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# NUTRITIONAL EFFICIENCY IN SUNFLOWER CULTIVARS UNDER DOSAGES OF POTASSIUM IN SEMIARID REGION

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**Abstract**
Potassium (K) participates in critical processes in sunflower cultivation, such as osmotic regulation and translocation of photosynthesis. However, the absorption or accumulation of this nutrient occurs differently owing to edaphoclimatic factors or between cultivars. The objective of this study was to evaluate the nutritional efficiency of sunflower cultivars as a function of different dosage K dosages in a semiarid region. To this end, two experiments were conducted in 2016 and 2017. The treatments consisted of five dosages of K at 0, 30, 60, 90, and 120 kg ha$^{-1}$ $K_2O$ and four sunflower cultivars, Aguará 6, Altis 99, Multissol, and BRS 122. The experimental design was a randomized block with four replications and subdivided plots. The characteristics evaluated were agronomic efficiency, physiological efficiency, recovery efficiency, utilization efficiency, and accumulation of total K in the plant. Sunflower cultivars responded to K dosages in the two crops, with variations in efficiency parameters. Crop 2 showed better nutritional efficiency compared to crop 1. Aguará 6 showed greater nutritional efficiency than the other two crops. The use of dosages between 75 and 91 kg ha$^{-1}$ of $K_2O$ provided better efficiency in K usage for the cultivars.

**Keywords:** *Helianthus annuus* L. Nutrition. Potassium fertilization. Yield.

## 1. Introduction

The cultivation of sunflower crop is of great importance to the world because of its multiple purposes, including the production of edible oil and biodiesel. In addition, this species has expanded its cultivation area in Brazil (Souza et al. 2015; Castro and Leite 2018). Nutritional management is one of the main factors influencing crop yield (Li et al. 2018).

In the semiarid region of the northeast, soils with low fertility occur, which limits productivity owing to the low availability of nutrients (Feitosa et al. 2013; Soares et al. 2015). On the other hand, excessive use of fertilizers above the demand required by the crop during its cycle can cause problems in plant development and considerable negative environmental impacts, indicating the need for adjustments to the recommendations ((García-López et al. 2014).

According to Aquino et al. (2013), the ability to express maximum productivity is related, in part, to the efficient management of crop fertilization. In addition to adequate nutrition, the requirements of each cultivar need to be considered to improve the accuracy of fertilizer management. The absorption or accumulation of nutrients in cultivars of the same plant species can be quantified by the relationship between nutritional efficiency and the amount of biomass produced (Abbadi 2017).

Potassium (K) is the second most absorbed nutrient in sunflower cultivation, behind only nitrogen (N), with participation in critical processes, such as the regulation of osmotic pressure and translocation of photosynthesis (Taiz et al. 2017). In effect, it is directly involved in the structure of plant cells and cellular respiration (Uchôa et al. 2011).

Ertiftik and Zengin (2016) analyzed the response of the sunflower to fertilization with K and magnesium in calcareous soils and found that the effects of K were the most pronounced in increasing sunflower production. Zörb et al. (2014) stated that, in optimal amounts, the presence of K can significantly improve growth and physiological characteristics in plants.

Therefore, the influence of K on nutritional efficiency in sunflower cultivation deserves special mention, as the efficient use of chemical fertilizers prevents excessive losses and reduces economic and environmental impacts. Therefore, the objective of this study was to evaluate the nutritional efficiency of sunflower cultivars under different dosages of K in semiarid regions.

## 2. Material and Methods

### Location and characterization of the experimental area

Two experiments were conducted at the Rafael Fernandes experimental farm, belonging to the Universidade Federal Rural do Semi-Árido, from March–June 2016 for crop 1 and March–June 2017 for crop 2 in different areas of cultivation.

The farm is located in the countryside, 20 km from the municipality of Mossoró-RN (5° 03′ 37′′ S, 37° 23′ 50′′ W, 72 m altitude). According to the Brazilian Soil Classification System (Embrapa 2018), the soil in the experimental area is classified as Abrupt Eutrophic Red-Yellow Latosol.

According to the Köppen classification, the local climate is of the BSh type, described as dry and hot, with two climatic seasons: a dry season, which generally comprises the months of June to January, and another rainy season, between the months of February and May, with an average temperature of 27.4 °C and precipitation of 673.9 mm (Alvares et al. 2013). The average meteorological data for the experimental period are shown in Figure 1.

