco[4], Diogo Gabriel dos Santos[5]

SAP 27429 Received: 20/05/2021 Accepted: 01/09/2021
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 20, n. 3, jul./sep., p. 287-294, 2021

ABSTRACT - The use of basalt rock powder associated with an organic fertilizer with compost can be an option to reduce the use of soluble fertilizers. Thus, this study aimed to evaluate the effect of organic compost and basalt rock powder on the agronomic traits of the corn crop and on the levels of nutrients available in the soil solution, with two additional treatments of fertilization with NPK. The experimental design used was completely randomized blocks, in a factorial scheme (5x2) + 2, with two additional and four replications. The first factor consisted of five doses of organic compost (0, 4, 6, 8 and 10 t ha^{-1}) and the second factor, with and without basalt rock dust (0 and 8 t ha^{-1}). The additional treatment consisted of the application of 150 kg ha^{-1} of formulated NPK (10-15-15), equivalent to ½ of the recommended dose for the crop, associated with 8 t ha^{-1} of basalt rock powder and the second additional treatment consisted in the application of 300 kg ha^{-1} of formulated 10-15-15 of NPK and without rock dust. The agronomic characteristics of corn and the nutrient contents in the soil solution were evaluated. The results showed that the use of organic compost associated with rock dust promoted soil chemical improvements, especially pH elevation and calcium content increase. There was no effect of organic compost with rock powder on the agronomic characteristics of corn evaluated. The use of chemical fertilizer of an NPK formulation improved the corn crop compared to the use of organic compost and rock dust. The application of 8 t ha^{-1} of basalt rock powder, associated with 150 kg ha^{-1} of a formulated NPK improved the development of the corn crop compared to the use of 300 kg ha^{-1}.
Keywords: composting, soil remineralizer, rock powder as natural fertilizer, alternative inputs.

PÓ DE ROCHA DE BASALTO E COMPOSTOS ORGÂNICOS NO CULTIVO DE MILHO

RESUMO - O uso de pó de rocha de basalto associado a uma adubação orgânica com composto pode ser uma opção para reduzir o uso de adubos solúveis. Desta forma, o objetivo deste trabalho foi avaliar o efeito de composto orgânico e pó de rocha de basalto nas características agronômicas da cultura do milho e nos teores de nutrientes disponíveis na solução do solo, com dois tratamentos adicionais de adubação com NPK. O delineamento experimental utilizado foi de blocos inteiramente ao acaso, em esquema fatorial (5x2) + 2, com dois adicionais e quatro repetições. O primeiro fator consistiu de cinco doses de composto orgânico (0, 4, 6, 8 e 10 t ha^{-1}) e o segundo fator, com e sem pó de rocha de basalto (0 e 8 t ha^{-1}). O tratamento adicional constou da aplicação de 150 kg ha^{-1} de formulado NPK (10-15-15), equivalente a ½ da dose recomendada para a cultura, associado a 8 t ha^{-1} de pó de rocha de basalto e o segundo tratamento adicional foi a aplicação de 300 kg ha^{-1} de formulado 10-15-15 de NPK e sem pó de rocha. Avaliou-se as características agronômicas do milho e os teores de nutrientes na solução do solo. Os resultados demonstraram que uso de composto orgânico associado com pó de rocha promoveu melhorias químicas do solo, especialmente elevação do pH e aumento nos teores de cálcio. Não houve efeito do composto orgânico com pó de rocha para as características agronômicas do milho avaliadas. O uso de adubo químico de um formulado NPK favoreceu a cultura do milho em comparação ao uso de composto orgânico e pó de rocha. A aplicação de 8 t ha^{-1} de pó de rocha de basalto, associado a 150 kg ha^{-1} de um formulado NPK favoreceu o desenvolvimento da cultura do milho em comparação ao uso de 300 kg ha^{-1}.
Palavras-chave: compostagem, remineralizador de solo, rochagem, insumos alternativos.

INTRODUCTION

Potential ways to ensure an efficient agricultural production with minimal environmental impact have been sought. Thus, new ways to obtain sustainable production causing minimal environmental impact are being developed. Among these solutions, organic farming deserves special mention as an economically viable and environmentally sustainable type of agriculture (AZADI et al., 2011). The use of soluble inputs is not allowed in organic or agroecological cultivation. Nutrient input can be done with organic fertilizers such as compost and vermicompost. These sources of fertilizers are ways for replacing nutrients exported at harvest and maintaining yield without impact to the environment. Its use, in addition to carrying nutrients to crops, contributes to improving the physical, chemical and biological characteristics of the soil (ALCÂNTARA, 2017).

[1]Universidade Estadual do Oeste do Paraná-Unioeste, *Campus* Marechal Cândido Rondon, Marechal Cândido Rondon, PR, Brasil. E-mail: edleusa.seidel@unioeste.br. [*]Corresponding author.

The most widely used organic fertilizers in agriculture and with good agricultural potential are poultry litter (CONSOLIN FILHO, 2020), swine manure and cattle manure, green manures and compost. Compost can be produced with different sources such as gardening pruning wastes, food leftovers from cafeterias, among others (SEDIYAMA et al., 2014.)

