



POTASSIUM FERTIRRIGATION ON ICEBERG LETTUCE

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ABSTRACT

The aim of this work was to evaluate the influence of potassium doses, being applied in fertigation on iceberg lettuce cultivar "Lucy Brown" in Typic Hapludox. The experimental design was in randomized blocks, consisting of six doses of K_2O (0; 15, 30, 45, 60, 75 kg ha⁻¹) and four blocks. The treatments were applied in six periods: 15, 21, 28, 34, 39, and 43 days after transplantation seedlings, using potassium chloride as a source of K_2O . The variables analyzed were: total fresh mass, fresh head mass, head circumference, number of inner leaves, number of outer leaves, total number of leaves, total yield and commercial yield. Data were subjected to analysis of variance and means compared by regression models. Thus, we can conclude that the K_2O doses that provides the highest value of the variables is 75 kg ha⁻¹, with the exception of the number of internal leaves that do not have a significant effect.

Palavras-chave:

Lactuca sativa L.
Cloreto de potássio
Hortaliças

FERTIRRIGAÇÃO POTÁSSICA NO CULTIVO DA ALFACE AMERICANA

RESUMO

O objetivo do trabalho foi avaliar a influência de doses de potássio, aplicadas via fertirrigação na alface iceberg, cultivar Lucy Brown, em Latossolo Vermelho distroférico. O delineamento experimental foi em blocos casualizados, constituído por seis doses de K_2O (0; 15, 30, 45, 60, 75 kg ha⁻¹) e quatro blocos. Os tratamentos foram aplicados parceladamente em seis períodos: 15, 21, 28, 34, 39, e 43 dias após o transplante das mudas, utilizando como fonte de K_2O , o cloreto de potássio. As variáveis analisadas foram: massa fresca total, massa fresca da cabeça comercial, circunferência da cabeça, número de folhas internas, número de folhas externas, número total de folhas, produtividade total e produtividade comercial. Os dados foram submetidos à análise de variância e as médias comparadas por meio de modelos de regressão. Conclui-se que, a dose de K_2O que proporciona o maior valor das variáveis é de 75 kg ha⁻¹, com exceção do número de folhas internas que não apresenta efeito significativo.

INTRODUCTION

Among the groups of lettuce, there is a group known as Iceberg lettuce (*Lactuca sativa*), which differs from the others by presenting external leaves of dark green color, internal leaves of yellow or white color (YURI *et al.*, 2002).

One of the most cultivated cultivars is Lucy Brown, which has a cycle at the time of harvest, from 48 to 65 days depending on the time of transplanting, presenting excellent compactness and average mass between 750 to 1300 grams. The leaves are thick, giving excellent protection to the head, light green in color and with good resistance to rot caused by fungi, which allows its cultivation in the summer (YURI *et al.*, 2004). According to Filgueira (2003), this cultivar has a large leaf area and shallow root system, requiring sandy-clay soils, rich in organic matter and with a good amount of nutrients readily available to the plant, as it is very demanding in potassium, nitrogen and calcium.

According to Malavolta (2006), specifically for lettuce, the nutrient potassium is more required than nitrogen. The author also reports that when the soil has a high potassium content, its absorption by the plant can be four times greater than that of nitrogen. However, the excess of potassium unbalances the nutrition of vegetables, making it difficult to absorb calcium and magnesium. When deficient in potassium, the plant has less protein synthesis and accumulation of soluble nitrogen compounds, such as amino acids, amides and nitrate (MOTA *et al.*, 2001).

Among the various functions that potassium exerts in plants, we can highlight better water use efficiency, as a result of controlling the opening and closing of stomata, greater translocation of carbohydrates produced in leaves to the other organs of the plant, greater enzymatic efficiency and improvement of the commercial quality of the plant (FILGUEIRA, 2003). In addition to the nutritional aspect, it is a culture of great importance from a socioeconomic point of view, being a source

of income for farmers (SOUZA *et al.*, 2017).

