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Agronomic performance of maize crop in response to the application of metabasalt powder rates

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Abstract

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The use of metabasalt powder in the soil can promote remineralization and increase crop yield. Therefore, this study was conducted with the objective of investigating the residual effect of metabasalt rock powder after one year of application on the agronomic performance of the maize crop. The experimental design used was a randomized block with four application rates of metabasalt powder (0, 3, 6 and 9 t ha^{-1}) and six replications. The metabasalt powder used is a residue from an amethyst stone mining company in Rio Grande does Sul, Brazil. At the physiological maturity of the crop, plant height, ear insertion height, ear length, ear diameter, number of grain rows per ear, number of grains per row, thousand grain mass and grain yield of maize were measured. The application of metabasalt powder resulted in increase in the number of grains per row, thousand grain mass and grain yield of the maize crop. The application of 6.0 t ha^{-1} of metabasalt rock powder resulted in the highest maize grain yield.

Keywords: nutrients; remineralizer; rock powder; *Zea mays*

Introduction

Maize (*Zea mays* L.) is the third most cultivated cereal crop in the world, with about 191 mln ha (FAO, 2019). In Brazil, the area cultivated with this cereal was 17.25 million hectares in the 2018/2019 growing season. This area is distributed in two growing seasons per year in the country (1st harvest and 2nd harvest or out-of-season corn) (CONAB, 2019). Maize grown out-of-season, from January to May, represents around 72% of the cultivated area in Brazil, and has an average yield of around 5857 kg ha^{-1}. This cereal is dependent on an appropriate soil nutrition to achieve high levels of productivity, which is usually accomplished through chemical fertilization. As an alternative, the use of rock powder for crops has been investigated, which consists of the incorporation of rocks ground in the soil (Santos et al., 2016), to improve the soil chemical properties and crop yield.

Several rock materials can be used in agriculture, such as metabasalt powder. According to Hartmann (2010), metabasalt powder is a residue from the mining of amethysts, and can be an excellent alternative source of nutrients for plants, especially due to its highly reactive clay minerals. Metabasalt powder has high contents of calcium (Ca), magnesium (Mg), phosphorus (P) and potassium (K); and, the application of this residue can contribute to soil fertilization, especially in areas with high levels of organic matter due to the contribution of humic substances in the solubilization and availability of some nutrients (Santos et al., 2016).

Therefore, as metabasalt powder has in its composition essential nutrients for plants, it has potential for use in agriculture. Dallacorte et al. (2015) showed that there was an improvement in the chemical properties of the soil and increase in the production of native pastures. However, the effect of the use of metabasalt powder on maize is still unknown.

In Brazil, with the expansion of agricultural cultivation areas and greater use of soils, there is a need to use new management practices that can minimize the impacts caused to the soil by agricultural production systems (Morais et al., 2020). In addition, it is also necessary to make agriculture more sustainable with less expenditure of chemical inputs and with the use of residues from other activities, such as mining mines. According to Korchagin et al. (2019), large amounts of amethyst stone residues are accumulated on the outside the various mining mines in the southern region of Brazil, and have made an unsustainable environmental issue. Therefore, the use of this material in agriculture has been an option in recent years.

The use of metabasalt powder can be an alternative or complementary source to the application of soluble fertilizers, and as an option in the recovery of degraded soils. This application allows farmers to keep the soil healthy and with adequate fertility for crops without causing degradation to the agroecosystem. Therefore, this study was conducted to investigate the performance of the agronomic characteristics of the maize crop after one year of superficial application of metabasalt powder in the soil.

Material and Methods

Study site description

The experiment was conducted in the experimental area at the Federal University of Mato Grosso do Sul (UFMS), in Chapadão do Sul, Mato Grosso do Sul, Brazil (18°46'18'' S, 52°37′25′ W and altitude of 810 m), during the 2019/2020 growing season. The regional climate, according to the Köppen classification, is Aw, characterized as humid tropical, with hot summers and a tendency toward high rainfall levels, and dry winters, with a dry season between May and September. The mean annual temperature is 24.0ºC, with a mean annual rainfall of 1260 mm. The climatic data gathered during the experiment are shown in Figure 1.

