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Foliar nutrients of second crop corn submitted to basalt and animal residues

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ABSTRACT
The use of basalt used with animal residues can be an efficient alternative for fertilization for corn crops. The objective of this study was to evaluate the effect of doses of basalt powder with cattle manure and chicken litter on the nutritional content of the leaves of the second corn crop, using soluble chemical fertilization (NPK) as a reference. The experiment was carried out in DBC with factorial arrangement (5 x 2) + 1, in four replications, using five basalt doses (0, 4, 8, 12 and 16 t ha-1) associated with cattle manure and chicken litter and an additional treatment with soluble chemical fertilization (NPK). The leaf contents of N, P, K, Ca and Mg were evaluated. The nutrients N, P, K of corn cultivated with basalt doses and animal residues did not show significant differences. The leaf Ca and Mg contents of the two residues showed positive responses. The use of basalt in association with residues provided responses equivalent to those obtained with the use of soluble chemical fertilization, and these inputs can be indicated for use in agriculture to contribute to the sustainability of agricultural systems.

Keywords: Fertilization, Chicken litter, Cattle manure, Remineralizer, Nutrient contents.

1 INTRODUCTION

The areas under cultivation of second crop corn (off-season corn) have been growing due to the technological evolution of Brazilian agriculture, which provides an increase in the country's agricultural production potential. The state of Paraná is the second largest producer of this commodity

and in recent years the crop has shown excellent profitability, becoming the main second crop crop (IBGE, 2022).

Fertilization in corn is one of the fundamental requirements for the supply of nutrients in order to meet the demand of the plant and make it express its maximum productive potential. In Brazil, the most common form of fertilization in agriculture is through industrialized sources of nutrients, which are basically soluble fertilizers such as NPK (a mixture of different concentrations of nitrogen, phosphorus and potassium), as well as other micronutrients specific to each type of soil and crop (TOSCANI; CAMPOS, 2017).

Brazil imports about 85% of the fertilizers it uses in agriculture, with 95% of N, 75% of P and 95% of K; and 23% of these is supplied by Russia (ANDA, 2022). With the recent conflicts between Russia, a major exporter of fertilizer raw material, and Ukraine, there was a reduction in the supply of this raw material, resulting in a rise in fertilizer prices, which directly impacted the increase in production costs in Brazil.

This reality shows a high level of external dependence and leaves the Brazilian economy vulnerable to fluctuations in the international fertilizer market (ANDA, 2022; BRAZIL, 2021), causing instability in the agricultural sector, which ends up compromising its sovereignty and food security.

In this sense, research has been advancing in order to propose alternative sources of fertilizers through the use of basalt rock powder also called remineralizers, which presents macro and micronutrients, as well as beneficial elements that can contribute to the nutrition and development of corn and have a residual effect for a long period (WRITZL et al., 2019). However, basalt needs to go through the solubilization process to release its nutrients. One of the alternatives to increase the rate of solubilization of minerals and favor the release of nutrients that are associated with the composition of the rock is its association with materials that have great biological activity, such as residues of animal origin (SILVA et al., 2012).

The use of basalt associated with animal residues may have an action equivalent to chemical fertilizer on the leaf nutrient content of maize; however, there are still few studies on its use in agriculture, and there is a need for further research (WRITZL et al., 2019).

The role of scientific research in this sense is paramount and has advanced in the sense of intensifying studies and validating the use of rock dust considering its various forms of use (associated or not with other materials/inputs), the different types of production systems in which they can be used and the soil conditions. All these factors need to be taken into account as they are decisive to increase the efficiency of use of remineralizers.

The objective of this study was to evaluate the effect of doses of basalt rock dust combined with animal residues (cattle manure and chicken litter) on the leaf nutrient contents of the second corn crop, using soluble chemical fertilization (NPK) as a reference.

