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# Sources and doses of potassium on yield components of soybean and sorghum

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## ABSTRACT

For a high agricultural yield, the soil must have adequate fertility to provide the nutrients required by crops. This study aimed to evaluate the effect of different potassium sources and doses on yield and its components in the soybean and sorghum in the second harvest. The experiment was installed in the 2018/2019 harvest in the experimental field of the State University of Goiás, University Unit of Ipameri, Campus Sul, in Ipameri-GO. The experimental design used was randomized blocks arranged in a 2 x 6 factorial scheme with four replications. Two potassium sources (potassium chloride 58% $K_2O$ and phonolite 8% $K_2O$ and 25% Si) and six potassium doses (0; 60; 120; 180; 240; and 300 kg $ha^{-1}$) applied via soil were evaluated. The experiments were carried out under the no-tillage system on corn straw, using the cultivars M 7110 IPRO and Atlântica MR 43 of soybean and sorghum, respectively. The main agronomic evaluations were carried out for the soybean and sorghum. Potassium fertilization favored the soybean grain yield, and the phonolite source showed higher grain yield up to the dose of 300 kg $ha^{-1}$ of potassium. The potassium doses influenced the grain yield of sorghum up to 300 kg $ha^{-1}$ of K.

**Keywords:** Fertilization, Phonolite, KCl, Yield

## Fontes e doses de potássio sobre os componentes da produção na cultura da soja e do sorgo

## RESUMO

Para uma boa produtividade agrícola é fundamental que o solo possua a fertilidade adequada, para disponibilizar os nutrientes exigidos pelas culturas. O objetivo do trabalho foi avaliar o efeito das diferentes fontes e doses de potássio sobre os componentes da produção e produtividades na cultura da soja e na safrinha com a cultura do sorgo. O experimento foi instalado na safra 2018/2019 no campo experimental da Universidade Estadual de Goiás, Unidade Universitária de Ipameri, Campus Sul, no município de Ipameri-GO. O delineamento experimental utilizado foi o de blocos casualizados, arranjados em esquema fatorial 2 x 6, sendo duas fontes de potássio (cloreto de potássio e fonolito) e seis doses de potássio (0; 60; 120; 180; 240 e 300 kg $ha^{-1}$), com quatro repetições e aplicadas via solo utilizando como fonte o cloreto de potássio (58% de $K_2O$) e fonolito (8% de $K_2O$ e 25% de Si). O sistema de plantio utilizado foi o sistema de plantio direto, sobre palhada de milho, utilizando a cultivar de soja M 7110 IPRO para cultura da soja e para o sorgo utilizando a cultivar Atlântica MR 43. Foram realizadas as principais avaliações agronômicas para a cultura da soja e para a cultura do sorgo. A adubação potássica favoreceu a produtividade da cultura da soja onde a fonte fonolito apresentou melhor produtividade de grãos até a dose de 300 kg $ha^{-1}$ de potássio. As doses de potássio influenciaram na produtividade da cultura do sorgo até a doses de 300 kg $ha^{-1}$ de K.

**Palavras-chave**: Adubação, Fonolito, KCl, Produtividade.

## 1. Introduction

Soybean (*Glycine max*) is the leading Brazilian agricultural commodity, showing high yield growth in the last three decades, and is currently cultivated in all regions of the country (Colussi et al., 2016). Also, the species is one of the main sources of vegetable protein, essential in the manufacture of animal feed, in addition to its importance in human nutrition (BRAZIL/MAPA, 2014). Brazil is the largest soybean producer in the world and has several production technologies that increase grain yield. The production estimate is 4.6% higher than the last harvest, with an approximate production of 120.3 million tons (Conab, 2021).

For high agricultural yield, the soil must have adequate fertility to provide the nutrients required by crops. Among the main essential minerals, potassium (K) is the second nutrient most absorbed by plants (Epstein and Bloom, 2006). This is a macronutrient, fundamental for the functions of enzymatic activation and transport of amino acids and sugars to storage organs, with participation in the opening and closing processes of stomata and in osmotic regulation (Malavolta, 2006; Gonçalves, 2018). K is essential for plants to have high vigor, producing the best quality harvested products.