Composting occurs through a controlled aerobic decomposition process, which stabilizes organic matter under conditions that allow the development of thermophilic microorganisms. When they break down organic matter, the microorganisms give off heat, and a stable, sanitized, organic end product rich in humic compounds is obtained (VALENTE et al., 2009)

Despite containing smaller amounts of nutrients compared to soluble mineral fertilizers, organic fertilizers increase soil organic matter content improving soil quality (RODRIGUES et al., 2011).

Another way to replace the nutrients exported by crops instead of soluble chemical fertilizers is the rock powder technique, since rock powder is one of the oldest natural materials used in soil fertilization. All the 18 essential nutrients that plants need to grow properly, except nitrogen, are derived from natural rocks and minerals. Their use is a strategy to take advantage of a locally abundant and low-cost material, as it is a by-product of quarries (HANISCH et al., 2013).

Silicate rocks are slow-release fertilizers (COLA et al., 2012), which is advantageous for the environment, since nutrient leaching is lower, and this is particularly important in tropical soils. In addition, most silicate rocks contain all the macro and micronutrients necessary for plant growth (TOSCANI et al., 2017); whereas, most commercial fertilizers only contain the three main plant nutrients: NPK macronutrients. The use of silicate rocks in tropical environments has many advantages, such as the rate of dissolution of the rocks, the reaction between mineral surfaces and soil solution that is increased under high temperature and humidity regimes. In tropical areas, soils are highly weathered, naturally poor in nutrients and greatly need the addition of nutrients (VAN STRAATEN, 2006).

Basalt rocks have great resistance to weathering factors and, therefore, have been used as activators of soil fertility (DEUS et al., 2007). Rock dust can be applied alone directly on the soil or in mixtures with other organic compounds, which favors biological activity (SILVA et al., 2017). The lower the particle size distribution of the rock dust to be used, the greater the potential of enhanced weathering of this material will be, because the contact surface will be wider, accelerating the availability of nutrients to the soil.

However, technical and scientific studies have not yet determined the ideal dose of basalt rock powder to be used in agronomic and economic terms. High doses of rock dust may not be financially viable and very low doses may have no agronomic effect. In a study conducted by Almeida Júnior et al. (2020) the best corn crop yield was obtained with a dose of 30 t ha^{-1}. Meanwhile, Writz et al. (2019) used a dose of 4 t ha^{-1} in the production of popcorn crop, which is the same dose applied by Mello Duarte et al. (2021) in bean plant.

Although there has been an increase in the number of studies on the use of rock dust, due to advances in the compression of weathering processes, there is still little information about its efficiency: some positive; others non-existent. Thus, the present study aimed to assess the effect of organic compost and basalt rock powder on the agronomic traits of corn crop and on the levels of nutrients available in the soil solution with two additional treatments of fertilization with NPK.

MATERIAL AND METHODS

The experiment was carried out under a protected cultivation system, located in the pond of Universidade Estadual do Oeste do Paraná (Unioeste), Campus Marechal Cândido Rondon, Paraná. The first 0.20 m of soil, classified as RED LATOSOL (Eutropherric), were used (SANTOS et al., 2018). Several simple soil samples were collected to make a composite sample, sent to Unioeste's Environmental Chemistry Laboratory for chemical analysis. As a result, we obtained: pH ($CaCl_2$) = 5.29; phosphorus (P) = 16.61 mg dm^{-3}; organic matter (OM) = 36.23 mg dm^{-3}; aluminum (Al^{3+}) = 0.00; potassium (K+) = 0.33 cmolc dm^{-3}; calcium (Ca^{+2}) = 3.59; magnesium (Mg^{+2}) = 2.22 cmolc dm^{-3}; sum of bases (SB) = 6.14 cmolc dm^{-3}; (V%) = 52.57; copper (Cu) = 7.70 mg L^{-1}; zinc (Zn) = 13.70 mg L^{-1}; manganese (Mn) = 33 mg L^{-1}; iron (Fe) = 14.10 mg $L^{-1.}$

Basalt rock powder was used in the experiment, since basalt is the main rock in western Paraná, and was acquired from the mining company Minerpal, located in the City of Palotina, Paraná, and a sample was sent for mineralogical chemical analysis. The results obtained by x-ray fluorescence spectrometry are shown in Table 1.

TABLE 1 - Chemical composition of a sample of basalt rock powder.

Chemical composition of basalt rock powder											
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	MnO	P_2O_5	PF	Total
%											
51.17	12.65	14.24	9.73	5.21	1.01	2.61	2.52	0.21	0.35	0.30	100

LOI = loss on ignition, total = total sum of all elements in percentage.

The organic compost was obtained from organic producers in the region, and the physicochemical characteristics were as follows: 14.50% moisture, pH in water = 7.2; 19 g kg^{-1} of nitrogen (N); 7.6 g kg^{-1} of phosphorus (P); 4.0 g kg^{-1} of potassium (K); 43 g kg^{-1} of calcium (Ca); 7.2 g kg^{-1} of magnesium (Mg) and C:N ratio of 18:1.