Although there is information on dosages, types of fertilizers and time of application, it is assumed that the mode of application is also very important, and one of these modes is fertigation, in which the drip irrigation system allows the addition of salts in the water. This kind of mode of application can be used with many advantages, such as: economy of labor and machinery; application at the exact moment the plant needs; possibility of applying the product at any stage of the cultural cycle; ease of installment and control; uniform distribution with irrigation water; greater flexibility of operations; simplification of cultural practices, such as the simultaneous application of pesticides and fertilizers; greater efficiency in the use of nutrients; easier application of micronutrients; less soil erosion and less physical damage to the crop (FRIZZONE *et al.*, 2012).

Thus, the objective of this work was to evaluate the influence of potassium doses applied in fertigation on the culture of Iceberg lettuce grown in Typic Hapludox.

MATERIAL AND METHODS

The experiment was performed in the experimental area of Irrigation and Drainage at the Faculty of Agricultural Sciences (FCA) of the Federal University of Grande Dourados (UFGD), in Dourados, MS, located at 22° 11 '45' 'S and 54° 55' 18 ' ' W, with an altitude of 446 m, from September to December 2016. The local climate is Aw, with dry winter, rainy summer, average annual rainfall of 1500 mm and average temperature of 23°C (ALVARES *et al.*, 2013). The soil in the experimental area is classified as a Typic Hapludox, with a very clayey texture (EMBRAPA, 2013).

The chemical characterization of the soil was performed before starting the experiment in order to evaluate the soil fertility (Table 1). The soil collection methods proposed by Rajj *et al.* (2001) were used. Twenty soil samples with deformed structure were collected using a screw auger in the 0.00-0.20 m layer.

Table 1. Chemical analyses of Typic Hapludox

Depth (m)	pH*	P	MO	K	Ca	Mg	H+Al	SB	T	V
		mg dm ⁻³			-----cmol _c dm ⁻³ -----					
0.0-0.2	4.9	39.6	2140	0.450	6.08	1.73	5.76	8.26	14.02	58.9

*pH in CaCl₂

According to the results of the soil analysis and following the recommendations of Sousa and Lobato (2004), liming was carried out sixty days before transplanting, using dolomitic limestone, equivalent to 1.9 Mg ha⁻¹, to increase the saturation base to 70%. For base fertilization, 80 kg ha⁻¹ of phosphorus was added, using simple superphosphate (SFS) (18% P₂O₅), 100 kg ha⁻¹ of nitrogen, using urea as source (45% of N).

Fertilization at planting was carried out seven days before transplanting the seedlings, with 10% nitrogen (22.2 kg ha⁻¹ of N) along with 100% P₂O₅ (444.4 kg ha⁻¹ of SFS) and 12 Mg ha⁻¹ of tanned manure. The remaining 90% of the nitrogen fertilizers and the potassium doses of the treatments were divided into six fertigations, at 15, 21, 28, 34, 39, and 43 days after transplantation (DAT).

The randomized blocks experimental design was performed, consisting of six treatments, with four blocks. The treatments corresponded to the K₂O doses 0, 15, 30, 45, 50 and 75 kg ha⁻¹. The experimental plots consisted of a bed measuring three meters long and 1.00 m wide containing three lines, spaced 0.30 m apart. In each plot, 30 plants were grown with a spacing of 0.30 m. The eight central plants were considered as a useful area of the plot, with the ends plants remaining as borders.

Fertigation was performed by a pressurized container system, called Fertipet (Figure 1), with the injection carried out by means of a pressure differential controlled by a plug. Fertipet uses bottles of Ethylene Politereflalate (PET) connected to polyethylene hoses (LDPE). This mechanism was patented with support from NIFI - Nucleus of Innovation and Intellectual Property of UFGD

(Patent Letter n° MU 9002574-1) (BISCARO; GOMES, 2010). In this container, the necessary amount of fertilizer was inserted according to each treatment. The constant pressure of 98 kPa, supplied by a motor pump set, was maintained for the lines of the entire system while fertigation was carried out and the pressure was controlled by a manometer.