The primary inorganic sources of potassium are potassium chloride (KCl), potassium sulfate ($K_2SO_4$), double sulfate of potassium and magnesium ($K_2SO_4.MgSO_4$), and potassium nitrate ($KNO_3$), emphasizing that the first two are the most used due to the higher $K_2O$ content and solubility (Prajapati and Modi, 2012). However, potassium chloride is not recommended for some crops, such as tobacco and potatoes, due to its high concentration of chlorine, which can impair the quality of the final product, so it is replaced by potassium sulfate (Marchand, 2010).

Soybean cultivars can have high potassium consumption and still take advantage of the nutrient available throughout the soil profile (Oliveira Junior et al., 2013). In turn, potassium deficiency impairs the functioning of several enzymes and facilitates the penetration of pathogenic fungi into plants, causing a decrease in the photosynthetic rate and, consequently, a reduction in seed quality (Sfredo, 2008). There are few studies on the application of potassium in the sorghum culture, and some are inconclusive, possibly due to the influences of edaphoclimatic conditions.

Inadequate nutrient management stands out among the main production limiting factors, such as applying lower or higher doses than crops require (Sediyama, 2015). In tropical soils, where $K^+$ levels are considered low (< 1.5 mmol$_c$ dm$^{-3}$), supplementation with potassium-based fertilizers is necessary (Prochnow et al., 2010). Potassium fertilization greatly affects the yield of crops such as soybeans due to its importance in the metabolic processes of plants.

Among potassium fertilizer sources, the most common is KCl, a saline metal halide composed of chlorine and potassium. It is extracted from minerals such as sylvite and carnallite. Still, it can also be obtained through other processes, such as a by-product of the production of nitric acid from potassium nitrate and hydrochloric acid. However, there are limitations involving conventional potassium fertilizers, such as dependence on imports of these inputs since some countries form an oligopoly that strongly influences the price of potassium in the market.

Currently, other sources of potassium are emerging, which are obtained by the natural grinding process, without using chemical processes for its production. These materials come from silicate rocks of volcanic origin, rich in macro and microelements, and their process is natural. Thus, this study aimed to evaluate the effect of different sources and doses of potassium on the yield components in the soybean and sorghum in the second harvest.

## 2. Material and Methods

The experiment was installed in the experimental area of the State University of Goiás, University Unit of Ipameri, Campus Sul, Ipameri-GO. The experiment was carried out in the field in the 2018/2019 harvest, with the soybean in the first and sorghum in the second harvest. The climate of the region, according to the Köppen-Geiger classification (Cardoso et al., 2014), is defined as a tropical climate (Aw-type) with a dry season in winter. The data on temperature and rainfall at the Ipameri University Unit were collected during the experiments (Figures 1 and 2).

The soil in the experimental area was classified as Latossolo Vermelho-Amarelo distrófico (Embrapa, 2018). The chemical and physical attributes of the soil were determined before the installation of the experiment, according to the methodology proposed by Ribeiro et al. (1999) and presented the following values of the chemical attributes in the 0-20 cm layer: 9.1 mg dm$^{-3}$ of P (Melich); 17.7g dm$^{-3}$ of O.M.; pH$_{(CaCl2)}$: 6.4; 0.26 of K; 2.40 of Ca; 0.90 of Mg, and 1.70 of H+Al cmol$_c$ dm$^{-3}$, and 67.7% of base saturation. The physical analysis showed 49% sand, 22% silt, and 29% clay.

The experimental design used was randomized blocks arranged in a 2 x 6 factorial scheme with four replications. Two potassium sources (potassium chloride 58% $K_2O$ and phonolite 8% $K_2O$ and 25% Si) and six potassium doses (0; 60; 120; 180, 240, and 300 kg ha$^{-1}$) applied via soil were evaluated.