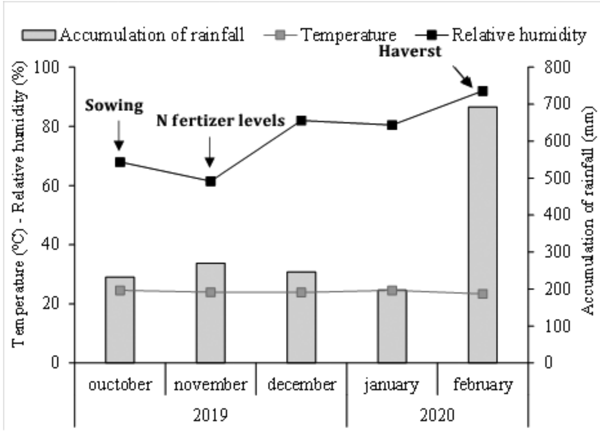

Fig. 1. Monthly rainfall, average monthly temperature, and relative humidity during the cropping of maize crop in Chapadão do Sul, Mato Grosso do Sul state, Brazil
Source: National Meteorological Institute (INMET)

The soil of the experimental area was a Rhodic Hapludox (Latossolo Vermelho distrófico under the Brazilian classification) with 545, 25 and 430 g kg^{-1} of clay, silt, and sand, respectively. In August 2018, the soil was sampled from the 0-0.20 m layer, and the main chemical properties are shown in Table 1.

The correction of soil acidity was carried out with the superficial application of 2,500 kg ha^{-1} of limestone (CaO: 29%, MgO: 20% and effective calcium carbonate equivalent: 90%), to raise soil base saturation to 60% (Sousa & Lobato, 2004). At 60 days after liming, soybean was sown in all experimental plots, and cultivated during the 2018/2019 growing season. Mineral fertilization was carried out with application of 150 kg ha^{-1} P_2O_5 and 30 kg ha^{-1} N [monoammonium phosphate (MAP)] at the sowing furrow, and 100 kg ha^{-1} K_2O

Table 1. Main chemical properties of soil in the experimental area

pH $CaCl_2$	OM g dm^{-3}	$P_{Mehlich-1}$ mg dm^{-3}	H+Al	Al^{3+}	Ca^{2+}	Mg^{2+}	K^+	CEC	V %
			-------------------- $cmol_c$ dm^{-3} ---------------------						
4.3	22.8	12.8	5.70	0.37	2.20	0.40	0.27	8.57	33.5

OM: Organic matter. CEC: Cation exchange capacity at pH 7.0. V: Soil base saturation.

[(potassium chloride (KCl)] in topdressing. In Abril 2019 after the soybean harvest, ruzigrass [*Urochloa ruziziensis* (R. Germ. & C.M. Evrard) Crins (Syn. *Brachiaria ruziziensis* Germ. & Evrard)] was sown at a density of 5.0 kg seeds ha^{-1}, without the addition of mineral fertilizer. At 50 days before sowing the maize crop, the ruzigrass plants were desiccated with glyphosate (920 g a.i. ha^{-1}) at a spray volume of 180 L ha^{-1}.

Experimental design and treatments

The experimental design used was randomized block with four application rates of ground metabasalt rock (0, 3, 6 and 9 Mg ha^{-1}), and six replications. The metabasalt powder used is a residue from an amethyst stone mining company from the Rio Grande do Sul State, Brazil. The rates of metabasalt powder were formulated from the mixture of ground rock particles of coarse and fine size in the proportion 3:1 (v:v). The main chemical characteristics of the metabasalt rock powder are shown in Table 2.