### Experimental design and treatments

The experimental design was a randomized block with four replicates and split plots. In the field plots, the dosages of K (0, 30, 60, 90, and 120 kg ha$^{-1}$ of $K_2O$) were distributed. In the subplots, the four sunflower cultivars, i.e., Aguará 06, Multissol, Altis 99, and BRS 122, were distributed. The experimental subplots consisted of four rows of 4.5 m in length each, spaced at 0.7 m, with an area corresponding to 12.6 m$^2$ (2.8 x 4.5 m). The functional area of the 2.73 m$^2$ plot was composed of two central rows, disregarding the plants at each end. The spacing adopted was 0.7 x 0.3 m (line x plant), totaling approximately 47.600 plants ha$^{-1}$.

### Implementation and conduction of experiments

Soil preparation consisted of plowing and harrowing. Before the start of the experiments, soil samples were collected at a depth of 0–20 cm for chemical analysis. The collections were conducted in two experimental areas. Soil analysis verified that the pH values were 3.54 and 3.25, referring to the area for each crop, implying the need to perform liming in the experimental areas to correct acidity. After liming, new soil samples were collected to detect acidity and soil fertility conditions (Table 1).

At 45 d after liming in the experimental areas during the 2016 and 2017 agricultural seasons, foundation fertilization was carried out, following fertilization recommendations for the crop and then planting.

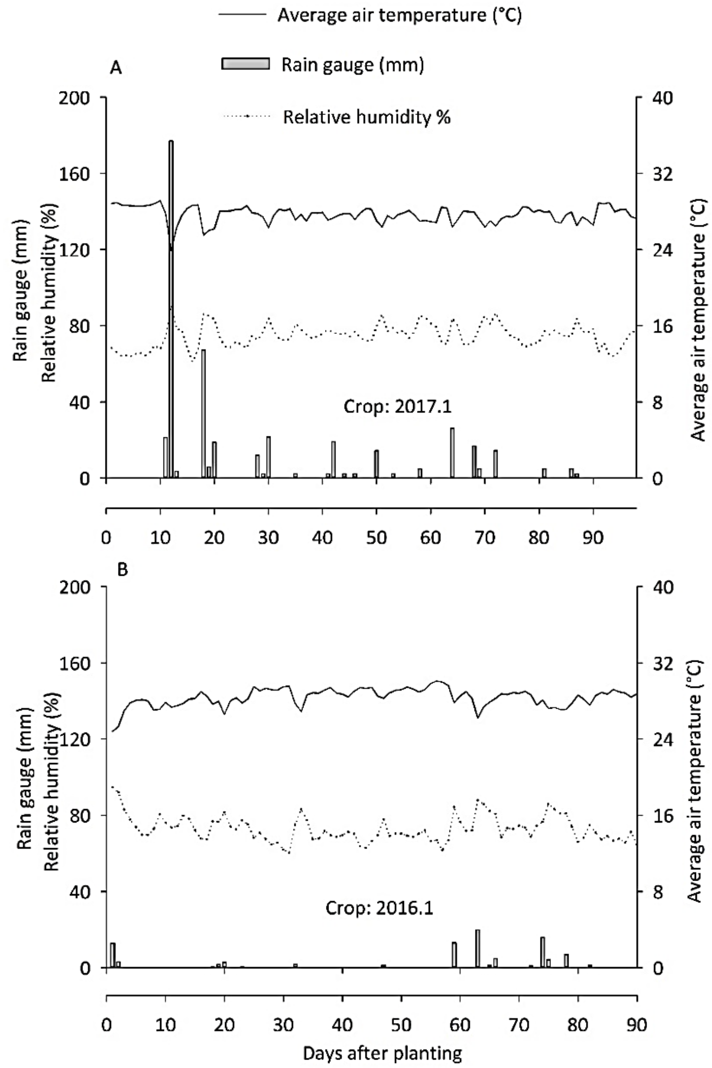


**Figure 1**. Average daily values of rainfall (mm), average air temperature (°C), relative humidity (%), and global solar radiation (MJ $m^{-2}$ $day^{-1}$) corresponding to the crops of 2016 (A) and 2017 (B).