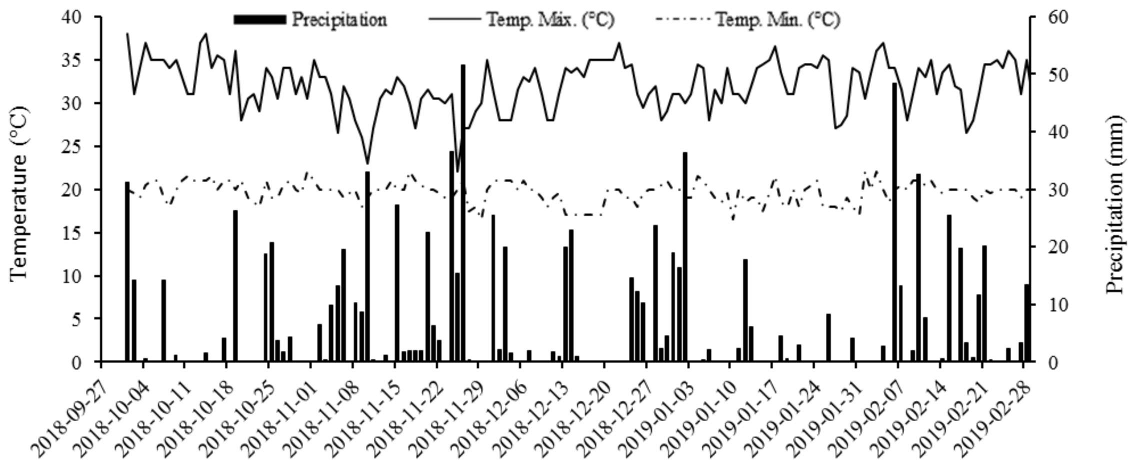


**Figure 1.** Maximum and minimum temperatures and precipitation at the State University of Goiás, University Unit of Ipameri, from October 2018 to February 2019. Ipameri-GO, 2019.

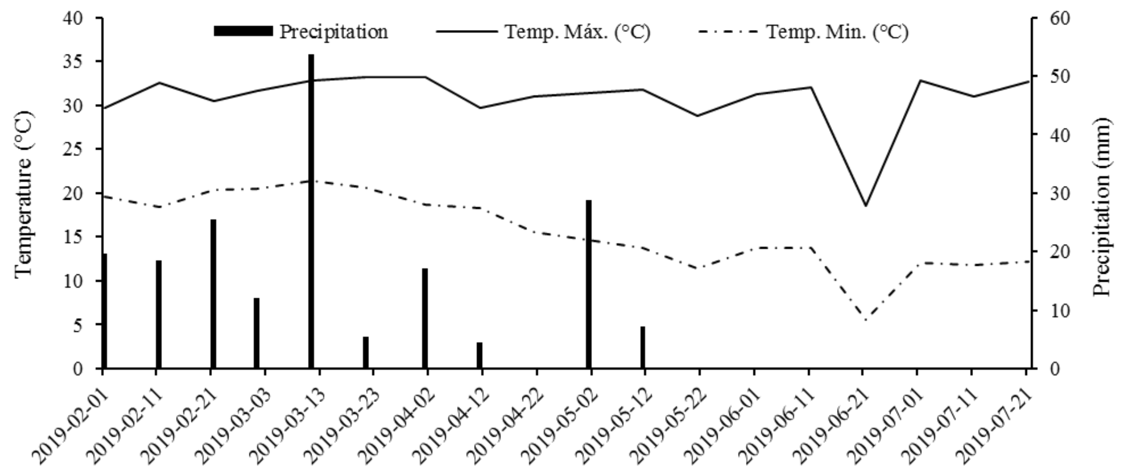


**Figure 2.** Maximum and minimum temperatures and precipitation at the State University of Goiás, University Unit of Ipameri, from February to July 2019. Ipameri-GO, 2019.