The hybrid of Iceberg lettuce, commercially known as Lucy Brown, with a cycle of 48 to 65 days was used. The seedlings were produced in polystyrene trays with 200 cells, using commercial substrate “green life”, and were transplanted on October 8, 2016 to the beds, when they presented between four to five leaves of approximately 5 cm in length.

In the soil preparation, plowing and harrowing were performed, and subsequently the beds were formed by a roto-plumber, connected to the power outlet of a tractor whose blade rotation was 200 rpm. The cleaning of the area consisted of the elimination of weeds manually whenever necessary.

A drip irrigation system was used, with a PETRODRIP® dripper hose, model Manari, with a spacing of 0.2 m between emitters and a flow rate of 1.5 L h⁻¹, with an irrigation line installed for each line of cultivation.

The irrigation management was performed via tensiometry, with two tensiometers per block installed at a depth of 0.15 m, for daily monitoring of water tension in the soil, as recommended by Marouelli (2008). The data of water tension in the soil were collected through the use of analog and digital pressure gauges, and the irrigations were

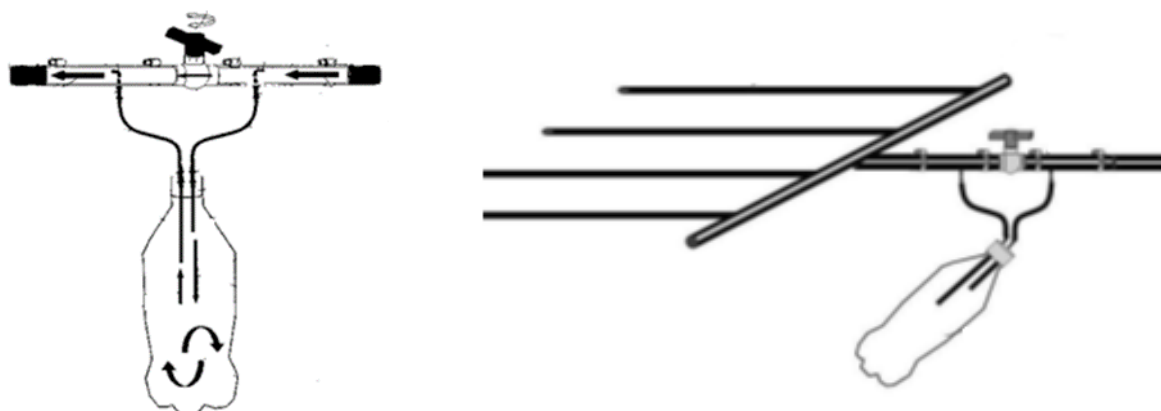


Figure 1. Assembly scheme of the Fertipet injector in the drip irrigation system

performed when the tension reached 15 kPa. The soil moisture in the field capacity was $0.389 \text{ cm}^3 \text{ cm}^{-3}$ and the critical soil moisture at the time of irrigation was $0.335 \text{ cm}^3 \text{ cm}^{-3}$, with water easily available in the order of 10.8 mm, with a percentage of wet area 100%.

The harvest was performed on November 29, 2016, which means 51 day after transplanting seedlings (DAT). In the collection of lettuce, the plants were cut just below the basal leaves, very close to the soil. After the collection, the plants were weighed using a digital scale and the total fresh mass and the commercial fresh mass were determined. Then, the measurement of its circumference was performed using a graduated measuring tape.

The plants considered as the outer leaves were defoliated until reaching the ideal point of commercialization in order to obtain the total number of leaves. Afterwards, the counting of the internal leaves of the commercial head was performed.