**Table 1.** Chemical characterization of soil in experimental areas.

| Crop | pH $H_2O$ | OM g $kg^{-1}$ | N g $kg^{-1}$ | P mg $dm^{-3}$ | $K^+$ mg $dm^{-3}$ | $Ca^{+2}$ mg $dm^{-3}$ | $Mg^{+2}$ $cmol_c$ | $Al^{+3}$ mg $dm^{-3}$ |
|---|---|---|---|---|---|---|---|---|
| 2016 (1) | 5.9 | 7.52 | 0.42 | 2.21 | 27.1 | 0.40 | 0.57 | 0.0 |
| 2017 (2) | 5.8 | 4.38 | 0.32 | 1.90 | 32.4 | 1.40 | 0.70 | 0.0 |

N, nitrogen; OM, organic matter; K, potassium; P, phosphorus; Ca, calcium; Mg, magnesium; Al, Aluminum; pH, ionic hydrogen potential.

Fertilization was carried out based on soil analysis, following the recommendation proposed by Ribeiro (1999), except for K. All fertilizations carried out during the two agricultural seasons were applied via fertigation.

For N fertilization, the source of N used was urea, with 20% of the recommended dosage used for planting, and the remainder was divided into two cover fertilization applications, applying 40% of the dosage N dosage at 30 d after emergence (DAE) and the other 40% of the dosage at 50 DAE. Monoammonium phosphate was used only in the foundation for phosphate fertilization. In K fertilization, potassium chloride (KCl) was used as a source, divided into two: the first application was performed in foundation corresponding to 50% of the dosages and the remaining 50% at 30 DAE.

Seeds of the four cultivars were provided by Atlântica Sementes®. The first crop, crop 1, was planted on March 9, 2016, and the second, crop 2, on March 9, 2017. The sowing was manual, using three seeds per hole at a depth of 4 cm. Ten days after planting, thinning was performed, leaving only one plant per hole.

The sunflower cultivars have the following agronomic characteristics: Multissol has white-black achenes and streaks, a cycle of 115–120 days, and oil content in the range of 39–50%, tested by the Coordination of Integral Technical Assistance. The cultivar Altis 99 has a cycle of 110–125 days, achenes with high oil content (43–50%), and high production capacity. Aguará 6 has a crop cycle of 110–120 days, with striated achenes and a high oil content ranging from 44–49%. BRS 122 has a cycle of 100 days. Achenes are black and have oil contents ranging from 40–44%.

The crops were irrigated using the drip system, with spaces between emitters of 0.30 m and an average flow of 1.5 L $h^{-1}$. Irrigation was performed daily based on the eTc of the culture (eTc = eTo × Kc), as described by Allen (1998).

**Variables analyzed**

The crops were harvested after the plants reached the R9 phenological phase, characterized by physiological maturation. For biomass determination, two plants were collected per functional area from all plots during the cropping season of the two crops. The plants were separated into three parts, i.e., leaves, stems, and achenes, packed in paper bags and dried in an oven with forced air circulation at 65 °C until these parts reached a constant weight. Subsequently, these parts were weighed on a precision scale, and after determining the values, the average weight per plant was calculated and expressed in grams.

The accumulation of K in different parts of the plant was determined following the methodology described by Carmo et al. (2000). The nutritional efficiency indices of K for the crop were calculated according to Fageria and Santos (2008):

Agronomic efficiency (AE; kg $kg^{-1}$) was determined and characterized by the increase in crop productivity per unit of applied nutrients (Equation 1).

(Equation 1) $$AE = (PGwf - pGof)/(aKa),$$

where PGwf is the production of grains with fertilizer, pGof is the production of grains without fertilizer (0 kg $ha^{-1}$ of $K_2O$), and aKa is the amount of K applied in kg $ha^{-1}$ of $K_2O$.

Physiological efficiency (PE; kg $kg^{-1}$): the increase in crop productivity per unit of nutrient of the absorbed fertilizer (Equation 2).

(Equation 2) $$PE = (PTMwf - PTMof)/(aKwf - akof),$$

where PTMwf is the production of total dry mass with fertilizer (kg), PTMof is the production of total dry matter without fertilizer (kg), aKwf is the accumulation of total K with fertilizer (kg), and aKof is the accumulation of total K without fertilizer (kg).

Recovery efficiency (RE; %) is characterized by the increase in nutrient absorption by the culture per unit of applied nutrients (Equation 3).