The experiment was carried out under a no-tillage system on corn straw. The application of potassium sources and doses was carried out 30 days before soybean sowing. Sowing took place in the first half of November 2018, and fertilization was carried out according to soil analysis using 200 kg $ha^{-1}$ of MAP (11% N and 52% P). The soybean cultivar used was the M 7110 IPRO, with sowing carried out using a tractor-seeder-fertilizer set with seven rows. Each plot consisted of six rows five meters in length, spaced 0.50 m apart, and 15 plants per meter, using the three central rows as useful area, disregarding 1.0 m at both ends of each row.

After the soybean harvest, the sorghum cultivar Atlântica MR 43 was sown in the second half of February 2019. The fertilization was 200 kg $ha^{-1}$ MAP (11% N and 52% P), using the potassium fertilizer residue at the time of soybean sowing. Each plot consisted of six rows five meters in length and spacing of 0.50 between rows, using the two central rows for the evaluations, disregarding 0.5 meters at both ends of each row. The other crop treatments necessary during the conduction of the experiments were applied in a mechanized way using a mechanical system pulled by a tractor.

The following agronomic evaluations were carried out on ten plants per plot in the soybean: Relative chlorophyll index: obtained with the portable electronic chlorofiLOG CFL 1030 meter in the plants at the R1 stage, where the values were represented in RCI; Leaf potassium content: Twenty leaves were collected from each plot, the 3rd leaf from the apex on the main stem, with the petiole in the flowering period, as recommended by Martinez et al. (1999) and the samples determined according to the methodology described by Malavolta et al. (1997), for potassium by Korndörfer et al. (2004); Plant height: measured in centimeters from the ground to the apex of the plants, individually randomly in the plot and then the result was presented as an average.

In addition: Stem diameter was measured at the base of the stem, using a digital caliper with two decimal places; First pod insertion height: the measurement was taken from the ground to the first pod; Number of pods per plant: the pods present on each plant within each plot were collected and counted, counting all the pods on each plant; pod length: it was carried out with the aid of a graduated ruler, measuring from one end of the pod to the other. Also, the number of grains per pod: was carried out by counting the number of grains present in the pods, obtaining the total number of grains; this number was divided by the total number of pods of each plant, resulting in the average; 100-grain weight: collection and counting of 100 grains per plot, weighing with the aid of a precision scale; Grain yield in kg ha$^{-1}$: it was determined by harvesting and threshing the useful plot, harvesting all the plants from the three central rows and adjusting the values to 13.0%; the results were expressed in kg ha$^{-1}$.

For the sorghum, evaluations were carried out on ten plants per plot, as follows: Leaf potassium content: the leaves were collected per plot (the 4th leaf from the apex to the base with the petiole) at the E6 stage (50% flowering), as recommended by Martinez et al. (1999), and the samples determined according to the methodology described by Malavolta et al. (1997), for potassium by Korndörfer et al. (2004); Plant height: measured in centimeters from the ground to the insertion of the panicle individually and randomly, resulting in the average height per plot.

In addition: Stem diameter, whose measurement was taken three centimeters from the ground using a digital caliper, and the value was expressed in millimeters; Panicle insertion height: individual and random measurements were taken from the panicle insertion to the end of the panicle resulting in the average height per plot; Panicle length: measurement performed using a graduated ruler, and the value expressed in centimeters; 100-grain weight: counting of 100 grains after harvest, determining grain moisture and correcting it to 13%; Grain yield: harvesting the two central rows and threshing the plants, determining the grain moisture and correcting it to 13%, the result being expressed in kg ha$^{-1}$.

Data were submitted for analysis of variance and means compared by the Tukey test at a 5% probability for agronomic characteristics for potassium sources. For potassium doses, regression analysis was performed. Analyzes were performed separately for plant species. Statistical analyzes were processed using the R software, version 3.1.2 (R Core Team, 2016).

