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BIOINPUTS: ANALYSIS OF POTASSIUM CONTENT AS AN ALTERNATIVE METHOD FOR BIOINPUTS PERFORMED IN ROOTS AND LEAVES OF SOYBEANS CULTIVATED WITH BIOTITE AND GRANITE REMINERALIZERS

BIOINSUMOS: ANÁLISE DE POTÁSSIO NAS RAÍZES E NAS FOLHAS DE SOJA CULTIVADAS COM REMINERALIZADORES BIOTITA E GRANÍTICA

INSUMOS BIOLÓGICOS: ANÁLISIS DEL POTASIO EN LAS RAÍCES Y EN LAS HOJAS DE SOYA CULTIVADAS COMO REMINERALIZADORES BIOTITA Y GRANÍTICO

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ABSTRACT

Soybean is among the world's main commodities, and Brazil depends heavily on chemical fertilizers: approximately 80% of synthetic nitrogen, phosphorus, and potassium fertilizers are imported, with a consumption growth trend of 6%, and, in some crops, fertilizers can account for up to 40% of total inputs. On the other hand, remineralizers (rock dust) provide efficiency to the planting process and rehabilitate the soil sustainably, without aggressive fertilizers. Given this, this study aimed to determine potassium content in root and leaf samples of soybean cultivated with remineralizers as alternative fertilizers. The analytical evaluation was performed by acid digestion with aqua regia, and potassium was quantified by atomic emission in a flame photometer, based on a calibration curve. Higher potassium content was observed in roots cultivated in Yellow Latosol compared to Red Latosol, both with granitic rock dust and biotite powder. For granitic rock powder in Red Latosol, leaf potassium content

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was higher than in Yellow Latosol, unlike biotite, which stood out in Yellow Latosol. The average content was 0.42% potassium in roots and 3.39% in leaves. Therefore, the use of biotite and granitic rock powder (remineralizers) as alternative fertilizers yields satisfactory results in supplying potassium to both roots and leaves.

Keywords: Alternative Fertilization. Potassium Quantification. Nutrient Absorption.

RESUMO

A soja está entre as principais commodities mundiais, e o Brasil depende fortemente de fertilizantes químicos: cerca de 80% dos fertilizantes sintéticos de nitrogênio, fósforo e potássio são importados, com tendência de crescimento de 6% no consumo, e, em algumas culturas, os fertilizantes podem representar até 40% dos insumos totais. Por outro lado, os remineralizadores (pó de rocha) conferem eficiência ao plantio e reabilitam o solo de forma sustentável, sem fertilizantes agressivos. Diante disso, este trabalho teve como objetivo determinar o teor de potássio em amostras de raízes e folhas de soja cultivadas com remineralizadores como fertilizantes alternativos. A avaliação analítica foi realizada por digestão ácida com água régia, e o potássio foi quantificado por emissão atômica em fotômetro de chama, com base em curva de calibração. Observou-se maior teor de potássio nas raízes cultivadas em Latossolo Amarelo em comparação ao Latossolo Vermelho, tanto com pó de rocha granítica quanto com pó de biotita. Para o pó granítico em Latossolo Vermelho, o teor foliar de potássio foi superior ao do Latossolo Amarelo, diferentemente da biotita, que se destacou no Latossolo Amarelo. O teor médio foi de 0,42% de potássio nas raízes e 3,39% nas folhas. Portanto, o uso de pó de biotita e de rocha granítica (remineralizadores) como fertilizantes alternativos apresenta resultados satisfatórios no fornecimento de potássio tanto para raízes quanto para folhas.

Palavras-chave: Adubação Alternativa. Determinação de Potássio. Absorção de Nutrientes.