(Equation 3) $$RE = (aKwf - aKof)/(aKa),$$

where aKwf is the accumulation of K with fertilizer (kg), aKof is the accumulation of K without fertilizer (kg), and aKa is the amount of K applied in kg $ha^{-1}$ of $K_2O$.

Utilization efficiency (UE; kg $kg^{-1}$) was calculated by increasing the productivity of the culture per unit of nutrient supplied (Equation 4).

(Equation 4) $$UE = PE \times RE,$$

where PE is the physiological efficiency multiplied by the recovery efficiency, RE.

**Statistical analysis**

The data were subjected to analysis of variance using the *F*-test, followed by a separate evaluation of the two crops to determine the homogeneity of variances and applicability of the joint analysis using the SISVAR program (Ferreira 2014). The means of qualitative treatments, with a significant difference, were compared using Tukey's test at 5% probability, and the means of quantitative factors were subjected to regression analysis.

## 3. Results

There was no homogeneity of variances for the variables studied. Therefore, it was unfeasible to perform a joint analysis of the experiments, with observed interactions between dosages and cultivars and between dosages and crops for the agronomic, recovery, and utilization efficiency variables.

Dosages of more than 30 kg $ha^{-1}$ of $K_2O$ were responsible for the decrease in AE (Figure 2A). However, the cultivars Aguará 6 and Altis 99 showed smaller reductions in AE and using a dosage of 60 kg $ha^{-1}$ of $K_2O$ provided AE values of 157.51 and 144.66 kg $kg^{-1}$ for the two cultivars, respectively. However, the cultivars BRS 122 and Multissol, exposed to the same dosage of 60 kg $ha^{-1}$ of $K_2O$, presented lower AE, obtaining only 99.93 and 97.7 kg $kg^{-1}$, respectively, with even greater decreases in AE t dosages of 90 and 120 kg $ha^{-1}$ of $K_2O$. The highest AE was achieved in crop 2, compared to crop 1 (Figure 2B).

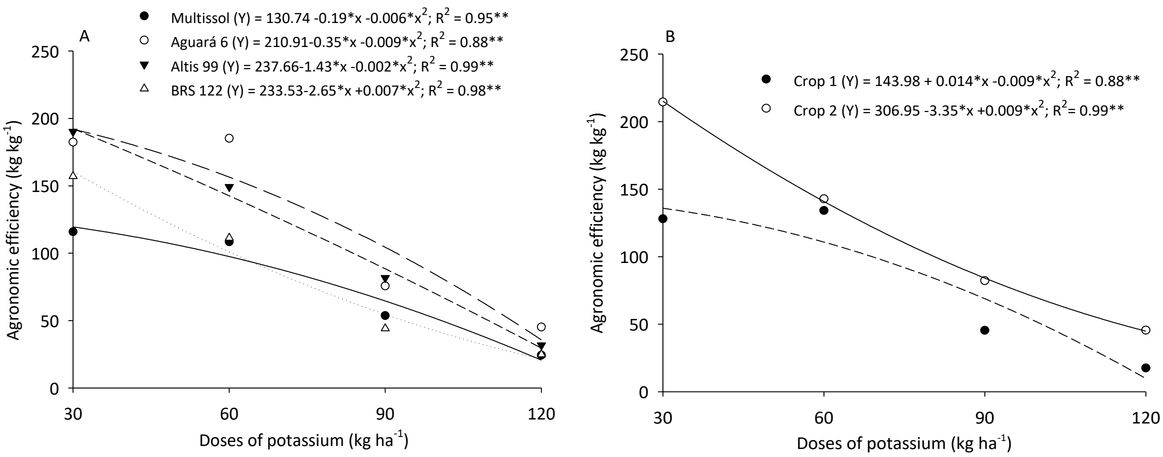


**Figure 2**. Agronomic efficiency of sunflower cultivars resulting from the interaction between dosages x cultivars (A) and dosages x crops (B) interactions in a semiarid region.