2 MATERIAL AND METHODS

The work was carried out in 2022, at the Professor Alcibíades Luiz Orlando Experimental Station located in the municipality of Entre Rios do Oeste-PR, belonging to the State University of Western Paraná - Campus Marechal Cândido Rondon-PR (UNIOESTE/MCR). The geographical coordinates are 24º40'32, 66" south latitude and 54º16'50.46" west longitude, at 244 meters altitude. The soil of the experimental area is classified as a typical Eutroferric Red NITOSOL, with a very clayey texture, with smooth undulating relief (SANTOS et al., 2018).

The soil of the experimental area showed the following results at depths of 0.00-0.20 m: 28.5 mg $^{dm-3}$ of P; 2.3 cmolc dm-3 of K; 5.9 cmolc dm-3 of Ca; 1.8 ^{cmolc} dm-3 of Mg; $^{14.1\ g\ dm-3}$ of CO; $^{5.3}$ pH (CaCl2); 4.6 H+Al; as well as the determination of the granulometry of the soil under study and obtained: 706.8 g kg-1 $^{of\ clay,\ 182.9}$ g kg-1 of silt, 166.3 g $^{kg-1}$ of sand.

According to the Köppen climate classification, the climate of the region is of the subtropical humid mesothermal type (Cfa), with hot summers, average temperatures above 22ºC and winters with average temperatures and below 18ºC and an average annual rainfall of 1600-1800 millimeters (CAVIGLIONE et al., 2000).

The experiment was conducted in randomized blocks (DBC) in a factorial arrangement (5 x 2) + 1, with four replications. Five doses of basalt powder (0, 4, 8, 12 and 16 t $^{ha-1}$) were combined with two sources of animal residues: cattle manure and chicken litter. In the additional treatment, soluble chemical fertilization was used with 285 kg ha-1 $^{of\ the\ commercial\ formulation\ 12-24-12.}$

The plots consisted of eight sowing rows and had a total area of 40 m2 (5x8 m), with a useful area of 28 m2.

Prior to corn sowing, basalt powder and residues were manually applied on the surface and in the total area of each plot, according to the respective doses and quantities of inputs, using 5 t ha-1 of residues.

Corn sowing was carried out mechanically in January 2022. The hybrid PIONER P3223VYH was used, with a spacing of 0.50 m between rows and a density of 3.3 seeds/linear meter.

Leaves were collected to determine the nutritional content when the plants were at the beginning of flowering (R1 stage). The evaluation of the Ca and Mg content in the leaf tissue was carried out according to the methodology proposed by Lana et al. (2016).

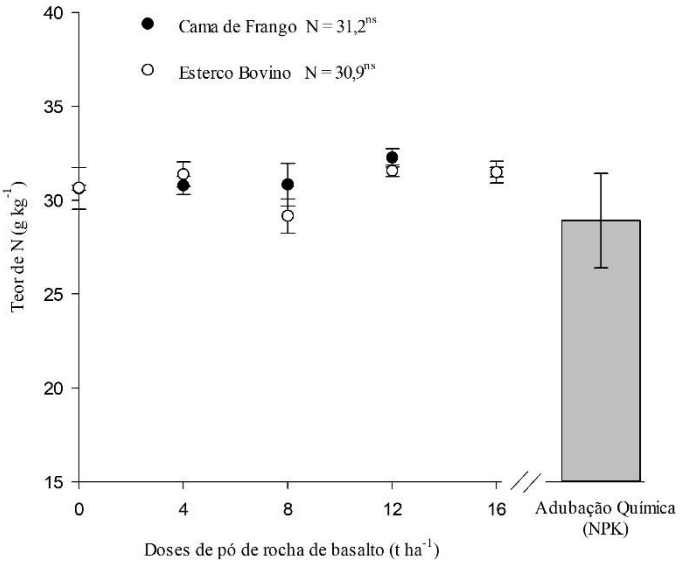
Once the assumptions were met, analysis of variance (ANOVA) was performed at the level of 5% significance for test F. For the doses within each residue, the data were submitted to polynomial regression analysis, and the model that best fit the investigated phenomenon was chosen. To compare the treatments (doses of rock dust and animal residues) with the additional control (soluble fertilization), the Dunnett test (5% probability of error) was applied, where the Dunnett DMS was

calculated, which was added and subtracted from the mean value of the control to obtain a margin of comparison.