## 3. Results and Discussion

Table 1 presents the values of the variables leaf potassium content, relative chlorophyll index, plant height, stem diameter, first pod insertion height, and the number of pods per plant in the soybean plants. For the potassium doses, there was a significant effect for the leaf potassium content, where the values fit the positive linear regression (Figure 3). The increase in leaf potassium content in soybean plants with potassium fertilization was also verified by Petter et al. (2012) in Latossolo Amarelo Distrófico in Bom Jesus-PI and Serafim et al. (2012) in a Latossolo Vermelho Distroférrico in the region of Dourados-MS.

**Table 1.** Analysis of variance and mean values for leaf potassium content (LPC), relative chlorophyll index (RCI), plant height (PLTH), stem diameter (SD), first pod insertion height (FPI), and the number of pods per plant (NPP) for potassium sources and doses in soybean. Ipameri-GO, 2019.

| Sources | LPC (g) | RCI (ICF) | PLTH (cm) | SD (mm) | FPI (cm) | NPP --- |
|---|---|---|---|---|---|---|
| KCl | 13.41 a | 40.78 a | 80.57 b | 5.84 a | 9.29 a | 36.64 a |
| Phonolite | 13.61 a | 38.99 a | 84.65 a | 5.34 a | 9.78 a | 36.95 a |
| F value | 0.18ns | 6.65ns | 4.83* | 1.44ns | 4.44ns | 0.72ns |
| Doses (kg ha$^{-1}$) | | | | | | |
| 0 | 12.67 | 39.67 | 85.00 | 5.54 | 9.19 | 36.97 |
| 60 | 11.58 | 38.92 | 81.19 | 5.52 | 9.87 | 36.33 |
| 120 | 13.75 | 39.25 | 83.50 | 5.41 | 8.61 | 36.33 |
| 180 | 13.50 | 39.65 | 82.47 | 5.27 | 9.91 | 36.39 |
| 240 | 15.58 | 40.30 | 82.11 | 5.08 | 10.52 | 37.49 |
| 300 | 14.00 | 41.50 | 81.38 | 6.68 | 9.11 | 37.27 |
| F value | 5.54** | 1.17ns | 0.39ns | 1.23ns | 1.77 ns | 0.14ns |
| CV (%) | 11.94 | 6.02 | 7.77 | 25.72 | 8.54 | 10.75 |

Means followed by the same lowercase letter in the column for each studied factor do not differ from each other by the Tukey test at 5% probability. **= Significant at 5% probability; *= Significant at 1% probability ns = not significant.

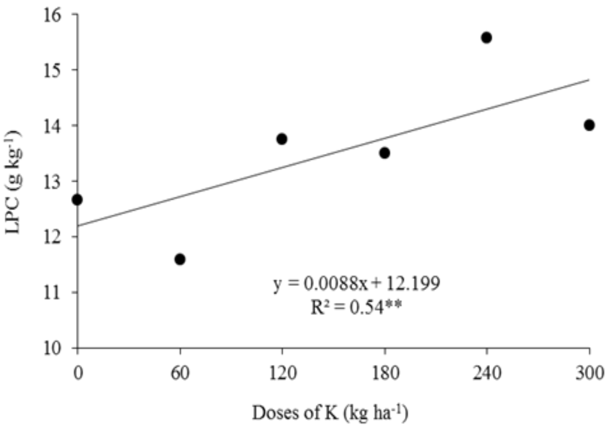


**Figure 3.** leaf potassium content (LPC) according to the potassium doses in the soybean. Ipameri-GO, 2019. **= Significant at 5% probability.

There was no difference between treatments and doses for the relative chlorophyll index, the stem diameter, the first pod insertion height, and the number of pods per plant (Table 1). Peter et al. (2012), working with the doses and times of potassium application in soybean, did not identify a significant effect on the relative chlorophyll index. Thus, there is no apparent correlation between leaf potassium levels and chlorophyll synthesis. In turn, the height of the plant differed since the plants that received phonolite were 5% higher than KCl; however, there was no significant difference for potassium doses.