Table 2. Main chemical characteristics of amethyst rock powder used in this study

Chemical elements	%
Silicon (SiO_2)	48.80
Aluminum (Al_2O_3)	14.64
Iron (Fe_2O_3)	16.85
Calcium (CaO)	8.48
Titanium (TiO_2)	3.64
Magnesium (MgO)	4.28
Potassium (K_2O)	2.10
Phosphorus (P_2O_5)	0.74
Manganese (MnO)	0.23

The metabasalt rock powder was applied in October 2018, in experimental plots of 2.0 x 4.0 m. Therefore, in this study we investigated the residual effect after one year of the application of ground amethyst rock on the maize crop. The experimental units consisted of four maize rows from 4.0 m long, with 0.45 m between rows. The useful area comprised the two central rows of each plot, disregarding 0.50 m of each edge.

Experiment Implementation and Conduction

Maize crop was mechanically sown on October 18th, 2019, at a depth of 3 cm, in rows 0.45 m apart at a density of 3.5 seeds per meter to reach a final stand of 70 000 to 75 000 plants per hectare. The maize genotype used was the simple hybrid FS 450 PW, with a super-early cycle. The base fertilization consisted of the application 120 kg ha^{-1} P_2O_5 and 25 kg ha^{-1} N [monoammonium phosphate (MAP)] at the sowing furrow. Maize seeds were previously treated with cyantraniliprole, metalaxyl-M, thiabendazole and fludioxonil at the rate of 70, 0.6; 4.5 and 0.75 g a.i. kg^{-1} of seed, respectively. At 30 days after the emergence of the plants (V4 stage – four fully expanded leaves), 200 kg ha^{-1} of N (urea) were applied in topdressing. At 40 days after the emergence of the plants (V6 – six fully expanded leaves), foliar fertilization was applied using 1 Lha^{-1} of Actilase ZM (50 g L^{-1} Zn; 42 g L^{-1} S; 30 g L^{-1} Mn).

The weed control was performed at 25 days after the emergence of the maize plants, using 1500 and 100 g a.i. ha^{-1} of herbicides Atrazine and Tembotrione, respectively. At the beginning of maize flowering, the fungicides Pyraclostrobin and Epoxiconazole was applied at a rate of 100 and 88 g a.i. ha^{-1}, respectively. The insecticides Metomil, Imidacloprid and Thiodicarb were also applied at a rate of 13, 45 and 135 g a.i. ha^{-1}, respectively.

Measurement of crop agronomic traits

At the physiological maturity (R_6 stage), plant height and ear insertion height were measured in ten plants per plot. The plant height (cm) was determined from the soil surface to the insertion of the last leaf and measured with a measuring tape. The ear insertion height (cm) was determined from the soil surface to the insertion of the first ear, with a measuring tape.

The maize ears contained in the useful area of the plots were manually harvested and then threshed in a Wintersteiger Classic® Plot Harvester. The grain yield and agronomic traits were then measured. The ear length, number of grain rows per ear, number of grains per row, and ear diameter were determined in twenty ears chosen at random. Then, the mass of one thousand grains (g) was determined according to the methodology described in Brasil (2009), and the grain yield (kg ha^{-1}) was standardized to 13% grain moisture.

Statistical Analysis

The data were subjected to analysis of variance by the F test, at the 5% probability level, using Sisvar® version 5.3 software for Windows (Statistical Analysis Software, UFLA, Lavras, MG, BRA). Regression analyzes were used to assess the residual effect of metabasalt rock powder rates, and significant equations with the highest coefficients of determination (F test, $P < 0.05$) were adjusted. Regression analysis was performed with SigmaPlot 11.0 software for Windows (Systat Software, Inc., San Jose, CA, USA). Canonical correlation analysis was used to study the relationship between the variables of residual effect of metabasalt powder (indepen-

Table 3. Summary of analysis of variance for measurements of plant height (PH), ear insertion height (EIH), ear length (EL), ear diameter (ED), number of grain rows per ear (NRE), number of grains per row (NGR), thousand grain mass (1000-G) and grain yield (GY) of maize crop grown under residual effect of metabasalt (amethyst) rock powder application rates in Chapadão do Sul, MS, Brazil, in the 2019/2020 growing season

Source of variation	PH	EIH	EL	ED	NRE	NGR	1000-G	GY
	F value							
Rates applied	1.45^{ns}	0.08^{ns}	2.34^{ns}	0.51^{ns}	0.02^{ns}	2.53*	3.16**	3.37**
CV, %	1.61	5.92	4.93	3.44	4.32	4.37	4.14	5.60

** and *: significant to the F test at 1% and 5%, respectively. ns: not significant. CV: coefficient of variation

dent variable) and the dependent variable group (number of grains per row, thousand grain mass and grain yield), using the Rbio software version 140 for Windows (Rbio Software, UFV, Viçosa, MG, BRA).