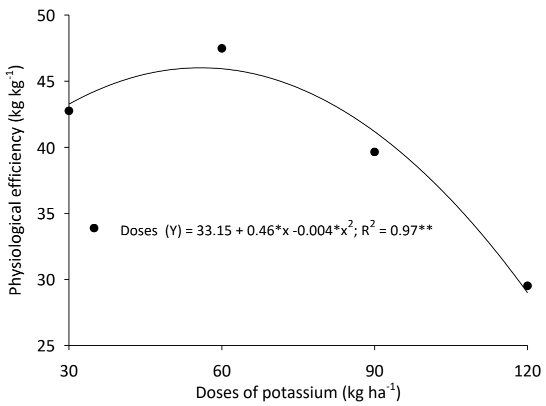


**Figure 3**. Physiological efficiency of sunflower cultivars in the function of potassium dosages in a semiarid region.

For PE, there was an isolated effect between the K dosages, with a 60 kg $ha^{-1}$ dosage of $K_2O$ providing the best result compared to the other dosages (Figure 3). Physiological efficiency considers the total accumulation of biomass produced by the plant, which provides an adequate supply of this nutrient in the soil solution.

There was also an isolated effect among the cultivars for PE, where the cultivar Altis 99 showed the highest efficiency (Table 2).

**Table 2**. Physiological efficiency (PE) of sunflower cultivars.

| Sunflower cultivars | PE (kg $kg^{-1}$) |
|---|---|
| Multissol | 30.38b |
| Altis 99 | 56.38a |
| Aguará 6 | 40.16b |
| BRS 122 | 32.45b |

*Averages followed by the same letter in the right column do not differ statistically, analyzed using Tukey's test at 5% probability.

There was a significant interaction in the RE between dosages and cultivars (Figure 4A). The cultivar Aguará 6 provided the best results, with a maximum value of 19% RE attributed to the estimated dosage of 80 kg $ha^{-1}$ of $K_2O$, followed by the cultivar Altis 99 with 15.8% RE, due to the estimated dosage of 77 kg $ha^{-1}$ of $K_2O$. When observing the interaction between dosages and crops, a higher RE (16.26%) was obtained for crop 2 than crop 1, with an estimated dosage of 80 kg $ha^{-1}$ of $K_2O$ (Figure 4B). In crop 1, the maximum value (15.18%) was achieved with an estimated dosage of 82 kg $ha^{-1}$ of $K_2O$.

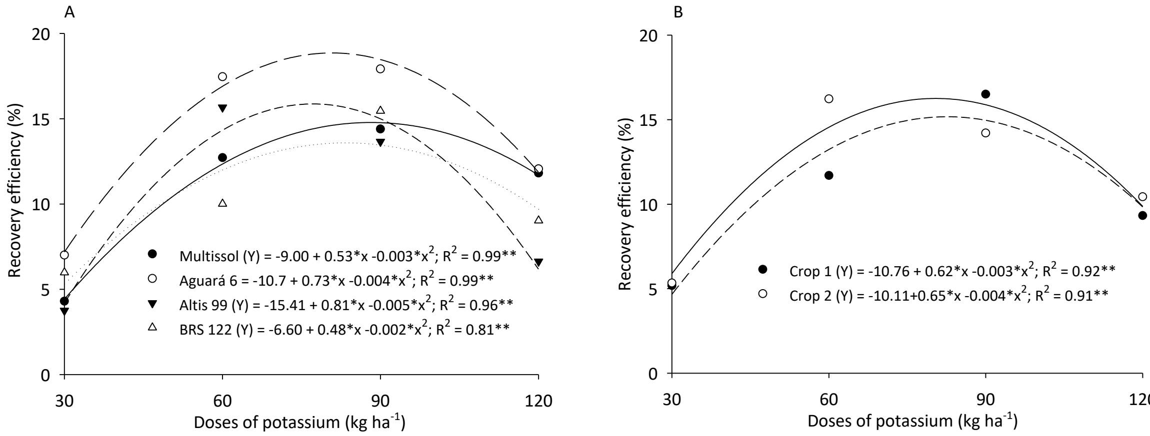


**Figure 4**. The recovery efficiency of sunflower cultivars is a function of the interaction between dosages x cultivars (A) and dosages x crops (B) in the semiarid region.

The cultivars Aguará 6 and Altis 99 obtained the best results for the efficiency of use (EU), with maximum values of 82.4 and 77.7 kg $kg^{-1}$, depending on the estimated dosage of 75 kg $ha^{-1}$ of $K_2O$. While BRS 122 and Multisol obtained greater efficiency of use (36.7 and 35.6 kg $kg^{-1}$), with dosages of 80 and 91 kg $ha^{-1}$ of $K_2O$ (Figure 5A). Through the significant interaction between dosages x crops, it was verified that crop 2 was superior to crop 1, with respective values of 64.91 and 52.91 kg $kg^{-1}$, with estimated dosages of 77 and 79 kg $ha^{-1}$ of $K_2O$ (Figure 5B).