The height of soybean plants cultivated with phonolite was higher than those with KCl (Table 1). This is probably due to the lower losses of potassium by leaching that the phonolite provides due to the accompanying anion being silicate, which enables higher development of plants with this product. Fertilization with KCl tends to have a high dose, to ensure that leaching losses are lower, according to Borkert et al. (1997). Potassium fertilization did not significantly influence the stem diameter, first pod insertion height, and number of pods per plant. Bharati et al. (1986) reported that the highest number of pods per plant increased with the addition of potassium fertilizer. This influence may be related to the type of soil, climatic conditions, and mainly the genetics of the plant.

The mean values for pod length, number of grains per pod, 100-grain weight, and grain yield are shown in Table 2. No significant differences were found between the sources studied for pod length and number of grains per pod. Potassium doses did not influence pod length, number of grains per pod, and 100-grain weight of soybeans. As for grain yield, there was a significant interaction between potassium sources and doses (Table 2). Bernardi et al. (2009), working with potassium fertilization in the soybean in a Latossolo Vermelho in the region of Turvelândia-GO, found that the fertilizer applied before sowing or at the time of sowing did not differ in terms of the grain yield, with these results being divergent from those found in this study. Soybean grain yield was influenced by the interaction between potassium sources and doses (Figure 4). For the phonolite and KCl sources, the values adjusted to the positive linear regression, increasing according to the increase in the applied doses, reaching the apex with the K dose of 300 kg $ha^{-1}$.

The phonolite presented a 19% higher grain yield than the KCl source. This may be related to the phonolite source having 25% silicon in its composition. Thus, mitigating the abiotic stress, such as the water deficit, as verified during the experimental conduction (Figure 1). Several authors have recognized the effect of silicon on the resistance to biotic and abiotic stresses of different cultivated species (Sonobe et al., 2011; Romero-Aranda et al., 2006; Melo et al., 2003).

We can observe the importance of potassium fertilization for the soybean crop since both sources and doses of K increased grain yield. This was observed by Leal et al. (2015), Petter et al. (2012), Silva and Lazarini (2014), Bernardi et al. (2009), and Aratani et al. (2007), evaluating the potassium fertilization in the soybean crop, observed that the application did not influence the soybean grain yield. The values shown in Table 3 for the potassium sources in the sorghum plants show evidence the potassium application influenced only the leaf potassium content and 100-grain weight.

The potassium chloride source differed statistically from the phonolite for leaf potassium content. These values are above the recommended range of 13 to 30 g $kg^{-1}$ for the development of the sorghum crop (Martinez et al., 1999). This difference may be related to the greater availability of potassium chloride to the plant concerning the phonolite, as it has a more gradual release. The application of the phonolite source significantly influenced the 100-grain weight of sorghum. Thus, presenting a higher grain weight than the potassium chloride source (Table 3).

Leaf potassium content values were adjusted to positive linear regression up to the maximum tested dose of 300 kg $ha^{-1}$ (Figure 5A). These values, as previously discussed, are above the recommended values for the sorghum crop. The genetic material and the edaphoclimatic conditions can influence the greater or lesser absorption of the nutrient since the new cultivars can present increasing gains, taking advantage of the maximum yield potential. According to Torres and Pereira (2008), the need for potassium ranges from 20 to 50 kg $ha^{-1}$; however, plants can absorb large amounts of potassium, commonly called luxury consumption.