3 RESULTS AND DISCUSSION

For the cultivation of the second corn crop with doses of basalt rock dust and animal residues, no polynomial regression model was observed that adjusted the data for the leaf nitrogen (N) contents. The leaf N content of maize cultivated with basalt powder at the rates of 12 t ha-1 (31.9 g kg-1), 16 t ha-1 (31.5 g kg-1) and residues were significantly higher than those obtained with soluble chemical fertilization (NPK) (28.9 g $^{kg-1}$) (Figure 1).

Figure 1 - Leaf N content of second crop corn as a function of doses of basalt rock dust and animal residues. ^{ns}: Not significant for polynomial regression fitting. Notes: Dot bars indicate the average error. Soluble Fertilization Bar indicates Dunnett's DMS (5% error).



Source: Authors (2023).

The absence of effect on the leaf N content of the second corn crop submitted to the treatments may be related to the composition of the residues used, as well as that of the basalt powder, where similar amounts of this nutrient were observed in chicken litter (24.78 g kg-1) and cattle manure (26.80 g kg-1), which may not have been sufficient to express significant differences in the leaves.

In addition, it should be noted that N was also supplied to meet the demand for this nutrient by the crop, from a soluble mineral source. The amounts of nitrogen applied were equivalent in all treatments and this may have contributed to the lack of its effect (GHIZZONI et al., 2021).

The average levels (31.2 and 30.9 g $^{kg-1}$) of N in the leaf tissue of the second crop maize demonstrate the high need for this nutrient, being the most accumulated by the plant (REIS, 2021).

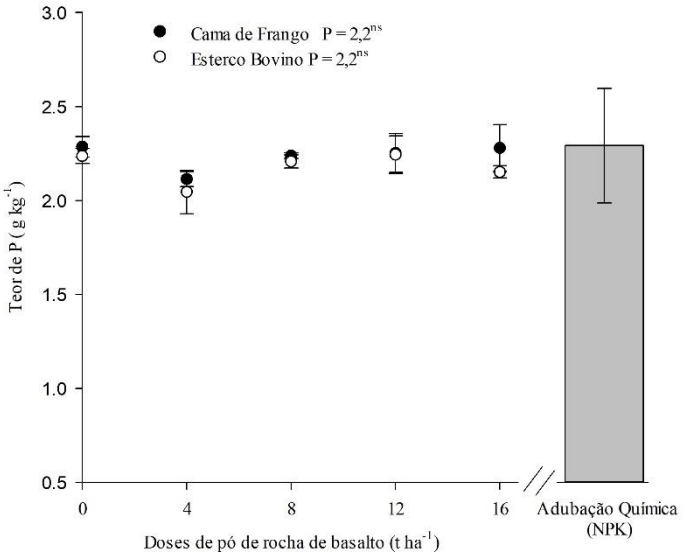
Although no significant effect was found from the treatments, the foliar contents of the nutrient can be interpreted as adequate, since they are within the sufficiency range (27-35 g $^{kg-1}$) indicated for

cultivation (SBCS/NEPAR, 2019). This fact is important since N is used in the formation of proteins; which participate as enzymes in the metabolic processes of plants, having a more functional than structural role. In addition, it participates in the composition of the chlorophyll molecule (RAIJ, 2011).

Similar results were obtained by Ghizzoni et al. (2021), who found no significant differences for N ter in maize grown with nutrient sources based on rock dust and organic residues.

The experimental results of the leaf phosphorus (P) content in the second corn crop show that there was no significant effect of the doses of basalt rock dust and residues. The P content obtained in maize cultivated with basalt powder and animal residues did not differ from that observed in soluble fertilization with NPK (Figure 2).

Figure 2 - Leaf P content of second crop corn as a function of basalt rock dust doses and animal residues. ^{ns}: Not significant for polynomial regression fitting. Notes: Dot bars indicate the average error. Soluble Fertilization Bar indicates Dunnett's DMS (5% error).