A total of 75,000 plants per hectare were considered in order to determine total productivity. The lettuce heads were defoliated to the commercial standard and then weighed in order to estimate commercial production.

The variables studied were subjected to analysis of variance at the level of 5% probability; when

significant, the means were proceeded to regression analysis.

RESULTS AND DISCUSSION

Data regarding precipitation and maximum and minimum temperatures during the experimental period, are shown in Figure 2. Due to the high rainfall recorded during the experimental period, irrigation was not performed, except to promote fertigation in the proposed treatments (Figure 2).

According to Oliveira *et al.* (2014), the monitoring of water consumption based on management via soil moisture, shows that the total applied layer tends to present excess water, once the sufficient layer, according to Gonçalves *et al.* (2005), is 167.0 mm, which means that approximately three times the ideal water consumption was applied.

Most of variables analyzed as a function of K_2O doses presented significant differences, except the variable number of internal leaves (NFI) (Table 2). Mota *et al.* (2001) observed a significant effect of K_2O doses on NFI, obtaining a higher NFI at a dose of $120.47 \text{ kg ha}^{-1}$ of K_2O . For the fastfood food chain, the increase in the number of internal leaves of Iceberg lettuce is a desirable characteristic, as long as they are compact, which facilitates transportation and processing (YURI *et al.*, 2002; RESENDE *et al.*, 2007).

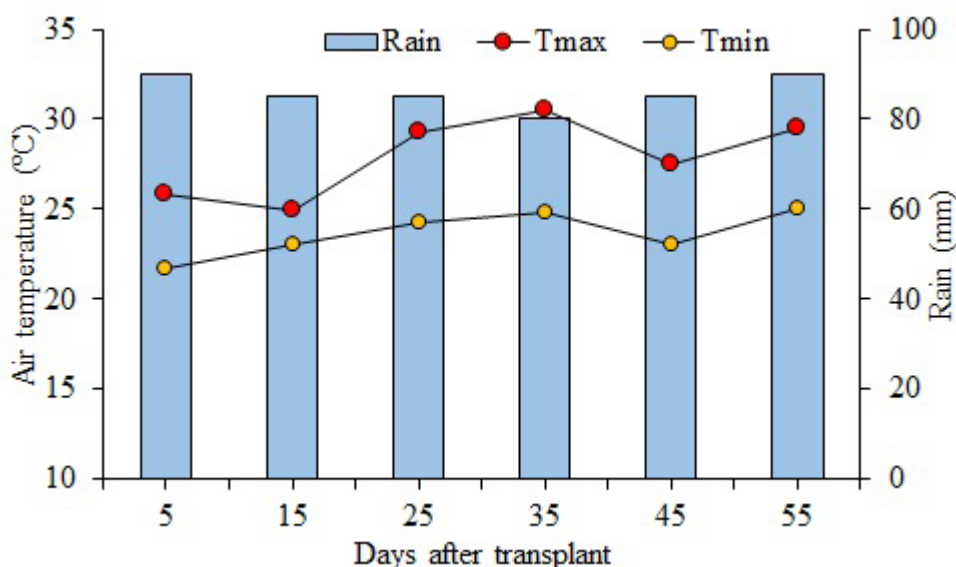


Figure 2. Decennial values of total rain, maximum (Tmax) and minimum (Tmin) temperatures from October to November 2016. Source: UFGD Weather Station

The total fresh mass (MFT) as a function of the K₂O doses applied in fertigation showed adjustment to the increasing linear regression model (Figure 3A). Therefore, it was not possible to identify which K₂O dose provided the highest MFT. The estimated regression model obtained an accuracy of 91.6%, with the highest MFT being 599.37 g, found by applying the dose of 75 kg ha⁻¹ of K₂O. The difference between the maximum and minimum MFT was 51.17g, that is, 8.50% increment. This small production difference in terms of fresh mass, can be explained by the fact that the potassium content in the soil was quite high, which provided a favorable condition for the development of lettuce, even without application of K₂O in planting. It is also likely and expected,

that higher doses could yield greater MFT until it found the point of inversion.