RESUMEN

La soja se encuentra entre las principales commodities mundiales, y Brasil depende fuertemente de fertilizantes químicos: aproximadamente el 80% de los fertilizantes sintéticos de nitrógeno, fósforo y potasio son importados, con una tendencia de crecimiento del consumo del 6%, y, en algunos cultivos, los fertilizantes pueden representar hasta el 40% de los insumos totales. Por otro lado, los remineralizadores (polvo de roca) confieren eficiencia al proceso de plantación y rehabilitan el suelo de forma sostenible, sin fertilizantes agresivos. Ante esto, este trabajo tuvo como objetivo determinar el contenido de potasio en muestras de raíces y hojas de soja cultivadas con remineralizadores como fertilizantes alternativos. La evaluación analítica se realizó mediante digestión ácida con agua regia, y el potasio se cuantificó por emisión atómica en un fotómetro de llama, con base en una curva de calibración. Se observó mayor contenido de potasio en las raíces cultivadas en Latosol Amarillo en comparación con el Latosol Rojo, tanto con polvo de roca granítica como con polvo de biotita. Para el polvo granítico en Latosol Rojo, el contenido foliar de potasio fue superior al del Latosol Amarillo, a diferencia de la biotita, que se destacó en el Latosol Amarillo. El contenido promedio fue de 0,42% de potasio en las raíces y 3,39% en las hojas. Por lo tanto, el uso de polvo de biotita y de roca granítica (remineralizadores) como fertilizantes alternativos presenta resultados satisfactorios en el suministro de potasio tanto para las raíces como para las hojas.

Palabras clave: Fertilización Alternativa. Determinación de Potasio. Absorción de Nutrientes.

1 INTRODUCTION

Soybean is among the most widely produced commodities worldwide, and its cultivation represents one of the most prominent activities in the global agricultural market. Brazil leads this production, with an estimated output of approximately 97.299 million tons in 2024 (ANEC, 2025).

Adequate potassium (K) availability improves water use efficiency in plants, as it reduces the amount of water required to produce a unit of dry biomass (FERREIRA; PRADO, 2025).

Soybean responds positively to K fertilization, especially in soils of tropical climates (FOLONI; ROSOLEM, 2008). However, soils intensively cultivated with soybean face increasing depletion of K reserves. In a high-fertility eutrophic Red Latosol, the crop cannot be grown for more than two years without potassium fertilization, and the replacement of 80 kg/ha/year of K_2O is insufficient: within five years of a soybean-wheat system, reserves become practically exhausted. Deficiency manifests in two forms — the visible one, with yellowing of leaf margins, and "hidden hunger," in which there is a restriction of productivity without clear symptoms, making the loss silent and difficult to diagnose. According to Embrapa, K imbalance is one of the most frequent nutritional problems in soybean in Brazil, as the nutrient is required in large quantities and easily exported by the grains (BORDOLI; MALLARINO, 1998).

Soybean demands K in high volumes: it is the second most extracted macronutrient by the crop, behind only nitrogen. As it benefits primarily from biological nitrogen fixation, K becomes the most required macronutrient in mineral fertilization, with an average demand of approximately 38 kg of K_2O per ton of grain. Physiologically, K regulates the opening and closing of stomata, controlling gas exchange and water balance, in addition to activating key enzymes of metabolism and ensuring the transport of carbohydrates from the leaves to the developing pods — a critical function during the grain-filling stage. Under deficiency, there is a reduction in photosynthesis and sugar translocation, resulting in empty pods, small and wrinkled grains, leaf retention, and green stems, as well as lower efficiency of biological nitrogen fixation and lower oil content in the seed. Plants with adequate K supply become more resistant to biotic and abiotic stresses, such as thermal variations, diseases, and drought.

Given this scenario, fertilization alternatives gain relevance. Soil treatment has been practiced for millennia to increase productivity and promote healthy plant growth, and, as

agriculture remains a pillar of global food production, fertilization has become essential to meet current productivity demands (BRITO et al., 2019). In this context, remineralizers (rock dust) correct the soil and provide mineral support to the roots, improving the planting process (MARTINS, 2016) and refining soybean productivity both qualitatively and quantitatively (ALMEIDA JR. et al., 2020). For nutrient quantification, in the absence of a universal method, sample extraction in alkaline media is widely employed for phosphorus and K analysis, facilitating solubilization and enabling precise elemental quantification (SOUSA et al., 2015).