Results and Discussion

The results of the analysis of variance reported that the residual effect of ground metabasalt rock application was significant ($P < 0.05$) on the number of grains per row, mass of 1000 grains and grain yield (Table 3). These results are contrary to those reported by Aguilera et al. (2020), which showed that the basalt rock powder rates did not significantly affect the production components and grain yield of out-of-season maize.

The residual effect of the applied rates of metabasalt powder was not significant ($P > 0.05$) for most of the agronomic traits of the maize crop (Figure 2). There was no significant effect of the ground metabasalt rock rates after one year of application on plant height (Figure 2a), ear insertion height (Figure 2b), ear length (Figure 2c), ear diameter (Figure 2d) and number of grain rows per ear (Figure 2e). Similar results were reported by Aguilera et al. (2020), who found that the application of basalt rock powder did not result in a significant effect on most of the agronomic traits of the maize crop.

The use of metabasalt rock powder resulted in increase in the number of grains per row (Figure 2f), thousand grain mass (Figure 2g) and grain yield (Figure 2h) of the maize crop. The maximum values of the number of grains per row (39 grains), thousand grain mass (458 g) and grain yield (10 088 kg ha^{-1}) were obtained with the application of 5.6; 4.8 and 5 t ha^{-1} of metabasalt rock powder, respectively. These results are contrary to those reported by Hanisch et al. (2013), who stated that the application of basalt rock powder did not affect the grain yield of the maize crop.

The beneficial effect of the application of metabasalt powder on the number of grains per row (Figure 2f), mass of 1,000-grains (Figure 2g) and grain yield (Figure 2h) of maize may be due to the release of nutrients contained in the ground rock material (Table 2). This metabasalt rock pow-

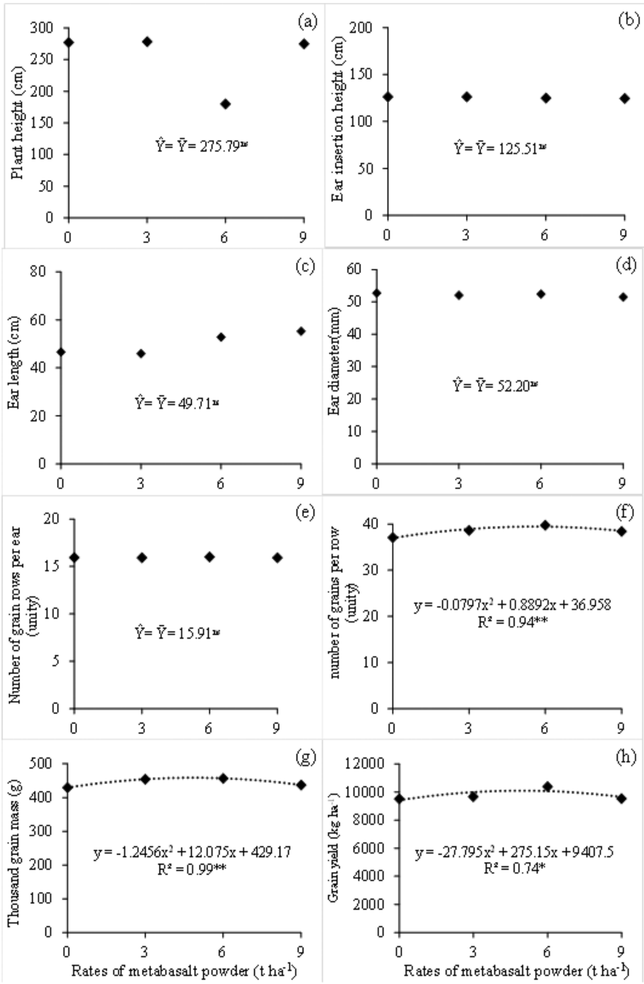

Fig. 2. Plant height (a), ear insertion height (b), ear length (c), ear diameter (d), number of grain rows per ear (e), number of grains per row (f) thousand grain mass (g) and grain yield (h) of the maize crop grown under residual effect of metabasalt (amethyst) rock powder application rates during the 2019/2020 growing season. Chapadão do Sul, MS, Brazil