Source: Authors (2023).

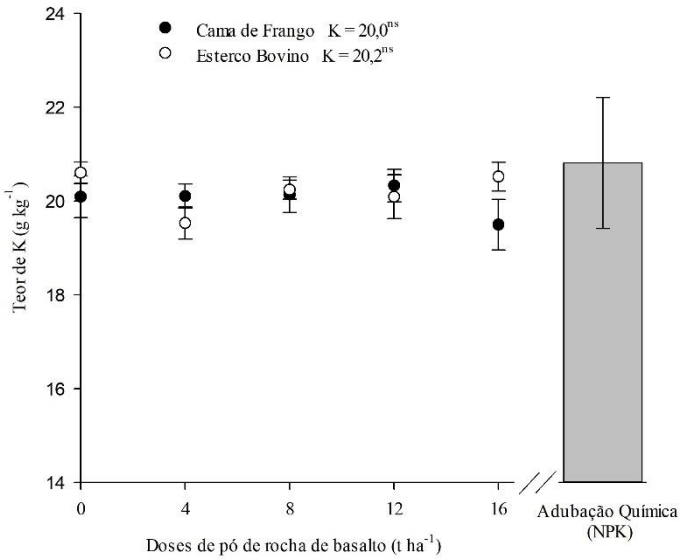
The lack of response in the leaf P contents did not interfere with the values obtained of the nutrient, which on average was 2.2 g kg-1, being within the appropriate range (1.9-4.0 g kg-1) for the crop. Phosphorus is present in energy transfer processes and its adequate supply is important for the formation of the beginnings of the reproductive parts. In adequate amounts, the nutrient stimulates root development (RAIJ, 2011).

Based on the P values, it is inferred that the rock dust together with the animal residues may have contributed to the release of the nutrient (a fact that was observed by the high levels of P found in the soil) and thus the absorption by the plant, reflecting in the adequate leaf contents. These responses reveal the potential of these inputs as alternative sources for crop nutrition (GHIZZONI et al., 2021).

Contrary results were found by Ghizzoni et al. (2021) who, studying corn submitted to nutrient sources, found that plots that received only the layer litter in isolation and associated with rock dust resulted in higher leaf P contents (1.7 g $^{kg-1}$).

The leaf potassium (K) content in maize cultivated with doses of basalt rock powder and animal residues did not show significant difference for any of the polynomial regression models tested. When this nutrient was compared in the second crop corn cultivated with the doses and residues, it was observed that both presented the same leaf K content when compared to soluble fertilization (Figure 3).

Figure 3 - Leaf K content of second crop corn as a function of basalt rock dust doses and animal residues. ^{ns}: Not significant for polynomial regression fitting. Notes: Dot bars indicate the average error. Soluble Fertilization Bar indicates Dunnett's DMS (5% error).



Source: Authors (2023).

K is one of the macronutrients most used by maize, being the second most demanded by the crop, second only to N. Its inadequate availability can directly interfere with productive factors (KINPARA, 2003; REIS, 2021). It is an essential element of metabolic processes in plants, as it plays a fundamental role in photosynthesis, regulates the entry of carbon dioxide through the opening and closing of stomata, activation of enzyme systems and maintenance of cell turgidity (ANDRADE et al., 2000; RAIJ, 2011).