Therefore, this study aimed to analyze K content in root and leaf samples of soybean cultivated with remineralizers as alternative fertilizers.

2 METHODS

This study was conducted in the Analytical Chemistry and Electrochemistry Laboratory of the State University of Goiás, Central Campus, located at Anápolis-CET-Henrique Santillo. Soybean root and leaf samples were obtained from the School of Agronomy at the Federal University of Goiás (UFG), as part of research projects involving the use of rock dust as a remineralizer in soybean cultivation.

Soybeans were cultivated in pots containing red and yellow latosols, fertilized with granite and biotite remineralizers. From a total of 196 samples, 56 samples were randomly selected for analysis. Fourteen samples were used for each latosol, totaling 28 samples per remineralizer, equally distributed between root and leaf samples.

Samples were pre-treated by grinding roots and leaves in a blender to obtain a fine powder. Sample and standard solutions were prepared as described by McGrath and Cunliffe (1985). Analytes were quantified according to the *Manual de Métodos Analíticos Oficiais para Fertilizantes e Corretivos do MAPA* published by the Brazilian Ministry of Agriculture and Livestock (BRASIL, 2017).

Acid digestion was performed using *aqua regia*, a strong oxidant composed of concentrated hydrochloric acid and nitric acid (3:1 ratio), which was used to prepare sample solutions for mineral analysis.

2.1 PREPARATION OF SOLUTIONS

2.1.1 Standard solutions

Standard K solutions were prepared from a 100 mg·L^{-1} K stock solution by dilution with deionized water to obtain final concentrations of 0.0 mg· L^{-1} (blank), 1.0, 5.0, 10.0, 20.0, and 30.0 mg· L^{1}. The resulting pH of the standard solutions was 6.02.

2.1.2 Sample solutions

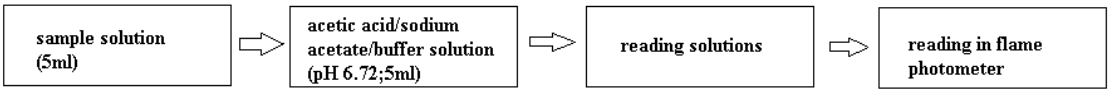
Approximately 0.2 g of each sample was weighed into porcelain crucibles, followed by the addition of 6 mL of cold *aqua regia*. Samples were pre-digested for 16 hours at room temperature. Then, crucibles were placed on a hot plate inside a fume hood and heated (300 °C) until the solution was reduced to about 1 mL. Once at room temperature, the digested samples were transferred to plastic vials and diluted to a final volume of 50 mL with deionized water.

2.2 QUANTIFICATION OF POTASSIUM

Due to the high acidity of the digested sample solutions, the pH of each aliquot was adjusted to approximately pH 6.00 prior to K quantification. Samples were adjusted using a 5 mL solution of acetic acid/sodium acetate buffer (pH 6.72) and 5 mL of each sample. K concentrations were measured using a CELM flame photometer (model FC-280), and quantification was performed based on a previously prepared calibration curve. The workflow was illustrated in Figure 1.

Figure 1

pH adjustment of sample solutions for K quantification by flame photometry.



Source: The authors (2025).

3 RESULTS AND DISCUSSION

K concentrations in the sample solutions were interpolated from the linear equation obtained from the calibration curve, according to Equation (1).