There was an isolated effect between K dosages for AcTK, with a higher accumulation of 142.13 g $ha^{-1}$ and a maximum dosage of 120 kg $ha^{-1}$ of $K_2O$ for this variable. Thus, the higher concentrations of K in the plant were due to the higher dosages used (Figure 6).

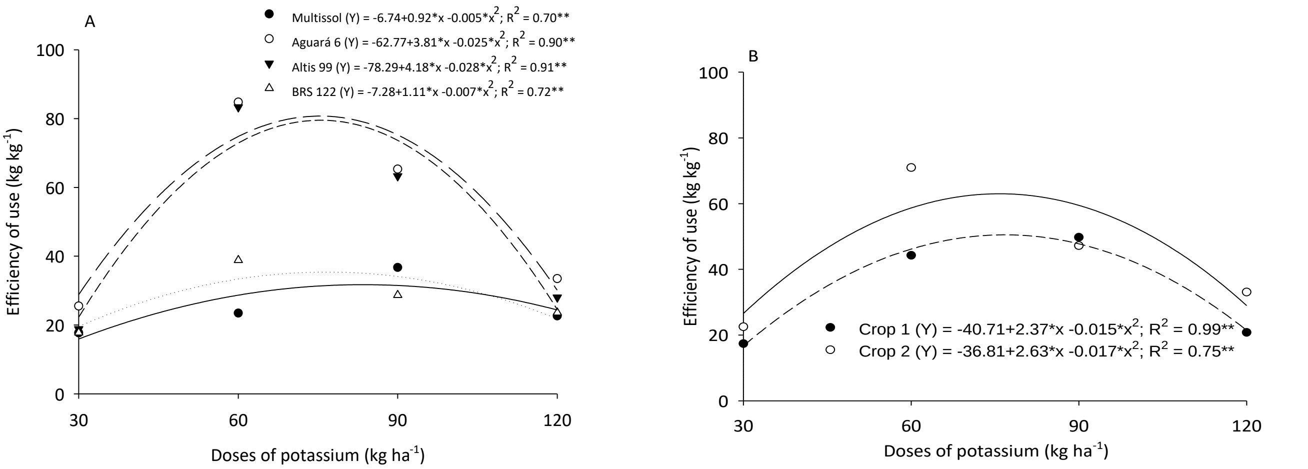


**Figure 5**. The efficiency of use (EU) of sunflower cultivars is a function of potassium dosages in the two crops.

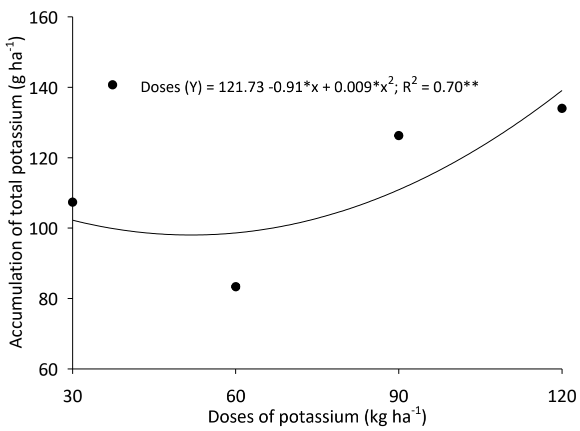


**Figure 6**. Accumulation of total potassium (AcTK) in sunflower cultivars using different dosages of potassium in the semiarid region.

## 4. Discussion

The effects of K dosages on AE (Figure 2A) were influenced by the interaction between the edaphoclimatic conditions in the region and limestone usage of limestone to correct soil acidity, for the two crops (Figure 2B). According to Feitosa et al. (2013), the climatic conditions in the semiarid region of the northeast may limit the availability of nutrients such as K and boron. According to the same authors, the increase in agricultural productivity due to K fertilizer supplementation to the soil may vary depending on available K amounts and the general soil fertility levels.