** e *: significant at 1% and 5% probability by Student's t test der material has 48% silicon oxide in its composition, and lower proportions of magnesium oxides (4.28%), potassium (0.74%) and phosphorus (0.23%), which are solubilized in the medium term in the soil and, therefore, can improve the mineral nutrition of plants and the grain yield of the maize crop. According to Duarte (2010), after the addition of rock powder to the soil, the chemical weathering will decompose slowly, being able to gradually release the essential nutrients to the plants.

The largest number of grains per row and grain weight is agronomic traits that have a direct effect on the grain yield of the crop. Hanisch et al. (2013) reported an increase in the contents of Zn, Cu, Fe, Mg and P in the soil after 14 months of the application of basalt rock powder rates. This fact is associated with the slow release of nutrients from rock powder to the soil. However, the application of basalt rock powder has a beneficial residual effect on the grain yield of maize crop, as reported in this study.

Canonical correlation analysis was used to identify the contribution of each dependent variable on residual effect of metabasalt powder application rates (Figure 3). For the scores to be represented in a two-dimensional graph, the percentage of retained variance must be higher than 80% (Mingoti, 2005). In this study, variances accumulated in the two main canonical variables were 74.4 and 97.1%, respectively,

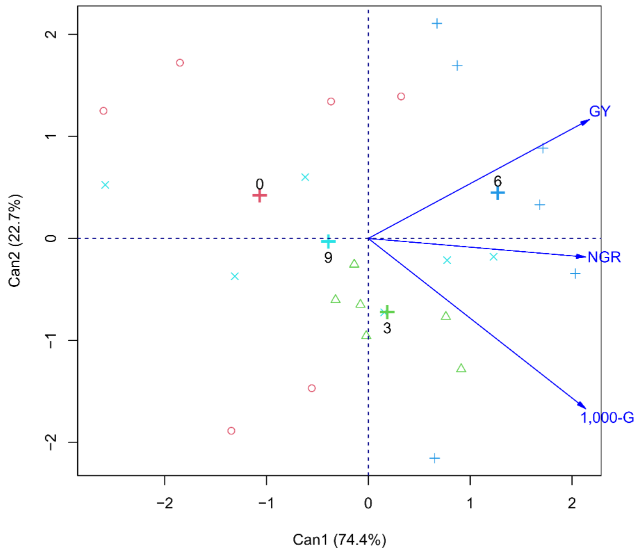

Fig. 3. Canonical correlation between the production components (number of grains per row – NGR, thousand grain mass – 1000-G and grain yield – GY) of the maize crop grown under residual effect of metabasalt (amethyst) rock powder application rates (0, 3, 6 and 9 t ha^{-1}) during the 2019/2020 growing season. Chapadão do Sul, MS, Brazil

for each graph (Figure 3), which allows an accurate interpretation.

The angles between the vectors are less than 90° indicating that there is a positive correlation between the maize production components (number of grains per row – NGR, thousand grain mass – 1000-G and grain yield – GY) and the application of 6.0 t ha^{-1} of metabasalt powder. Thus, the greater the number of grains per row and thousand grain mass, the greater the grain yield of the maize crop. In turn, it can also be observed that the application of 3.0 t ha^{-1} of metabasalt powder is associated with the variable thousand grains mass (1000-G).

The treatment without application of metabasalt rock powder and the application of 9 t ha^{-1} have no association with the dependent variables, as can be seen from the distance of the vectors, confirming the results of the conventional analysis of variance (Table 3 and Figure 2). Therefore, the recommendation of an adequate rate of metabasalt powder application is essential since the amount of ground rock applied has a direct influence on the production components of the maize crop.