The experimental design used was completely randomized blocks, in factorial scheme (5x2) + 2, with four replications, totaling 48 pots. The first factor consisted of five doses of compost (0, 4, 6, 8 and 10 t ha^{-1}) and the second factor, of two doses of basalt rock powder (0 and 8 t ha^{-1}). The additional treatment consisted of an application of 150 kg ha^{-1} of NPK 10-15-15, equivalent to ½ of the recommended dose for the crop and 8 t ha^{-1} of basalt rock powder, and the second additional treatment consisted of NPK (10-15-15) at 300 kg ha^{-1} and without rock dust.

Chemical analysis results revealed the need to correct soil acidity. Thus, 4,200 kg ha^{-1} of dolomitic limestone were applied, homogenously distributed on the site. After the application, the 17 L pots were filled with 10 kg of previously sieved Latosol. Subsequently, the organic compost, the rock dust and the chemical fertilizer were applied, at the recommended doses, also homogeneously, and manual irrigation was performed. Two days after the application of rock dust, organic compost and chemical fertilizer, the hybrid corn CD 384 PW was manually sowed, with six seeds placed in each pot at a depth of 5 cm. Eleven days after emergence, seedlings were thinned, and two plants two were kept in each pot.

After 30 days, watering was performed daily, with the aid of a sprinkler. In all treatments, topdressing fertilization with 80 kg ha^{-1} of urea was made. After 56 days, there was an incidence of fall armyworm (*Spodoptera frugiperda*). However, chemical control was not performed, as the plants would be harvested four days later. The control of spontaneous plants was carried out manually, as soon as they emerged and there was no incidence of diseases.

Sixty days after sowing, some agronomic traits were evaluated, such as plant height (cm) and stalk diameter (cm). Plant height was determined with a measuring tape, with measurement of the distance from the ground to the top of the plant. The diameter of the stalk was evaluated with a digital caliper, and the middle third of the stalk was measured. Soon after the assessments, the aerial parts of the plants were cut close to the ground, placed in Kraft paper bags, identified and taken to the laboratory for drying in an air circulation oven at 65ºC. The plants remained in the greenhouse for 48 h until reaching constant biomass. After removal of the aerial part of the plants, 150 g of soil was collected for chemical analysis, which was performed according to the methodology of Teixeira et al. (2017).

For roots removal, soil was washed with running water until its total removal and the volume (cm^3) and dry biomass of the roots (g) were determined in the laboratory. The water displacement method was used for determining root volume. A 5000 mL graduated cylinder was filled with 3000 mL of water. Then, the roots were immersed in the beaker, and the volume of water displaced was recorded. Soon after, the roots were conditioned in paper bags and taken to an oven at 65±2ºC, until a constant mass was obtained to determine the dry biomass of the roots (g).

The results obtained were tabulated and submitted to analysis of variance, with the aid of the computer program for statistical analysis Sisvar (FERREIRA, 2011). Regarding quantitative data, when there was significance, regression analysis was performed.

RESULTS AND DISCUSSION

For plant height, stalk diameter, dry biomass of the aerial part, dry biomass of root and volume of root system of corn plants, there was no significant effect for interaction, nor isolated effect in response to fertilization with compost and rock dust. There was a tendency of increase in plant height, stalk diameter, dry biomass of the aerial part and of the roots, with increasing doses of the compound associated with rock dust, but such increase did not increase crop yield (Figure 1).

A probable cause of the non-existence of significant differences with the use of organic compost may be the low dose used in this experiment. In a study carried out by Rodrigues et al. (2011), an increase in dry biomass production was observed in corn fertilized with organic compost, with the application of a dose 4 times higher (40 t ha^{-1}) than the one used in the present experiment. In a study carried out by Silva et al. (2020) 60 t ha^{-1} of organic compost + green sunn hemp manure were used.

The production of dry biomass in corn with the use of 8 t ha^{-1} of basalt rock powder did not differ from the treatment without rock dust, demonstrating that the responses described in the literature regarding the use of dust powder have been contradictory. Mello Duarte et al. (2021) also did not find significant differences with the use of rock dust in bean cultivation. Silva et al. (2012) did not obtain an increase in bean production with the use of basalt rock powder. However, there were significant differences in the foliar contents of P, Ca, Mg and Zn. On the other hand, in a study carried out by Silva et al. (2020) obtained an increase in corn yield with doses of 21 t ha^{-1} of basalt rock powder. For Waigwa et al. (2003) and Husnain et al. (2014) the effectiveness of rock dust can be increased by combining organic materials. However, in the present study this did not occur.

