ARTICULO DE INVESTIGACION

Revista Latinoamericana de la Papa. 24 (1): 2 – 12, 2020

Received: 25/02/2020 | Accepted: 11/04/2020
Published online: June 2020
DOI: 10.37066/ralap.v24i1.386 ISSN: 1853-4961

Sources of potassic fertilizers in the quality of potato tubers

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Abstract

The potato response to fertilization requires relevant attention, especially when supplementing with potassium (K) because this element affects the composition of tubers. The high concentration of Chlorine in the main source of K for plants (KCl) may have a negative effect on tuber quality and this can be a critical problem, especially to cultivars destined for processing. The objective of this study was to evaluate the influence of potassium chloride and double sulfate of potassium and magnesium (KCl and $K_2SO_4.2MgSO_4$) and combinations between them in order to verify the effect of chlorine in the composition of potato tubers, cv. Asterix, suitable for industry. The amount of N, P and K used was determined by soil analysis and crop requirements. The determination of the reducing sugars was carried out according to the spectrophotometric method (Somogyi-Nelson), as well as the total glycides and starch by the Lane Eyno method (titulometric). The higher dry matter and starch in the Asterix cultivar is related to the application of the combination: 26.3% of KCl and 73.7% of $K_2SO_4.2MgSO_4$ and 41.9% of KCl and 58.1% of $K_2SO_4.2MgSO_4$, respectively. So, the combination of the two sources is indicated to promote higher content of these tuber qualities. On the other hand, sources and proportions of potassium fertilizers do not interfere in the composition of sugars. The rate used in this study (180 kg ha^{-1}) was probably not enough to reflect the deleterious effect of chlorine on the sugar tubers constituents.

Keywords: *Solanum tuberosum* L., Cultivar Asterix. Potassium chloride, double potassium sulfate and magnesium.

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Fontes de fertilizantes potássicos na qualidade dos tubérculos de batata

Resumo

A resposta da batateira à adição de nutrientes ao solo proporciona relevante atenção, especialmente a adubação com potássio (K), por ser um elemento que interfere na composição dos tubérculos, consequentemente em sua qualidade. O cloro, presente na principal fonte de K para as plantas (KCl), pode gerar efeito negativo em atributos relacionados a qualidade dos tubérculos. Neste sentido, objetivou-se avaliar a influência de duas fontes de fertilizante potássico (KCl e $K_2SO_4.2MgSO_4$) e combinações entre elas na composição dos tubérculos de batata, cv. Asterix. A quantidade de N, P e K utilizada foi determinada mediante análise de solo e necessidade da cultura. A determinação dos glicídios redutores foi realizada segundo o método espectrofotométrico (Somogyi-Nelson), já os Glicídios totais e o amido, pelo método de Lane Eyno (titulométrico). A maior massa seca e amido na cultivar Asterix está relacionada à aplicação de 26.3% de KCl e 73.7% de $K_2SO_4.2MgSO_4$ e 41.9% de KCl e 58.1% de $K_2SO_4.2MgSO_4$, respectivamente. Assim, a combinação das fontes é indicada para promover maior teor dessas qualidades nos tubérculos. Por outro lado, fontes e proporções, de fertilizantes potássicos não interferem na composição dos açúcares. A taxa usada neste estudo (180 kg ha^{-1}) provavelmente não foi suficiente para refletir o efeito deletério do cloro nos constituintes de açúcares dos tubérculos.

Palavras-chave: *Solanum tuberosum* L., cultivar Asterix, cloreto de potássio, sulfato duplo de potássio e magnésio.

Introducción

Potato (*Solanum tuberosum* L.) is the third most important food crop on the planet, the first non-grain commodity, and the crop that produces the highest nutrient content (Zhao *et al.* 2016). With the increasing demand of potatoes for direct human consumption and food processing, the need for a high quality product in the market grows as consumers and food processors look for tubers that are free from defects and disorders (Sanchez *et al.* 2020).