Thus, for efficient fertilization management, a few variables need to interact with each other, such as appropriate dosage, time of application and source of nutrients. These factors are critical considering the peculiarity of the production system used (Bruulsema et al. 2009).

The application of higher dosages in this study implied an excess of K in the soil, causing a consequent reduction in the biomass production of plants and reflecting in physiological efficiency (Figure 3). Uchoa et al. (2011) reported that the excessive application of KCl can also inhibit the absorption of $Ca^{2+}$ and $Mg^{2+}$ and lead to a decrease in available P. It is known that the omissions of P, Mg, and Ca limit the vegetative growth of the sunflower and decrease the dry matter production by the plants.

The central concept of efficiency is related to the ability of the plant to transform the nutrients obtained through fertilizers into biomass, enabling optimal economic and productive returns (Fageria et al. 2014).

Santos et al. (2020) found that the climatic conditions of the semiarid region influence the genetic characteristics of sunflower cultivars during the two growing seasons. Several factors influence the results, such as cultivar, environment, and management. In addition, low physiological efficiency can occur because of nutritional deficits, water stress, or mineral toxicity (Reetz Junior 2017).

Optimization of the exploration capacity of the plant root system, soil properties and their management, climatic conditions, and water availability are a few essential factors that need to be considered to increase the efficiency of nutrients used by the plant. In addition, part of the success of the sunflower crop in Brazil is associated with the appropriate choice of cultivars adapted to different environments, thus justifying studies using various sunflower cultivars (Jardini et al. 2014).

The RE (Figura 4) was determined by the amount of K recovered by the sunflower cultivars, depending on the K dosage supplied. Therefore, it is the most logical measure to establish the efficient use of nutrients from an environmental point of view considering the nutrient amounts the crop absorbs throughout its cycle (Reetz Junior 2017).

The EU (Figure 5) is crucial for determining the best dosage to be applied because it characterizes the dosage that is best used by the crop, contributing to the efficient use of fertilizer. Potassium is a necessary nutrient in large quantities, and its export rate is low (Castro et al. 2014). When the cultivation of agricultural species is carried out in hot and dry climates, with situations of nutritional scarcity, there is a greater requirement for the supply of chemical fertilizers to avoid nutritional restrictions and cause great variations in the results of crop production (García-López et al. 2014).

Abadi (2017) studied the efficiency of K use by saffron and sunflower cultivated in different types of soils and found that both cultures accumulated significantly higher amounts of K as the K supply increased. As observed in this study, for the sunflower crop in the semiarid region (Figure 6).

In general, the results obtained in this study allow us to infer that higher concentrations of K do not determine greater nutritional efficiency for the cultivars studied; that is, the greater accumulation of this nutrient in the plant did not favor efficiency parameters. However, the need for K fertilization in this region cannot be excluded. Regarding cultivars, Aguará 6 showed greater efficiency in the use of K, since the other cultivars did not have the same capacity for recovery and use of K. Cultivars that have a high demand for nutrients in their physiological processes but are not very efficient in their recovery and absorption, have little or no gain at the agronomic level.

As for the better performance acquired due to crop 2, in contrast to crop 1, the climatic conditions in the region during this period can be attributed mainly to the initial stages of crop development. Ribeiro et al. (2019) studied the accumulation of nutrients in sesame cultivars under semiarid conditions and found that climatic factors influenced the accumulation of nutrients by plants, justifying the results obtained in this study. In this context, all of these factors allow the identification of cultivars and dosages that favor better acclimatization to dynamic environments in semiarid, with variable availability of K.

## 5. Conclusions

The cultivar Aguará 6 showed greater nutritional efficiency in the two crops.

The use of dosages between 75 and 91 kg $ha^{-1}$ of $K_2O$ provided better efficiency in the use of nutrients for the cultivars.

**Authors' Contributions:** SANTOS, G. L.: analysis and interpretation of data, drafting the article; SANTOS, A. P.: acquisition of data, analysis and interpretation of data; SANTOS, M. G. and LINS, H. A.: acquisition of data and critical review; SOUZA, A. R. E.: acquisition of data; TARTAGLIA, F. L.: acquisition of data; SILVEIRA, L. M.: acquisition of data; BARROS JÚNIOR, A.P.: conception and design, analysis and interpretation of data, drafting the article. All authors have read and approved the final version of the manuscript.

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**Ethics Approval:** Not applicable.

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