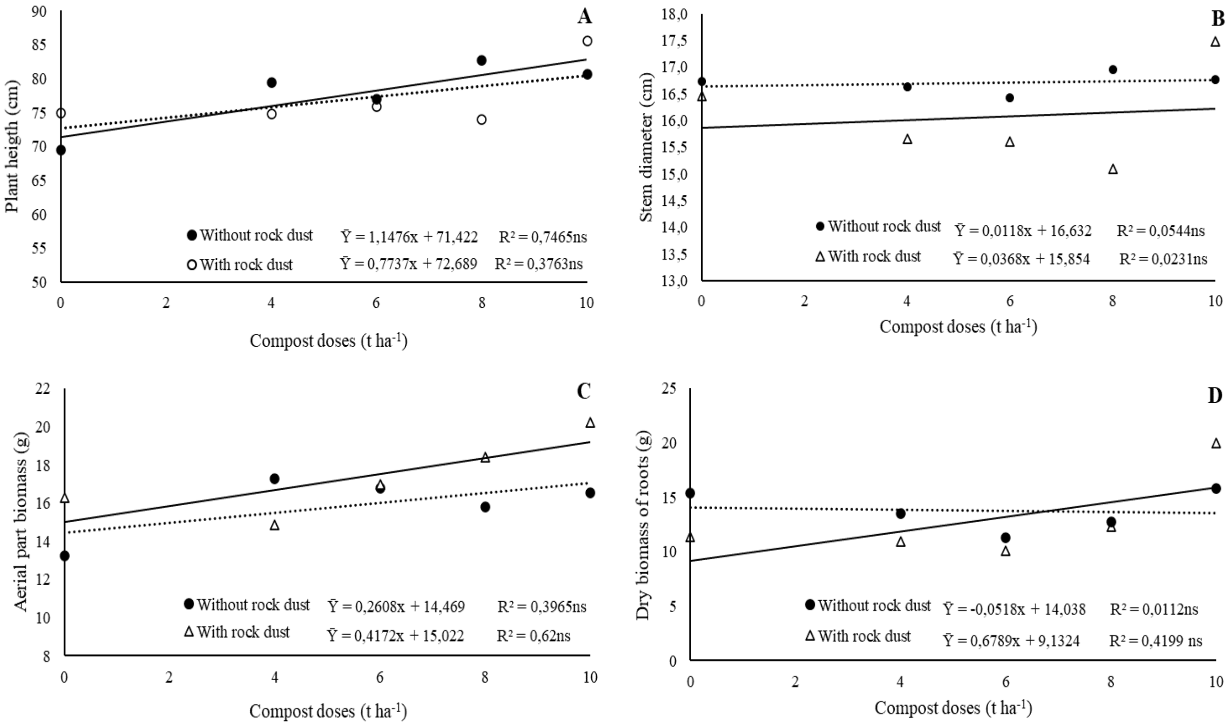

FIGURE 1 - Plant height (cm) (A), stem diameter (cm) (B), dry biomass of the aerial part (C), root biomass (g) (D) and volume (cm^3) of the root system of corn plants, after application of compost doses with and without basalt rock powder.

There was a significant difference between the factorial treatment (compost doses with and without rock dust) and the additional treatment (300 kg ha^{-1} of chemical fertilizer and 150 kg of chemical fertilizer + rock dust) in all variables evaluated. In the additional treatment, it was found that the use of ½ dose of the fertilizer with NPK (150 kg ha^{1}), together with 8 t ha^{-1} of rock dust, provided a greater amount of dry biomass of the aerial part and roots, compared to 300 kg ha^{-1} of the NPK formula without rock dust (Figure 2). These increases were 13.32% and 27.47%, respectively. In this treatment, the volume of the roots was higher, with an average increase of 48.88%. In the additional treatments, there was no significant difference for plant height and corn stalk diameter**.**

The best results obtained with the use of 150 kg ha^{-1} of chemical fertilizer (NPK) + 8 t ha^{-1} of basalt rock powder can be attributed to the composition of the rock powder itself, which, in addition to the P and K nutrients, contains other macronutrients, such as Ca, Mg, S and micronutrients important for plant development. Rock dust can also activate the soil microbiota, improving the availability of nutrients. Contrasting results were observed by Sékula (2011), according to whom no significant differences were found regarding the agronomic traits of corn cultivated with NPK and NPK + basalt rock powder.