Conclusion

The application of metabasalt powder resulted in an increase in the number of grains per row, thousand grain mass and grain yield of maize. The application of 6.0 t ha^{-1} of metabasalt powder resulted in the highest grain yield of the maize crop.

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References

Aguilera, J. G., Zuffo, A. M., Ratke, R. F., Goes, R. J., Jesus, N. S., Silva, L. N., Marques, K. G. A., Lima, R. E., Krewer, B. I. & Godoy, M. L. (2020). Production components of off-season corn are not influenced by basalt powder doses after two years of application. In: Zuffo, A. M., and Aguilera, J. G. (org). *Agronomy: advances and perspectives.* Nova Xavantina: Pantanal editora, 91-100. doi: 10.46420/9786599120862cap8 (Portuguese).

Brasil (2009). Ministry of Agriculture, Livestock and Supply. *Rules for seed analysis.* Brasília: MAPA/ACS, Brasil. (Portuguese).

Conab (2019). National Supply Company. Monitoring the Brazilian crop: grains, tenth survey, July 2019. Companhia Nacional de Abastecimento, Brasília, Brasil. (Portuguese).

Dalacorte, L., Korchagin, J., Abreu, C. T., Tonini, V., Muller, R. & Bortoluzzi, **E. C.** (2015). Soil acidity components and pasture production in native grassland subjected to hydrothermalized basalt powder application. XXXV Congresso Brasileiro de Ciência do Solo. Natal-RN, Brasil. (Portuguese).

Duarte, W. M (2010). Potential of phlogoptite, granite and syenite rocks in the availability of potassium in soils. Dissertation (Master in Soil Science) – Centro de Ciências Agroveterinárias, Lages, RS, Brazil. (Portuguese).

FAO (2020). Technology of production of edible flours and protein products from soybeans. Chapter 1. Food and Agriculture Organization. Available in: http:// https://app.amis-outlook.org/#/market-database/supply-and-demand-overview, accessed in: 15/07/2019, 2020.

Hartmann, L. A. (2010). Geodes with amethysts formed by hot water in the time of the dinosaurs. In: Hartmann, L. A. *Geology of the richness of Rio Grande do Sul in Amethyst and Agate geodes.* 1. ed., Porto Alegre: UFRGS, 15-26. (Portuguese).

Hanisch, A. L., de Fonseca, J. A., Balbinot Junior, A. A. & Spagnollo, E. (2013). Effect of basalt powder on soil and annual crops during four seasons, in a straight tillage system. *Revista Brasileira de Agropecuária Sustentável*, *3(2),* 100-107. doi: 10.21206/rbas.v3i2.224 (Portuguese).

Korchagin, J., Caner, L. & Bortoluzzi, E. C. (2019). Variability of amethyst mining waste: A mineralogical and geochemical approach to evaluate the potential use in agriculture. *Journal of Cleaner Production*, *210*, 749-758. doi: 10.1016/j.jclepro.2018.11.039

Mingoti, A. S. (2005). Data analysis through multivariate statistical methods: An applied approach.1. ed. Belo Horizonte: Editora UFMG (Portuguese).

Morais, K. A. D., Zuffo, A. M., Aguilera, J. G., Oliveira Neto, F. M. & Silva, E. L. S. (2020). Agronomic performance of early soybean cultivars as a function of amethyst powder doses. In: Zuffo, A.M., and J.G. Aguilera, (org). Agronomy: advances and perspectives. Nova Xavantina: Pantanal editora, 101-106. doi: 10.46420/9786599120862cap9 (Portuguese).

Santos, E. P., Fioreze, M. & Benatti, M. E. (2016). Chemical composition and potential use of amethyst stone extraction residue as agricultural fertilizer. *Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental*, *20(1),* 515−523. doi: 105902/2236117019705 (Portuguese).

Sousa, D. M. G. & Lobato, E. (2004). Cerrado: soil correction and fertilization. 2. ed. Brasília: Embrapa Informação Tecnológica (Portuguese).

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