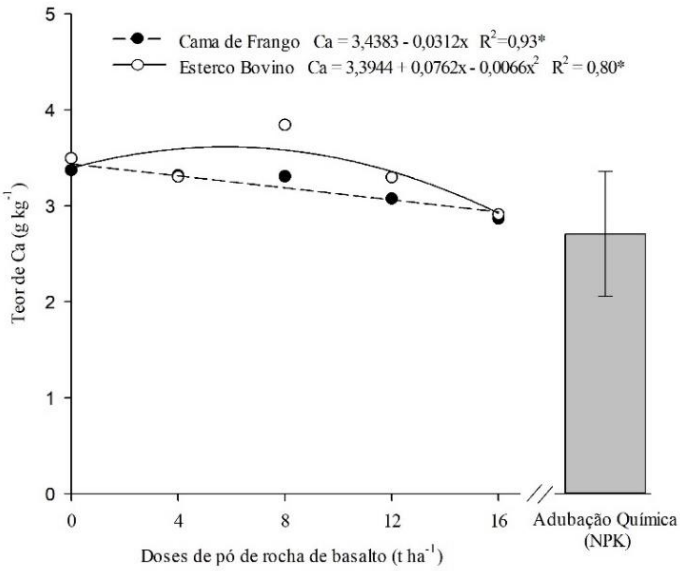
K was present in adequate amounts in the leaves (17-35 g kg-1), a fact found in the present study (20.00 and 20.2 g kg-1 for chicken litter and cattle manure, respectively), which is a good indication, as it may be a reflection of the treatments used. As this nutrient was in high quantities in the soil, the climate and soil conditions favored its absorption in sufficient quantities, which was verified by the leaf contents. K in leaves is a consequence of the availability of the nutrient in the soil,

the conditions of absorption by the roots and its translocation to the aerial part, including the grains (NOVAIS et al., 2007).

In most silicate minerals, nutrients are released gradually in a concentration dependent on the mineral composition of the rock. However, this slow release does not prevent a significant impact on crop nutrition in the medium to long term, where slower and more gradual availability can optimize the use of the nutrient by plants and reduce leaching losses (SUSTAKOWSKI, 2020; RESENDE et al., 2006).

There was a significant difference ($p<0.05$) for the leaf calcium (Ca) content in corn cultivated with doses of basalt, chicken litter and cattle manure (Figure 4). The doses of basalt associated with broiler litter showed a decreasing linear behavior for Ca, thus obtaining a maximum content of 3.4 g kg-1 in the absence of rock dust (0 t ha-1) and decreasing according to the increase of the doses. On the other hand, for cattle manure, it was possible to verify a quadratic effect, presenting maximum Ca content (3.6 g kg-1) with the dose of 6.0 t ha-1 of basalt powder.

Figure 4 - Leaf Ca content of second crop corn as a function of doses of basalt rock dust and animal residues. *: Significant for polynomial regression fitting. Note: Soluble Fertilizer Bar indicates Dunnett's DMS (5% error).



Source: Authors (2023)

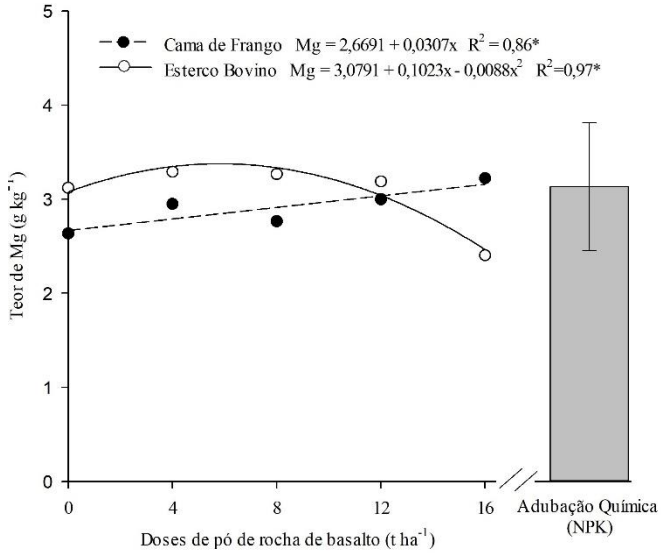
It can be identified that the use of basalt doses with cattle manure provided higher leaf Ca levels in corn when compared to chicken litter and, despite the decrease in its values as doses increased, the nutrient remained at adequate levels in leaf tissue, remaining within the recommended range for the crop (2.3-8.0 g kg-1) (SBCS/NEPAR, 2019).

Corn cultivated with cattle manure showed a difference in leaf Ca content (above 3.4 g kg-1) between the doses of basalt rock dust from 0.5 to 11.03 t ha-1, when compared to that obtained in

soluble fertilization (2.7 g kg-1). Already analyzing the doses of basalt powder associated with chicken litter, it is possible to observe that these were the same as those found in corn using soluble fertilization.