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$$I = 0{,}26398 + 1{,}4377 * K$$

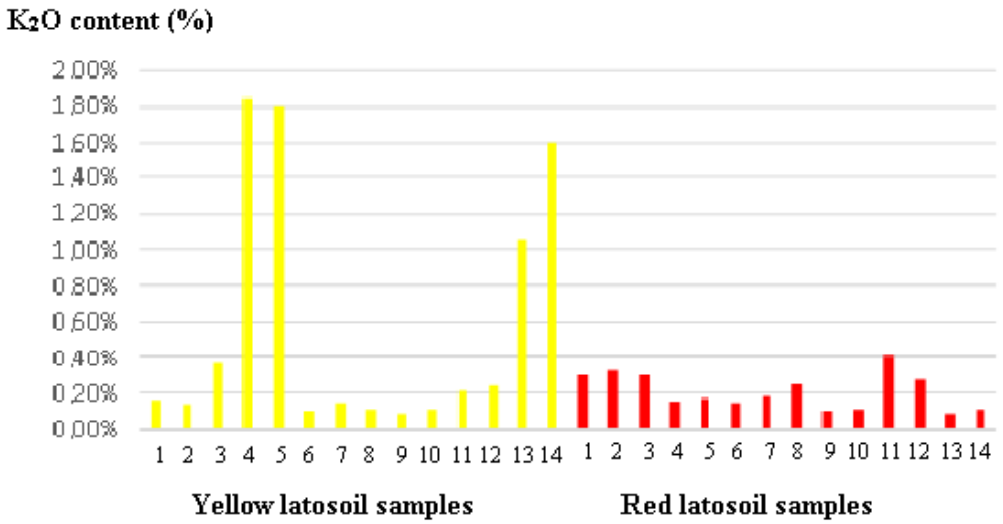
$$(K) = \frac{(I - 0{,}26398)}{1{,}24721} \quad (1)$$

$r^2 = 0.99825$

Samples were analyzed in triplicate, and the means of the results were calculated and plotted in the Excel® software. The results for K concentrations in soybean root samples cultivated with alternative remineralizers as fertilizers are presented in Figures 2 and 3.

Figure 2

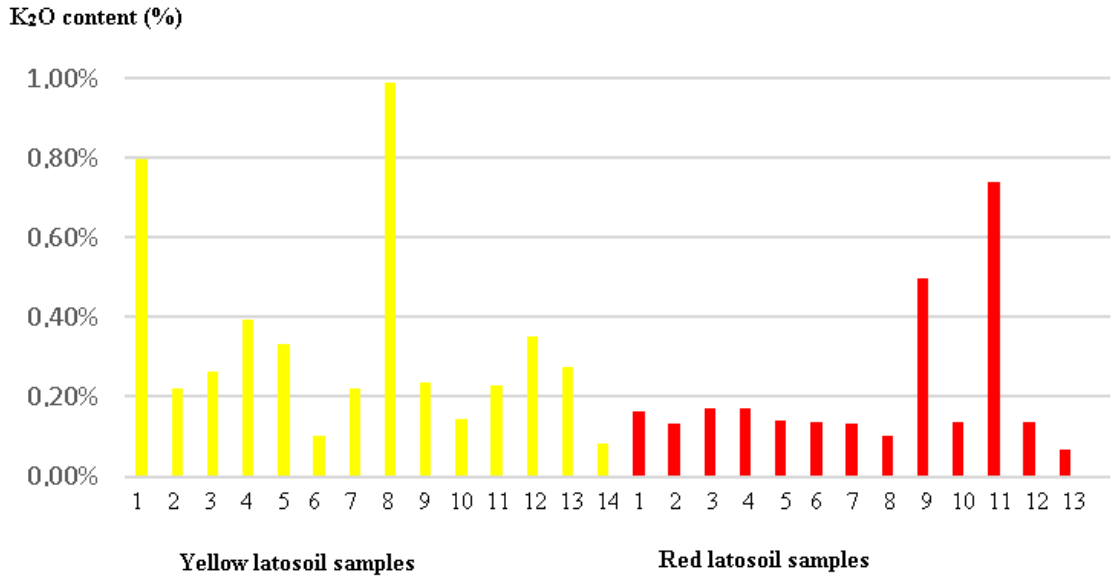
K concentration (K_2O content) in samples of soybean roots grown in yellow and red latosol using granite remineralizer as an alternative fertilizer.