**Table 2.** Analysis of variance and mean values for pod length (PODLG), number of grains per pod (NGP), 100-grain weight (100W), and grain yield (YIEL) for potassium sources and doses in soybean. Ipameri-GO. 2019.

| Sources | PODLG (cm) | NGP | 100W (g) | YIEL (kg ha-¹) |
|---|---|---|---|---|
| KCl | 3.74 | 2.84 | 16.67 | --- (¹) |
| Phonolite | 3.66 | 2.70 | 16.39 | --- |
| F value | 3.46ns | 3.01ns | 1.60ns | --- |
| Doses (kg ha$^{-1}$) | | | | |
| 0 | 3.84 | 2.80 | 16.46 | --- |
| 60 | 3.74 | 2.78 | 16.05 | --- |
| 120 | 3.60 | 2.50 | 16.82 | --- |
| 180 | 3.63 | 2.66 | 16.52 | --- |
| 240 | 3.77 | 2.83 | 16.74 | --- |
| 300 | 3.61 | 3.02 | 16.59 | --- |
| F value | 3.53 ns | 2.82 ns | 0.92ns | 12.92** |
| CV (%) | 4.04 | 10.73 | 4.80 | 7.65 |

Means followed by the same lowercase letter in the column for each studied factor do not differ from each other by the Tukey test at 5% probability. ns = not significant; **= Significant at 5% probability; (1) = Significant regression for joint analysis of the interaction between sources and doses of potassium.

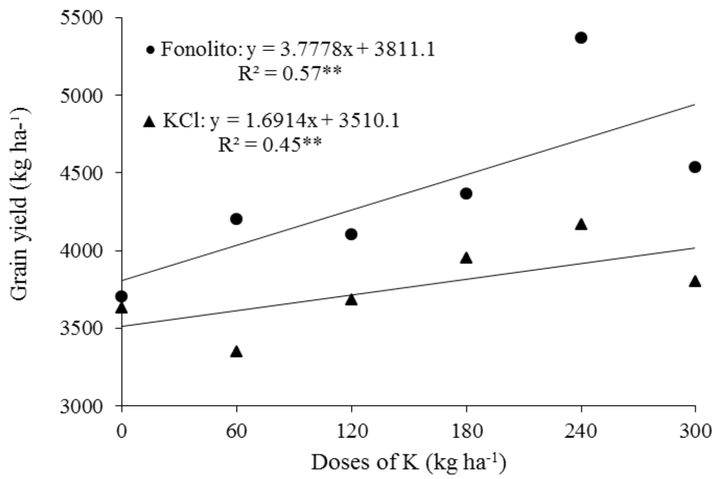


**Figure 4.** Soybean grain yield according to the interaction between potassium sources and doses. Ipameri-GO. 2019. **= Significant at 1% probability.

**Table 3.** Leaf potassium content (LPC). plant height (PH). stem diameter (SD). panicle insertion height (PIH). panicle length (PL). 100-grain weight (100W). and grain yield (YIEL) for sources and doses of potassium in sorghum. Ipameri-GO. 2019.

| Sources | LPC (g kg$^{-1}$) | PH (cm) | SD (mm) | PIH (cm) | PL (cm) | 100W (g) | YIEL (kg ha$^{-1}$) |
|---|---|---|---|---|---|---|---|
| KCl | 38.49 a | 102.51 a | 13.21 a | 82.74 a | 19.85 a | 3.43 b | 3019 a |
| Fonolito | 36.72 b | 101.99 a | 12.50 a | 82.12 a | 19.75 a | 3.64 a | 3120 a |
| F value | 4.61* | 0.09ns | 2.14ns | 0.21ns | 0.02ns | 6.06* | 0.86ns |
| Doses (kg ha$^{-1}$) | | | | | | | |
| 0 | --- (¹) | 102.25 | 12.62 | 83.19 | 19.58 | 3.83 | --- (¹) |
| 60 | --- | 102.42 | 12.57 | 82.55 | 19.80 | 3.38 | --- |
| 120 | --- | 95.94 | 11.45 | 77.80 | 18.13 | 3.64 | --- |
| 180 | --- | 103.50 | 13.01 | 83.52 | 19.97 | 3.62 | --- |
| 240 | --- | 106.56 | 13.52 | 84.69 | 21.86 | 3.32 | --- |
| 300 | --- | 102.25 | 13.60 | 82.80 | 19.44 | 3.43 | --- |
| F value | 4.26** | 2.63ns | 1.09ns | 1.95ns | 1.49ns | 1.73ns | 4.70** |
| CV (%) | 25.07 | 14.93 | 11.06 | 8.57 | 18.70 | 5.75 | 2.39 |

Means followed by the same lowercase letter in the column for each studied factor do not differ from each other by the Tukey test at 5% probability. ns = not significant; **= Significant at 5% probability; (1) Regression = Significant doses of potassium.