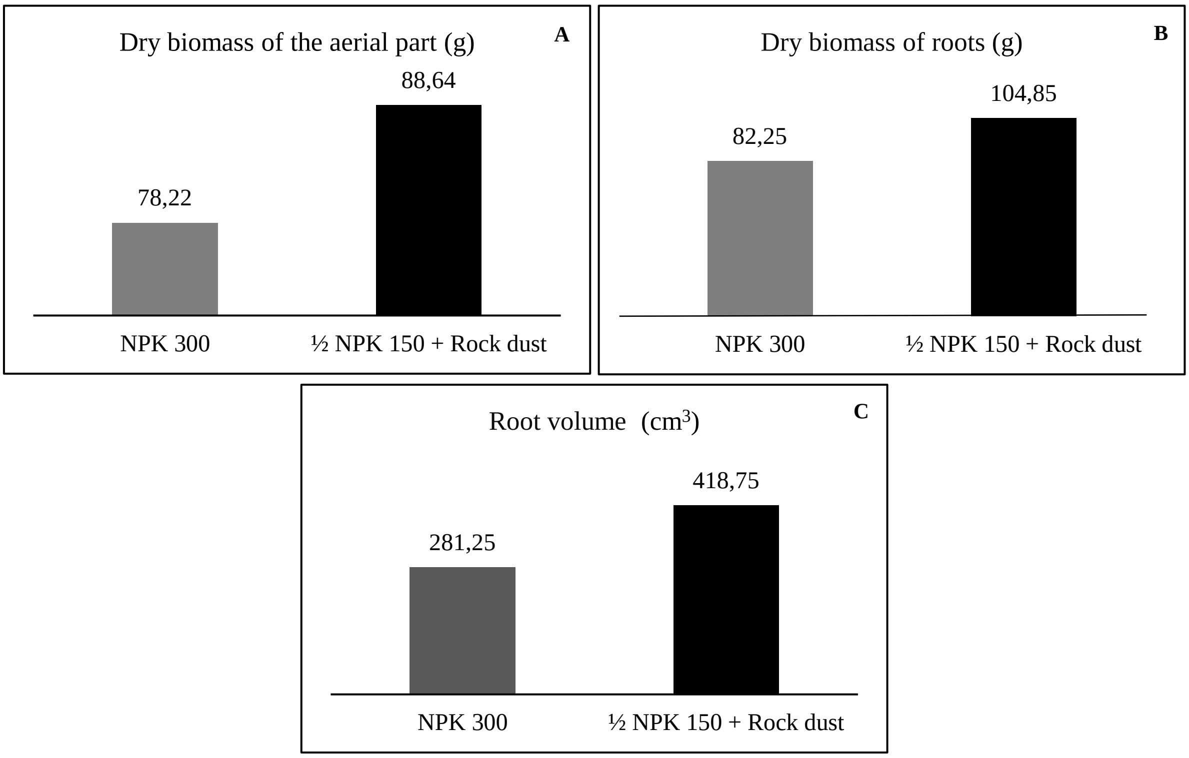

FIGURE 2 -. Dry biomass of the aerial part (g) (A), dry mass of root(g) (B) and root volume (cm^3) (C) of corn after application of 300 kg ha^{-1} of NPK fertilizer and 150 kg ha^{-1} of NPK fertilizer with rock dust.

The additional treatment statistically differed from the factorial treatment for all the agronomic traits evaluated. Fertilization with NPK at the rate of 300 kg ha^{-1} and 150 kg ha^{-1} plus rock dust favored corn development. This result demonstrates that the organic compost used in this experiment with or without rock dust was not able to supply the nutrients in the amount required by the plants (Table 3).

TABLE 3 - Plant height (cm), stalk diameter (cm), dry biomass of the aerial part (g), dry biomass of corn root (g) and root volume (cm^3) of corn plants grown with organic compost, rock dust and NPK fertilization.

Treatment	AP (cm)		DC (cm)		BSPA (g)	
Factorial*additional	77.00*	125.81	16.48*	21.39	13.34*	93.45
CV(%)	10.00		9,50		24.80	
	BSR (g)		RV (cm^3)			
Factorial*additional	16.64*	83.43	89.62*	350		
CV(%)	25.72		35.77			

*Significant at 5%, AP = plant height, DC = stalk diameter, BSPA = dry biomass of the aerial part BSR = dry biomass of root, RV = root volume, CV (%) = coefficient of variation.

Regarding soil chemical properties, a positive effect was observed with the use of the compost with rock powder. This increase was linear for soil pH (KCl), Ca content, SB and V%. In the absence of rock dust, there was no adjustment of an equation (Figure 3). The use of compost and rock dust did not promote a significant difference for potential acidity (H+Al), organic matter content, P and K.