Source: The authors (2025).

Figure 3

K concentration (K_2O content) in samples of soybean roots grown in yellow and red latosol using biotite remineralizer as an alternative fertilizer.



Source: The authors (2025).

After treatment with granite remineralizer, samples 4 (1.85%), 5 (1.80%), 13 (1.05%), and 14 (1.60%) of soybean roots cultivated in yellow latosol showed increased K concentrations compared with those cultivated in red latosol (Figure 2). Soybean root samples 1 (0.80%) and 8 (0.98%) cultivated in yellow latosol and treated with biotite presented increased K content compared with those cultivated in red latosol, including samples 9 (0.50%) and 11 (0.75%), as shown in Figure 3.

Both granite and biotite remineralizers presented improved performance in yellow latosol, resulting in increased K accumulation in root tissues compared with those cultivated in red latosol.

To ensure quality parameters, Normative Instruction No. 05/2016 (BRASIL, 2016) establishes rules for soil remineralizers, defining the minimum specifications and guarantees that these products must have concerning nutrients, and must present, in terms of physical nature, a potassium oxide (K_2O) content of at least 1%. In this case, both soil types used exhibited similar concentrations of K, indicating that both remineralizers effectively supplied K for soybean development.

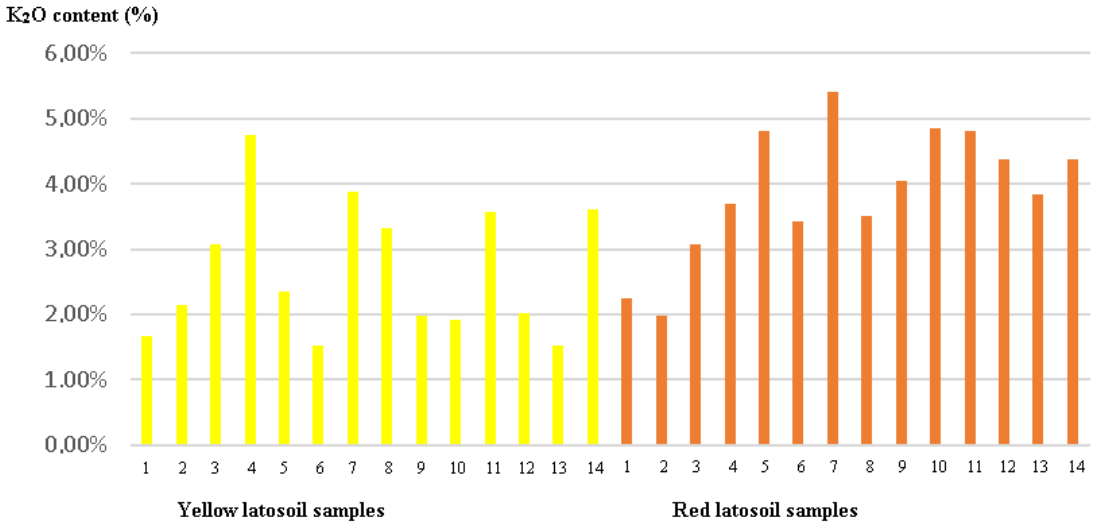
K is presented in its ionic form (K^+) in plants and exists predominantly as free ions electrostatically bound to components within plant tissues. Although K has no structural role,

this compound acts as a vital enzymatic cofactor, regulates osmotic potential and membrane permeability, and facilitates photosynthesis.

All measurements were conducted in triplicate, and the results consistently fell within the established calibration range. The mean values of each set were calculated to ensure the accuracy and reliability of the data. The results of the analyses on soybean leaf samples grown using biotite and granite remineralizers as alternative fertilizers are presented in Figures 4 and 5.