The high response of potato to the addition of nutrients to the soil gives important attention to aspects related to fertility, since nutritional management is able to influence the chemical composition of tubers (Fernandes *et al.* 2015). Rational use of mineral fertilizers, ensuring 30–50% yield increase of good quality while preserving or even increasing soil fertility, is one of the important factors for sustainable and efficient functioning of agricultural ecosystems (Yakimenko and Naumova, 2018).

Poor use efficiency of applied nutrients leads to increase in cost of cultivation as well as deterioration of environmental quality (Das *et al.* 2019). Therefore, it is important to note that adequate fertilizer rates and sources allow a balance between soil and plant nutrients, resulting in excellent yields for producers and betterquality products to consumers and industry.

Potassium is an absolutely necessary element for potatoes (Neshev and Manolov, 2016), being the nutrient absorbed in greatest quantity by potato. K affects productivity and quality of potato tubers (Kavvadias *et al.* 2012; Fernandes and Soratto 2013), and it has beneficial effects on human health, reason for what its concentration in the harvest product is considered a quality parameter. Owing to its fundamental roles in turgor generation, primary metabolism, and long-distance transport, K plays a prominent role in crop resistance to drought, salinity, high light, or cold as well as resistance to pests and pathogens (Zorb *et al.* 2014).

The sources of K used in potatoes production are a combination of different anions, such as sulfate and chloride. Potassium chloride (KCl) is a source that has a lower price and can be found in higher concentration (58-60% K_2O) compared to other sources, and is therefore the most used potassium source. In addition to these factors, the source's choice depends on the plant requirements, the edaphoclimatic factors and the availability in the market. These factors can interfere with both the tuber dry mass efficiency and its accumulation of starch (Mallmann *et al.* 2011), as the accompanying ions can be reflected in the plant's metabolism.

There are several possible molecular mechanisms of Cl uptake and translocation in plants (Sun *et al.* 2014). However, the chlorine action in the plant is variable between species. Lam *et al.* (2015) observed within a single family of plants, there were species that showed positive action on the presence of chlorine, while in others no evidence of any interaction was found.

The potato is considered a chlorophobic species, as some varieties are sensitive to chloride. The negative effect is related to the decrease in tuber quality, such as dry matter content, specific weight and starch content of tubers (Mallmann *et al.* 2011).

The chemical composition is decisive in selecting tubers destined for processing. It is essential to have high dry matter, soluble solids, low reducing sugars, and low internal damages. These will guarantee products of uniform gold coloration, absence of dark spots, pleasant taste, low absorption of oil during frying and crunching (Furlaneto *et al.* 2014).

Sources that do not contain chlorine have been adopted by large potato farmers who plan their productions for processing, especially those who have used chlorine in combinations with chloride in order to dilute the high cost of sulfate.

Potassium magnesium sulfate is an example of a fertilizer containing sulfate, with the advantage of providing magnesium which increases the availability of three macronutrients required by plants (Khan *et al.* 2014).

The objective of this study was to evaluate the influence of potassium chloride and potassium magnesium sulfate (KCl and $K_2SO_4.2MgSO_4$) and their combinations in order to verify the effect of chlorine in the composition of potato tubers, cv. Asterix, suitable for industry.

Material and Methods

The experiment was carried out in the municipality of Perdizes-MG (latitude: 19 ° 21'10 "S and longitude: 47º17'34" W), in the state of Minas Gerais, between May to October, using the potato cultivar Asterix (intended for industry).

The experimental design was a randomized block, with five treatments and four replications. Each plot consisted

of six lines, with 0.75 cm space between rows, six meters long, totaling 27 m^2 of total area per plot.

The treatments consisted of the combination of two sources of potassium fertilizer (potassium chloride-KCl and potassium magnesium sulfate $K_2SO_4.2MgSO_4$ (Table 1). The quantity of nutrients (N, P and K) was based on the physical and chemical soil analysis and according to the crop needs. 90 kg ha^{-1} of N, 180 kg ha^{-1} of K_2O and 750 kg ha^{-1} P_2O_5 were applied, with 55% of nitrogen and potassium being added to the soil at the planting time and the remaining 45% at the moment in which the ridging was carried out, 26 days after planting-DAP.