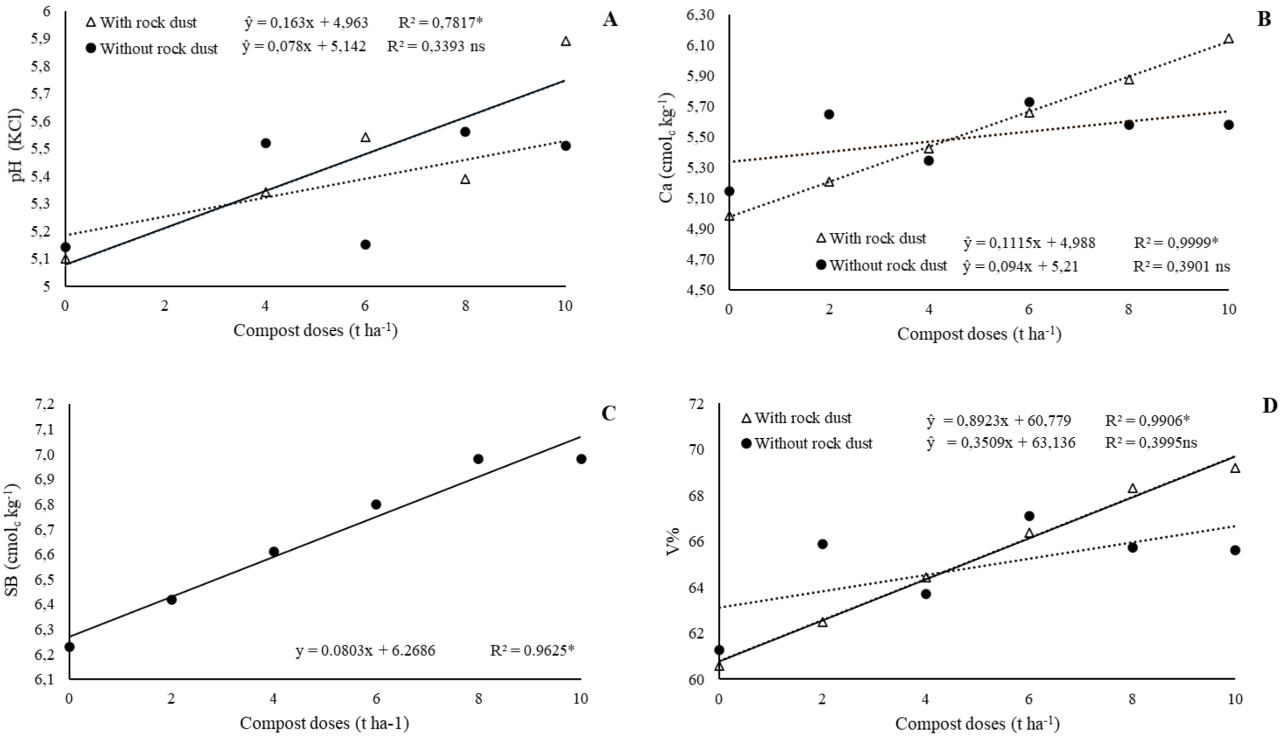

FIGURE 3 - Chemical properties of the soil after application of compost doses with and without basalt rock powder. pH (A), calcium (B), Base saturation (SB) (C) and V% (D).

This ability of rock dust to increase Ca levels and soil pH and, consequently, SB and base saturation is due to the presence of 16% of oxides in basalt rock powder (Table 1). When rock dust was applied with the organic compound, rich in microorganisms, part of the oxides may have been weathered, becoming available in the soil solution.

Similar results were found by Mayumi et al. (2020) when they applied five doses of basalt rock dust associated or not with bioactives in Latosol. The authors observed an increase in K, Ca and Mg contents and a reduction in soil active acidity and potential. Different results were observed by Hanisch et al. (2013) following application of up to 12 t ha^{-1} of basalt rock powder in soybean and corn cultivation. The authors found no significant difference for pH, Ca, Mg and K contents.

The organic compost is also a source of macronutrients, especially Ca, which can lead to an increase in base saturation (Figure 3). Similar results were observed by Rodrigues et al. (2011), who found an increase in Ca content in the soil after addition of 80 t ha^{-1} of organic compost, compared with the control group. The use of organic sources (compost, green manure, manure) in order to increase the weathering of rock dust and, consequently, increase the availability of nutrients in the soil, can be a good strategy to improve the agronomic efficiency of rock dust for the crops.

Analysis of the additional treatments showed a significant difference for Ca, Mg and SB and there was no significant difference for the contents of OM, pH, Al+H, K, CEC and V%. The highest Ca content was observed in the treatment with 150 kg ha^{-1} of NPK fertilizer + basalt rock powder (8 t ha^{-1}). The explanation for this is that in the treatment with rock dust there is 9.73% of calcium oxide (Table 1). On the other hand, regarding Mg and SB contents, the highest values occurred in the treatment where 300 kg ha^{-1} of the same chemical fertilizer was applied (Table 4).

There were significant differences for factorial versus additional interaction for pH, H+Al, Ca, K, CEC and V(%).The factorial treatment showed the highest pH (KCl) and, consequently, the lowest H+Al content and the highest content of Ca and CEC, probably due to the oxides present in the rock dust. According to Silveira (2016), naturally acidic tropical soils favor the dissolution of silicate minerals present in rock dust. Tebar et al. (2021) also observed an increase in pH with doses of up to 10 t ha^{-1} of basalt rock dust in soybean cultivation.

TABLE 4 - Soil chemical characteristics after growing corn treated with compost, rock dust and NPK.