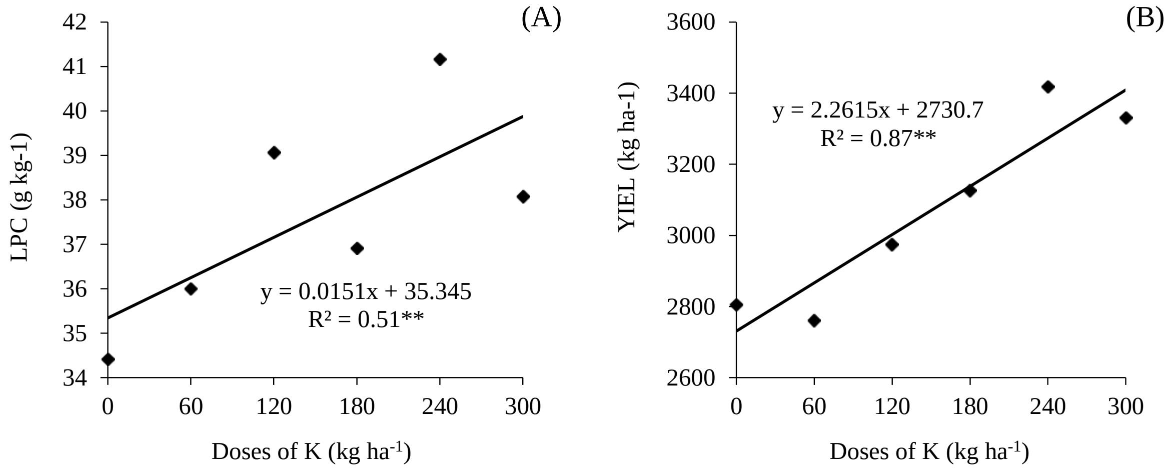


**Figure 5.** Leaf potassium content (LPC) (A) and grain yield (YIEL) (B) according to the potassium doses in sorghum. Ipameri-GO. 2019. **= Significant at 1% probability.

The application of potassium doses influenced sorghum grain yield; the values were adjusted to positive linear regression (Figure 5B). The increase in sorghum grain yield was approximately 18% (525 kg) between dose 0 and 300 kg $ha^{-1}$. This shows the need for adequate nutrition for sorghum plants with potassium fertilization. There are few conclusive studies on potassium fertilization in sorghum plants. Some authors have observed a significant effect of potassium application using potassium chloride on grain yields, such as Parente et al. (2016) and Rodrigues et al. (2014) in corn, Leal et al. (2015) in the soybean, and Carvalho et al. (2018) in beans.

## 4. Conclusions

Potassium fertilization favors the grain yield of the soybean crop, and the phonolite source showed higher grain yield up to the dose of 300 kg $ha^{-1}$ of K. The potassium doses influenced the sorghum grain yield up to 300 kg $ha^{-1}$ of K.

## Authors' Contribution

Cleiton Gredson Sabin Benett contributed to setting up the experiment, reviewing the data, writing the manuscript, data analysis, designing the graphs, and guiding the second and third authors. Lucas Robson de Oliveira and Marcos Cesar Fonseca Filho contributed to the installation of the experiments, evaluations, data collection, tabulation, and manuscript writing. Rafael Marangoni Montes contributed by donating inputs and correcting the manuscript. Katiane Santiago Silva Benett contributed to setting up the experiment, manuscript writing, and data analysis.

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