Table 1. Percentage (%) of potassium fertilizer sources (KCl and $K_2SO_4.2MgSO_4$) used in each treatment, in potato cv. Asterix

Treatments	Planting	
	KCl (%)	**$K_2SO_4.2MgSO_4$ (%)**
1	0	100
2	25	75
3	50	50
4	75	25
5	100	0

The nitrogen source used in the planting was urea (45% N) and ammonium nitrate (35% N). The source of phosphorus was triple superphosphate (45% P_2O_5) and the potassium source was potassium chloride-KCl (58% K_2O) and $K_2SO_4.2$ $MgSO_4$ (21% K_2O, 11% Mg and 22% S). All sources were weighed in proportions for each line of the plots (six meters) separately using an analytical balance, packed in plastic bags and later homogenized.

The experiment was performed according to recommendations for potato crop: plowing, dewatering / leveling and opening of the grooves. The fertilizer distribution in the planting groove was done manually. The ridging was carried out at 26 DAP.

The methodologies used were those recommended by the Adolfo Lutz Institute (IAL, 1985). Reducing sugars were determined according to the spectrophotometric method (Somogyi-Nelson) and the total sugars and starch by the Lane Eynon method, titration method (Somogyi 1952; Lane and Eynon, 1934). The ashes were determined by the muffle calcination at 550ºC, according to AOAC method 942.05 (2000).

The results were submitted for variance analysis. The means of the parameters were compared by regression or Tukey test at 5% probability. In all analyses, the data were analyzed using the SISVAR statistical software package (Ferreira, 2011).

Results and Discussion

The soil of the area was classified as yellow Latosol, with a clayey texture. Soil chemical analysis was performed before soil preparation at 0-20 cm depth. The soilshowed the following results: P = 38.72 mg dm^{-3}; K = 0.18 $cmoldm^{-3}$, pH = 5.7; Ca^{2+} = 1.70 cmolc dm^{-3}; Mg^{2+} = 0.39 cmolc dm^{-3}, Al^{3+} = 0 cmolc dm^{-3}, CTC: 5.8 $cmolcm^{-3}$, T = 2.27 cmolc dm^{-3}; SB = 2.27 cmolc-dm^{-3}.

The percentage of humidity did not differ between potassium fertilizer sources and their combinations, ranging from 79.2 to 83% (Figure 1A). Quadros (2010) observed an average of 81.5%, a value within the range observed in this research.