The fresh mass of the commercial head (MFC) as a function of the K₂O doses was adjusted to the linear regression model, with significant slope (t<0.01). The commercial fresh mass without the application of K₂O in coverage was 234.16 g and with the dose of 75 kg ha⁻¹ it was 282.08 g, causing an increase of 47.92 g, or 17.63% (Figure 3B).

Analyzing the loss of MFT in relation to MFC, there is an average difference of 313.5 g, (54.7%). This characteristic is due to the Iceberg lettuce Lucy Brown obtaining in the outer leaves a large presence of more rigid ribs (stems) which can promote, in a certain way, greater mass, and greater area. Another characteristic is that these leaves, being more rigid, may have a greater dry mass.

Table 2. ANOVA summary of the variables, total fresh mass (MFT), fresh mass of the commercial head (MFC), number of total leaves (NFT), number of external leaves (NFE), number of internal leaves (NFI), circumference of the commercial head (CIC), total productivity (PT) and commercial productivity (PC) as a function of potassium doses

Source of variation	Degrees of freedom	MFT	MFC	NFT	NFE	NFI	CIC	PT	PC
Mean square (MS)									
Block	3	107,3	770,8	4,2	0,2	5,7	1,2	13249,5	95169,96
K ₂ O	5	192,1**	159,9**	4,2**	2,2**	0,5 ^{ns}	10,1*	237429,1*	196415,05*
Error	15	319,8	241,1	0,7	0,4	0,6	2,7	3948906,4	2989217
CV%		3,1	6,0	3,3	4,9	5,8	3,3	3,1	6,0

^{ns} not significant; *, ** significant at 5% and 1% probability respectively by the F test.

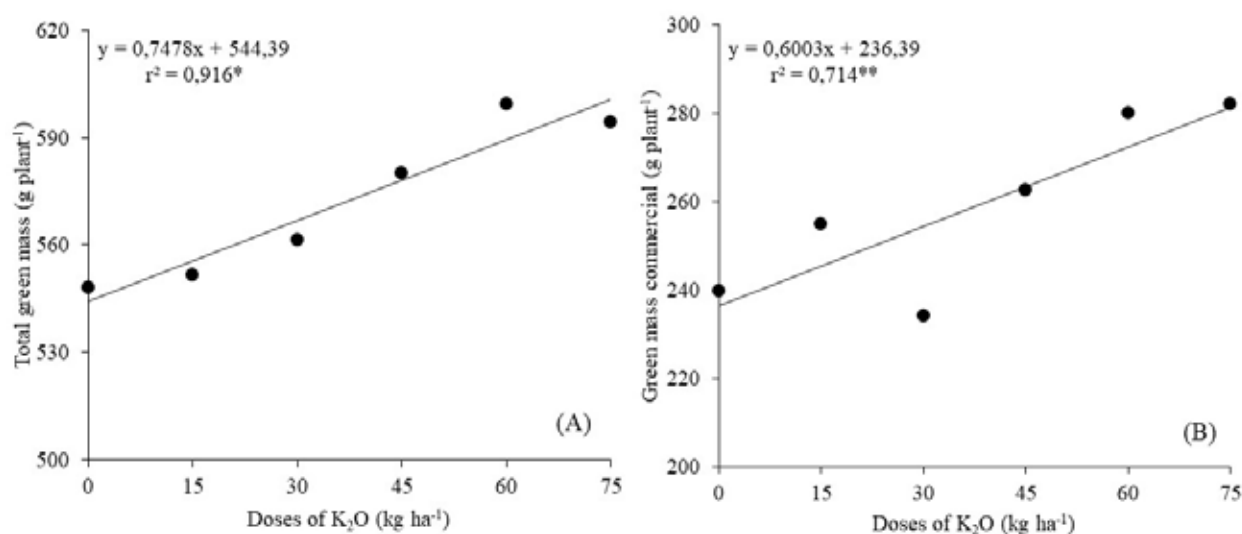


Figure 3. Total fresh mass (A) and fresh head mass (B) of Iceberg lettuce, cultivar Lucy Brown as function of the potassium doses applied via fertigation. *, ** significant at 5% and 1% probability by the F test, respectively