Figure 4

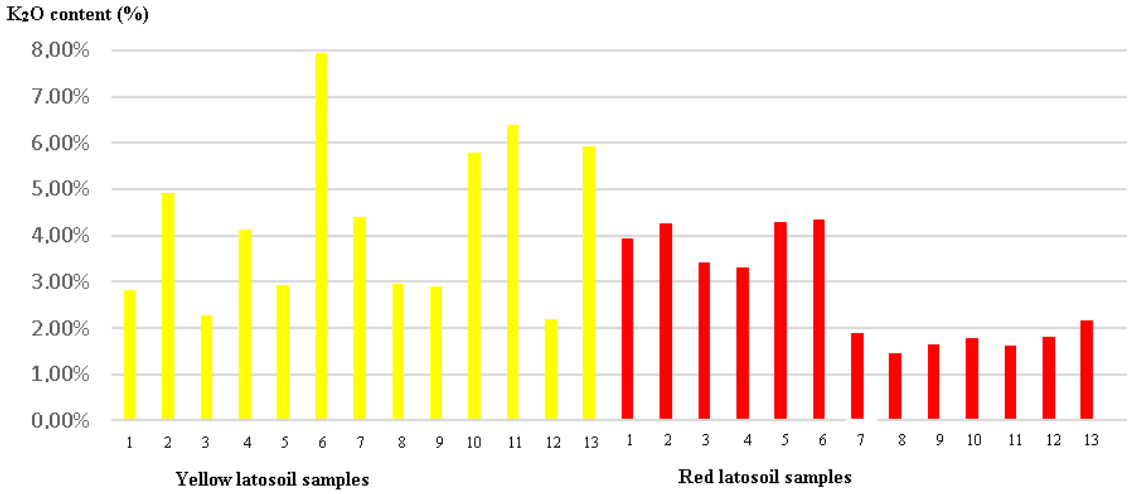
K concentration (K_2O content) in samples of soybean leaves grown in yellow and red latosol using granite remineralizer as an alternative fertilizer.



Source: The authors (2025).

Figure 5

K concentration (K_2O content) in samples of soybean leaves grown in yellow and red latosol using biotite remineralizer as an alternative fertilizer.



Source: The authors (2025).

For the soybean leaf samples treated with the granite remineralizer, the mean K concentration was 2.73% in the yellow latosol and 3.69% in the red latosol, indicating increased K concentration in the latter (Figure 4). Samples 4 (4.90%) and 7 (3.90%) from the yellow latosol showed decreased K concentrations compared with samples 5, 10, and 11 (4.90%) and 7 (5.50%) of the red latosol (Figure 4). According to Ker (1997), yellow latosols with low Fe2O3 content typically exhibit low saturation and a low sum of bases, as well as high aluminum saturation. In acidic soils, these characteristics may limit K availability and other nutrients, potentially impairing plant development.

Following treatment with the biotite remineralizer, soybean leaf samples 6 (8.00%), 10 and 13 (5.90%), and 11 (6.30%) cultivated in the yellow latosol (Figure 5) showed increased K concentrations compared with those from the red latosol, indicating superior performance from the former. These findings suggest that biotite performed more efficiently in yellow latosol, while granite showed better results in red latosol.

Although biotite is a K-rich mineral, K is preferentially translocated to the aerial parts of the plant, including leaves, meristematic tissues, and fruits, where it remains in the K+ form. As a result, K accumulation is less pronounced in root tissues, which explains the reduced K content in root samples despite high K availability from biotite.

4 CONCLUSION

This study demonstrated the viability of biotite and granite remineralizers as effective alternative fertilizers, as both provided a satisfactory K supply for soybean cultivation. The increased K accumulation in the aerial parts of the plant compared to the root samples highlights the physiological relevance of K during soybean cultivation.

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