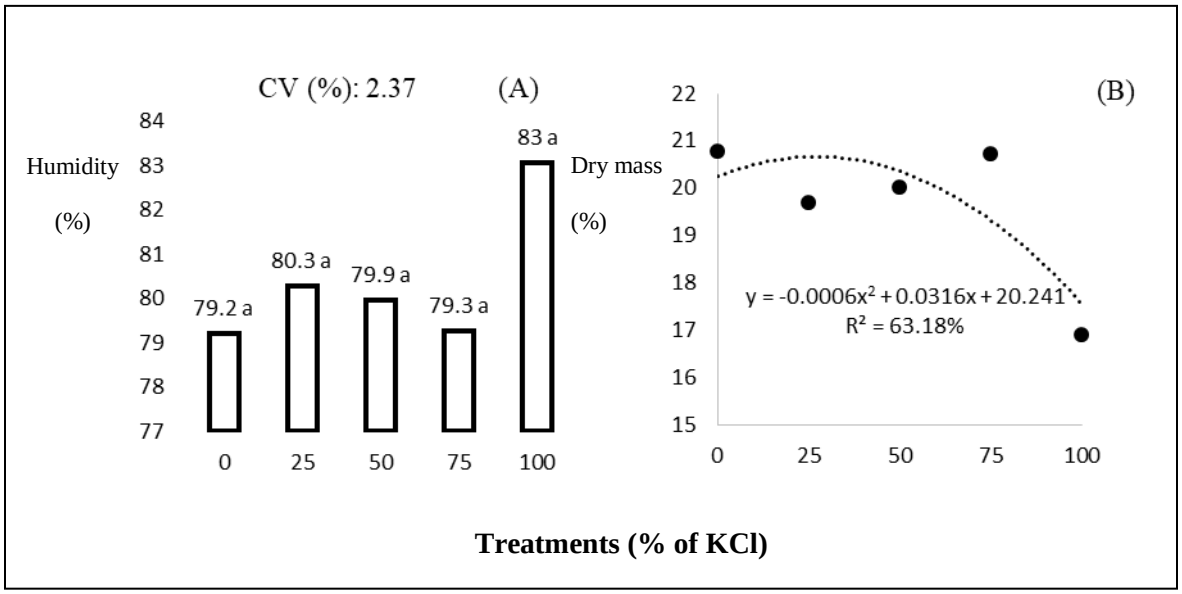

Figure 1. Percentage (%) of humidity (A) dry mass (B) in potato tubers Asterix according to treatments with potassium fertilizers (% K supplied by KCl, supplemented with $K_2SO_4.2MgSO_4$). * Means followed by the same letter did not differ from each other by Tukey test at 0.05. CV: coefficient of variation.

Potassium, by being involved in the physiology of different enzymes, is directly involved in plant water management, and it maintains turgor and reduces water loss and wilting (Haddad *et al.* 2016). The increase in water absorption, expressed by the reduction in water potential, favors the accumulation of water in tissues (Laboski and Kelling 2007). This is an undesirable factor because it reduces the dry matter content and consequently reduces the commercial value of the potatoes, such as the cultivar analyzed in this study (Asterix), destined for industry. The percentage of dry mass (DM) showed statistical differences between potassium fertilizer sources and their combinations, adapting to the polynomial regression. The higher DM (20.6%) was related to application of 26.3% of KCl and 73.7% of $K_2SO_4.2MgSO_4$ (Figure 1B). Tajner-Czopek *et al.* (2014) found in cultivars for processing, dry matter range needed to be from 20 to 23%.

High dry matter and starch content improve texture and enables lower oil absorption while frying (Araujo *et al.* 2016; Mello *et al.* 2018). According to Cacace *et al.* (1994), the DM contents can be classified as high (contents> 20.0%), intermediate (contents between 18.0% and 19.9%) and low (contents <17.9%). In the present work, all the treatments varied between intermediate and high (most of them being classified as intermediate), except for the treatment referring to the application of 100% KCl that presented low DM content (16.9%).

In literature, high potassium doses are related to negative effect of K in the quality of post-harvest potato, reducing the specific gravity of tubers and dry matter content of tubers (Haase *et al.* 2007; Braun *et al.* 2010; Silva and Fontes, 2016). The K application management should be adjusted to the local edaphic and climatic conditions (Grzebisz *et al.* 2017; Balík *et al.* 2019).

The percentage of ash did not differ between potassium fertilizer sources and their combinations, ranging from 0.9 to 1.1% (Figure 2A). The amount of minerals (ashes) is influenced by the cultivar, agronomic practice, climate, planting site and maturity of the tubers (Quadros, 2010). Quadros (2010) found values of ashes between 0.87 and 0.93%, values close to this work.