It was possible to verify a significant effect of the doses of basalt rock dust and residues ($p<0.05$) for the leaf Magnesium (Mg) contents in maize. It is noted that the nutrient showed different behavior for each residue and doses of basalt used in the study (Figure 5).

Figure 5 - Leaf Mg content of second crop corn as a function of doses of basalt rock dust and animal residues. *: Significant for polynomial regression fitting. Note: Soluble Fertilizer Bar indicates Dunnett's DMS (5% error).



Source: Authors (2023).

There was an increase in the leaf Mg content in an increasing linear manner in corn cultivated with chicken litter as the doses increased, presenting a maximum concentration of the nutrient of 3.2 g kg-1 with the highest dose applied (16 t ha-1). The mean increase in Mg content as a function of the application of the highest dose of rock dust was 15.6% in relation to the absence of rock dust (2.7 g $^{kg-1}$).

When cattle manure was used with basalt rock powder doses, quadratic regression was the one that best adjusted the leaf Mg data. At the dose of 6 t ha-1, the highest leaf Mg content (3.4 g kg-1) can be obtained in the second corn crop.

According to the results, the cattle manure with the increase of the doses of basalt powder presented higher Mg contents than the chicken litter up to the dose of 12.01 t $^{ha-1,}$ and from this on, there was an inverse behavior, with the chicken litter presenting the highest values of leaf Mg.

Comparing the doses of basalt rock dust and residues with soluble chemical fertilization, it was found that the leaf Mg contents were equal. It is also important to note that the leaf Mg content was within the appropriate range (1.5-5.0 g $^{kg-1}$) of leaf concentration (SBCS/NEPAR, 2019).

According to Ferreira et al. (2009), basalt (basic rock of volcanic origin) is mainly composed of aluminosilicate minerals from the pyroxene and plagioclase groups, which are not very resistant to

chemical weathering and are important sources of Ca, Mg and micronutrients. Kämpf et al. (2009) also state that nutrients such as Ca and Mg are released faster by rocks compared to other nutrients, but this may still vary since rock solubilization is dependent on numerous factors.

Reis (2021) emphasized that the levels of Ca and Mg oxides contained in basalt powder suggest that the material can be a source of these nutrients and with this, a greater response of these nutrients is expected.

This fact may justify the results obtained, since the basalt powder used in the study presented in its composition about 9.73 % of CaO and 5.21% of MgO, which associated with the elements contained in the animal residues (chicken litter had 110 g kg-1 of CaO and 57 g kg-1 of MgO; and cattle manure with 13 ^{g} kg-1 of CaO and 15.0 g $^{kg-1}$ of MgO), were made available in the soil and used by the corn and its contents reflected in the leaf to a certain extent of the use of the doses, since, in general, the plant absorbs the nutrients necessary to meet its metabolic functions, even though it is widely available in the soil.

In addition, the slow and continuous decomposition process of the rock allows the unabsorbed minerals to be subjected to various processes of interactions with the biological components of the soil and can be used in a new cultivation cycle (ALMEIDA JÚNIOR et al., 2022).

Da Silva et al. (2017) also point out that the association of rock powders with organic materials that favor biological activity, such as those used in the research, can influence the process of alteration of minerals and availability of nutrients, causing them to be used by the crop. These effects may have been preponderant for the partial release of some nutrients to the soil and subsequent use by the plant.

4 CONCLUSIONS

The contents of N, P, K and Mg in the leaf tissue of the second crop corn cultivated with basalt powder associated with chicken litter and cattle manure were the same as those found in the soluble chemical fertilization.

The use of cattle manure with doses of basalt rock powder favored higher levels of Ca and Mg in leaf tissue in corn, being the same as in conventional fertilization.

Basalt rock dust associated with chicken litter and cattle manure can be recommended and used for corn nutrition, being sustainable sources and with great potential for building a healthy and balanced soil over time.

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