Treatments	OM (g cm^{-3})	pH (KCl)	H+Al
300 Kg ha^{-1} of NPK	15.89^{ns}	5.10^{ns}	4.31^{ns}
150 Kg ha^{-1} of NPK (½) + rock dust	19.13	5.20	4.33
CV1(%)	24.51	4.44	14.17
Factorial*Additional	15.87^{ns} 17.51	5.40* 5.16	3.65* 4.37
CV2(%)	21.03	5.61	15.16
	Ca (cmo$_c$ kg^{-1})	Mg (cmo$_c$ kg^{-1})	K (cmo$_c$ kg^{-1})
300 Kg ha^{-1} of NPK	4.77^{*}	1.20^{*}	0.54^{ns}
150 Kg ha^{-1} of NPK (½) + rock dust	5.20	0.73	0.65
CV1(%)	4.49	22.90	29.54
Factorial*Additional	5.43* 5.0	0.99^{ns} 0.99	0.20^{*} 0.59
CV2(%)	9.71	18.1	40
	SB (cmo$_c$ kg^{-1})	CEC (cmo$_c$ kg^{-1})	V(%)
300 Kg ha^{-1} of NPK	7.04^{*}	11.36^{ns}	62.03^{ns}
150 kg ha^{-1} of NPK (½) + rock dust	6.15	10.59	58.22
CV1(%)	6.99	6.0	7.17
Factorial*Additional	6.60^{ns} 6.60	10.30^{*} 10.97	64.45^{*} 60.13
CV2(%)	9.46	7.80	6.96

*Significant by t test with 5% error probability, ns = not significant, OM = organic matter, H+Al = hydrogen+ aluminum, Ca = calcium, Mg = magnesium, K = potassium, SB = sum of bases, CEC = cation exchange capacity, V% = base saturation, CV1(%) = coefficient of variation within the additional treatment, CV2(%) = coefficient of variation (factorial*additional).

The use of basalt rock powder can be a strategy for soil chemical improvements, but the rate of dissolution is still slow. Further studies aimed to observe increase in the dissolution of minerals from rock dust, such as microorganisms, use of animal residues, green manures, vermicomposts, as well as the use of rock dust mixtures of different origins are needed.

CONCLUSIONS

The use of organic compost associated with rock dust promoted soil chemical improvements, especially pH elevation and calcium content increase.

There was no effect of organic compost with rock powder on the agronomic traits of corn evaluated.

The use of chemical fertilizer with NPK formula favored corn crop compared to the use of a compost and rock dust.

The application of 8 t ha^{-1} of basalt rock powder, associated with 150 kg ha^{-1} of a fertilizer with NPK formula favored the development of the corn crop compared to the use of 300 kg ha^{-1}.

ACKNOWLEDGMENTS

To “Fundação Araucária” for the scientific initiation scholarship granted to academic.

REFERENCES

ALCANTARA, F.A. **Manejo Ecológico do Solo.** Ed. EMBRAPA Arroz e Feijão, v.1, n.1, 2017, 28p.

ALMEIDA JÚNIOR, J.J.; HENCHEN, M.E.; JESUS, I.J.; MOURA, R.F.; CARNEIRO, A.O.T.; OLIVEIRA, E.J.C.; VILELA, J.P.M.; BORGES, S.R.C.; ROCHA, S.A.; PICININI, M.; BATISTA, M.F. Análise das variáveis tecnológicas do milho em função das doses crescentes de condicionador pó de rocha. **Brazilian Journal of Development**, v.6, n.11, p.88440-88446, 2020.

AZADI, H.; SCHOONBEEK, S.; MAHMOUDI, H.; DERUDDER, B.; MAEYER, P.; WITLOX, F. Organic agriculture and sustainable food production system: main potentials. **Agriculture, Ecosystems and Environment**, v.144, n.1, p.92-94, 2011.

COLA, G.P.A.; SIMÃO, J.B.P. Rochagem como alternativa de suplementação de potássio na agricultura agroecológica. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v.7, n.4, [s.p.], 2012.

CONSOLIN FILHO, N.; FARIAS, A.J.B.; CONSOLIN, M.F.B.; PIZA, M.A.; CRESPAN, E.R. Estudo de viabilidade da cama de aviário peletizada não compostada como adubo orgânico. **Natural Resources**, v.10, n.3, p.145-161, 2020.

DEUS, A.A.F.; CASSIOLATO, A.M.R.; SILVA, E.A.; FERNANDES, F.M.; SANTOS, T.E.B.; MALTONI, K. L. **Influência da rochagem nos atributos químicos e atividade microbiana de um Latossolo.** 2007. Available at: <https://www.feis.unesp.br/Home/Eventos/encivi/iencivi-2007/9-angelica-c.f.d.pdf>. Access in: 04 dez. 2021.

FERREIRA, D.F. Sisvar: um sistema computacional de análise estatística. **Ciência e Agrotecnologia**, v.35, n.6, p.1039-1042, 2011.

HANISCH, A.L.; FONSECA, J.A.; BALBINOT JUNIOR, A.A.; SPAGNOLLO, E. Efeito de pó de basalto no solo e em culturas anuais durante quatro safras, em sistema de plantio direto. **Revista Brasileira de Agropecuária Sustentável**, v.1, n.3, p.100-107, 2013.