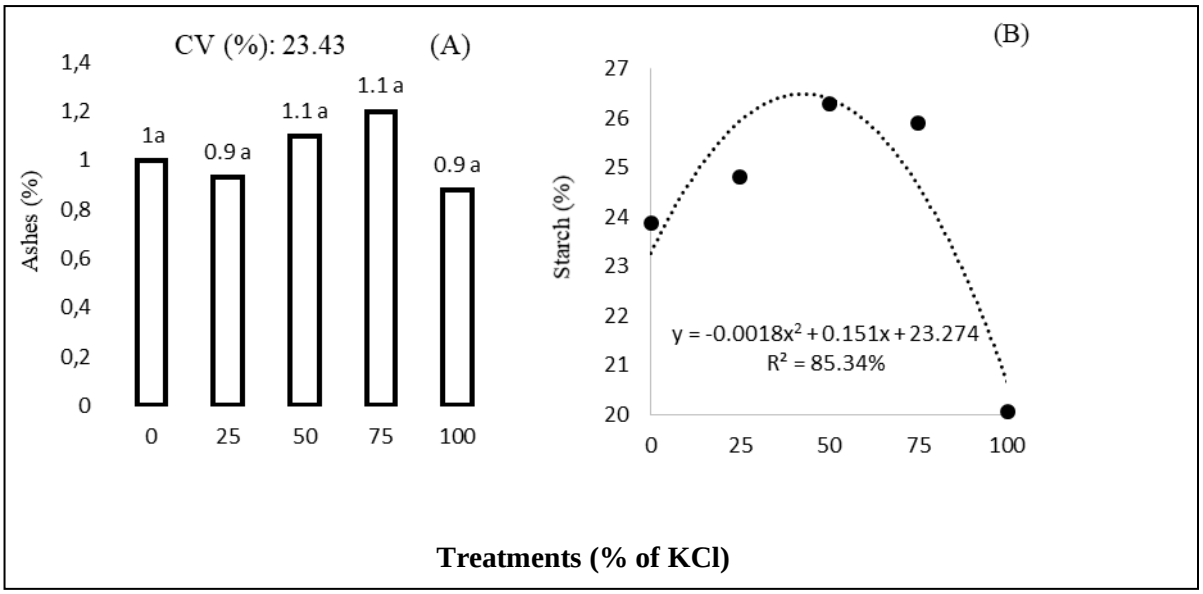

Figure 2. Percentage (%) of ashes (A) and starch (B) in potato tubers Asterix according to treatments with potassic fertilizers (% K supplied by KCl, supplemented with $K_2SO_4.2MgSO_4$). * Means followed by the same letter did not differ from each other by Tukey test at 0.05. CV: coefficient of variation.

The percentage of starch showed statistical differences between potassium fertilizer sources and their combinations, adapting to the polynomial regression. The higher starch content (26.4%) was related to the application of 41.9% of KCl and 58.1% of $K_2SO_4.2MgSO_4$ (Figure 2B).

Crunchiness and hardness are positively related to starch and dry matter contents (Mello *et al.*, 2018). In this way, the association of sources with sulfate such as

$K_2SO_4.2MgSO_4$, can be an important action of producers to achieve better quality of the tubers. The use of 58.1% of $K_2SO_4.2MgSO_4$, for example, increases the starch in 31.7%, compared to 100%KCl treatment. The higher amount of KCl also reduced the starch in the study of Westermann *et al.* (1994).

The percentage of total sugars and reducing sugars did not differ between potassium fertilizer sources and their combinations ranging from 22.26 to 29.18% and 0.05 to 0.09%, respectively (Figure 3A and 3B). Silva *et al.* (2018) did not find any significant effect of sulfate or potassium mixture on the quality of the cultivars BRSIPR Bel and Atlantic. Quadros (2010) found values of total sugars lower than observed in this experiment, which may be related to the interactions between the factors during the growing cycle (environmental and management).

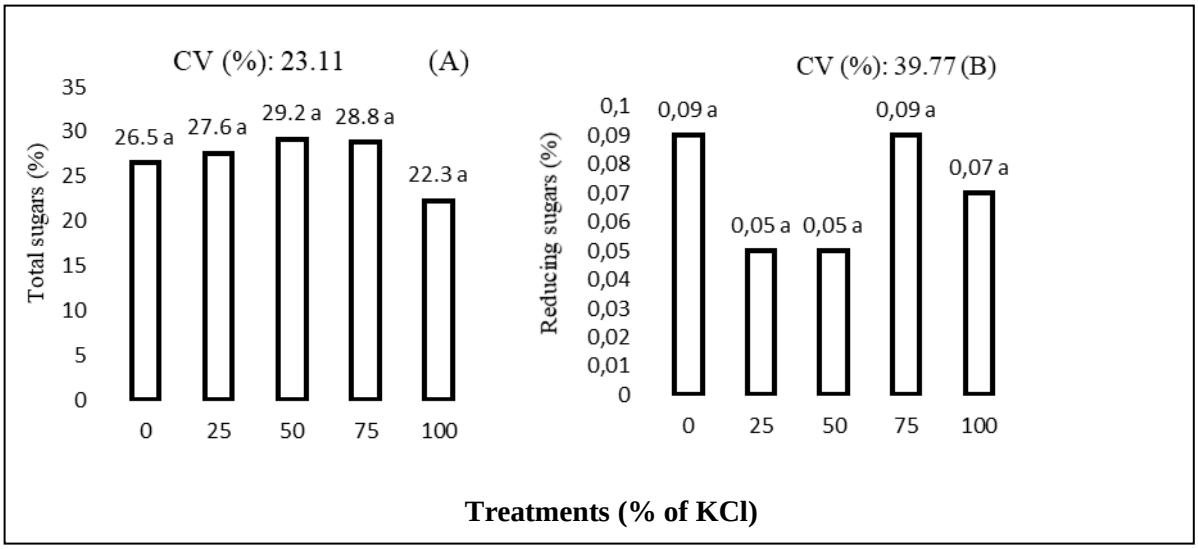

Figure 3. Percentage (%) of total sugars (A) and reducing sugars (B) in potato tubers Asterix according to treatments with potassium fertilizers (% K supplied by KCl, supplemented with $K_2SO_4.2MgSO_4$). * Means followed by the same letter did not differ from each other by Tukey test at 0.05. CV: coefficient of variation.

Quadros *et al*. (2010) also found no differences between rates and sources of potassium fertilizer in reducing sugars (RS). The authors reported that the sulfate source (K_2SO_4) produced 10.1% more RS than the chloride (KCl), and the cultivar Asterix presented the highest amount of RS, compared to other varieties.

The reducing sugar content is the most important parameter used in potatoes processing industry. Potato tubers selected for french fries, such as Asterix, should contain less than 0.3% of reducing sugar (Tajner-Czopek *et al.* 2014). Therefore, the treatments produced tubers with sugar content compatible with industry acceptability (0.049 to 0.094%) and these values were close to that found by Quadros (2010) (0.048%). Silva *et al.* (2018) did not found significant effect of potassium source on yield components, specific gravity and

chip color in BRSIPR Bel and Atlantic. These different results related to the literature may be attributed to different K levels, fertilizer K rates, or potato varieties, and need further investigation (Li *et al.* 2015). The absence of a significant response to the greatest quality parameters should be related to nutrient dynamics (cation and anion absorption and translocation). The expected deleterious effect of chlorine did not affect the sugars content (total and reducing sugars), possibly because the nutrient was not in excess in the soil, which therefore did not generate a consistent breakdown that could negatively be reflected in plant metabolism.

The choice of which source to use should be made through soil analysis (macro and micronutrient contents) supplemented by foliar analysis (real demonstration of potential absorption of the cultivars). This makes it possible to choose the best source according to the cost / benefit of the action.

Although many studies report superiority of potassium associated with sulfate in tuber quality, the rational application of potassium chloride, with balance between cations and anions in total fertilization, means that it is possible to obtain favorable responses in tuber quality and economic viability, since the chloride is more economically accessible than sulfate.

Conclusions

To obtain higher dry matter and starch in the Asterix cultivar the estimated combinations of 26.3% of KCl and 73.7% of $K_2SO_4.2MgSO_4$ and 41.9% of KCl and 58.1% of $K_2SO_4.2MgSO_4$, are recommended to promote higher content of tubers. On the other hand, sources and proportions of potassium fertilizers do not interfere in the composition of sugars. The rate used in this study (180 kg ha^{-1}) was probably not enough to reflect the deleterious effect of chlorine on the sugars constituents of the tubers.

Conflicts of interest

The authors declare no conflict of interest.

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