HUSNAIN, R.S.; SUTRIADIA, T.; NASSIRB, A.; SARWANIC, M. Improvement of soil fertility and crop production through direct application of phosphate rock on maize in Indonesia. **Procedia Engineering**, v.83, n.1, p.336-343, 2014.
LOPES, O.M.M.; CARRILHO, E.N.V.M.; LOPES-ASSAD, M.L.R.C. Efeito de pó de rocha e vinhaça em dois tipos de solos. **Revista Brasileira de Ciência do Solo**, v.38, n.5, p.1547-1557, 2014.
MAYUMI, A.; ALOVISI, A.M.T.; TAQUES, M.M.; ALOVISI, A.A.; TOKURA, L.; SILVA, J.A.M.; CASSOL, C.J. Rochagem como alternativa sustentável para a fertilização de solos. **Revista Gestão & Sustentabilidade Ambiental**, v.9, n.1, p.918-932, 2020.
MELLO DUARTE, J.R.; BASÍLIO, S.A.; SILVA, M.B.; VAZ, V.; PIRES, J.P.D.; BERTI, M.P.S. Produtividade e qualidade de sementes de feijão em resposta a fertilizante mineral, biofertilizante e pó de rocha. **Revista Cultura Agronômica**, v.30, n.1, p.78-92, 2021.
RODRIGUES, P.N.F.; ROLIM, M.M.; NETO, E.B.; COSTA, R.N.T.; PEDROSA, E.M.R.; OLIVEIRA, V.S. Efeito do composto orgânico e compactação do solo no milho e nutrientes do solo. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v15, n.8, p.788-793, 2011.
SANTOS, H.G.; JACOMINE, P.K.T.; ANJOS, L.H.C.; OLIVEIRA, V.A.; LUMBRERAS, J.F.; COELHO, M.R.; ALMEIDA, J.A.; ARAUJO FILHO, J.C. de; OLIVEIRA, J.B.; CUNHA, T.J.F. **Sistema brasileiro de classificação de solos.** 5ª. ed. Brasília, DF: Embrapa, p.356, 2018.
SEDIYAMA, M.A.N.; SANTOS, I.C.; LIMA, P.C. Cultivo de hortaliças no sistema orgânico. **Revista Ceres**, v.61, n.1, p.829-837, 2014.
SÉKULA, C.R. **Características químicas do solo e produção de grandes culturas com rochagem e biofertilizantes.** 2011. 61p. Dissertação (Mestrado em Agronomia). Universidade Estadual do Centro-Oeste, Guarapuava, 2011.
SILVA, A.; ALMEIDA, J.A.; SCHMITT, C.; AMARANTE, C.V.T. Fertilidade do solo e desenvolvimento de feijão comum em resposta adubação com pó de basalto. **Revista Brasileira de Ciências Agrárias**, v.7, n.4, p.548-554, 2012.
SILVA, A.S.; OLIVEIRA, M.; MOURA, M.F.; SILVA, S.P. Efeito da adubação verde na qualidade nutricional do milho (*Zea mays* L.). **Revista GEAMA**, v.1, n.6, p.31-37, 2020.
SILVEIRA, R.T.G. **Uso de rochagem pela mistura de pó de basalto e rocha fosfatada como fertilizante natural de solos tropicais lixiviados.** 2016. Dissertação (Mestrado em Geociências) - Universidade de Brasília, Brasília, 2016.
TEIXEIRA, TEIXEIRA, P.C.; DONAGEMMA, G.K.; FONTANA, A.; TEIXEIRA, W.G. **Manual de métodos de análise de solos.** 3ª. ed. Brasília, DF. Ed. EMBRAPA, v.1, p.574, 2017.
TEBAR, M.M.; ALOVISI, A.M.T.; MUGLIA, G.R.P.; VILLALBA, L.A.; SOARES, M.S.P. Residual effect of basaltic rock powder on the chemical and microbiological attributes of the soil and on the nutritional status of the soybean crop. **Research, Society and Development**, v.10, n.11, p.e375101119612, 2021.
TOSCANI, R.G.; CAMPOS, J.E.G. Uso de pó de basalto e rocha fosfatada como remineralizadores em solos intensamente intemperizados., São Paulo, UNESP, **Geociências**, v.36, n.2, p.259-274, 2017.
VALENTE, B.S.; XAVIER, E.G.; MORSELLI, T.B.G.A.; JAHNKE, D.S.; BRUM J.R.; CABRERA, B.R.; MORAES, P. de O.; LOPES, D.C.N. Fatores que afetam o desenvolvimento da compostagem de resíduos orgânicos. **Archivos de Zootecnia**, v.58, n.1, p.59-85, 2009.
VAN STRAATEN, P. Farming with rocks and minerals: challenges and opportunities. **Anais da Academia Brasileira de Ciências**, v.78, n.4, p.731-747, 2006.
WAIGWA M.W.; OTHIENO C.O.; OKALEBO J.R. Phosphorus availability as affected by the application of phosphate rock combined with organic materials to acid soils in western Kenya. **Experimental Agriculture**, v.39, n.4, p.395-407, 2003.
WRITZ, T.C.; CANEPELLE, E.; STEIN, J.R.S; KERKHOFF, J.T.; STEFFLER, A.D.; SILVA, D.W.; REDIN, M. Produção de milho pipoca com uso do pó de rocha de basalto associado à cama de frango em Latossolo. **Revista Brasileira de Agropecuária Sustentável**, v.9, n.2, p.101-109, 2019.