Souza (2007) working with potassium doses covered by fertigation in the Iceberg lettuce cultivar Tainá did not observe any significant difference between the studied doses (0, 60, 90, 120 kg of K_2O ha^{-1}) for the fresh matter of the commercial aerial part “head”, having reached an average value of 637.3 g $plant^{-1}$.

As it was not found the maximum development value for the MFC, it is understood that researches using higher doses of K_2O should be performed, in order to find the maximum point or the ideal dose. However, the viability of application must be taken into account, depending on the response of this characteristic.

Therefore, the fertilization with K_2O provided smaller stems, based on the mass of the stalk. Thus, the result allows to infer that the potassium fertilization increases external leaves and reduces the stem, making the lettuce plants more compact.

In relation to the circumference of the commercial head, the doses of K_2O applied influenced significantly, showing an increasing linear effect, as shown in Figure 4.

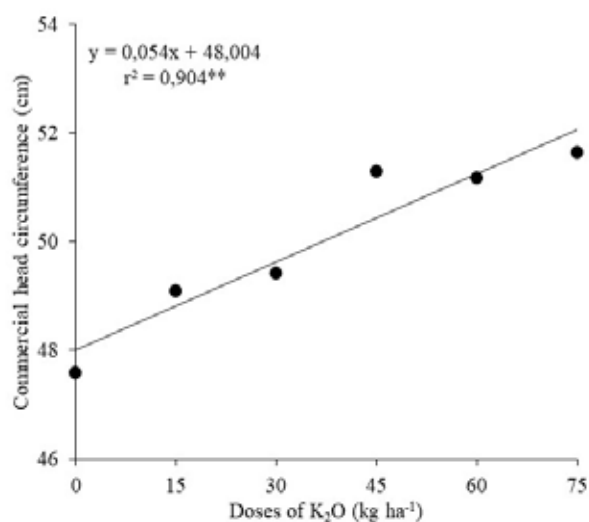


Figure 4. Circumference of the commercial head (cm) of Iceberg lettuce, cultivar Lucy Brown according to the potassium doses applied via fertigation. ** significant at 1% probability by the F test

It should be noted that the larger the circumference of the commercial head, the faster it will be processed, which is desirable for “fastfood” chains. According to Bueno (1998), the size of the lettuce, both in terms of length and height, is an important characteristic at the time of its acquisition.

The total number of leaves per plant (NFT) of the lettuce is a very desirable parameter, since the product is purchased by the consumer per unit and not by weight (MOTA *et al.*, 2001). Therefore, this variable responded linearly to the tested potassium doses (Figure 5A).

Considering the regression model, it can be seen that the projection for increasing the NFT is in the order of 0.035 leaves for each kilogram of K_2O . The highest NFT was obtained with the dose of 75 $kg\ ha^{-1}$ with an average of 27 leaves per plant, with an increase of three leaves or 11.33% higher than that obtained with the minimum dose of K_2O .

In Figure 5B we can observe that the number of external leaves increases with the increase of K_2O doses. Furthermore, through the model, an increase of one leaf is observed every 65.36 $kg\ ha^{-1}$. According to Mota *et al.* (2001), the increase in the number of external leaves of Iceberg lettuce is an undesirable characteristic, because, in general, it makes the heads appear less compact, making transportation and processing difficult. Thus, the doses of K_2O are not interesting when it is intended to increase the number of internal leaves, as this has a greater effect on the external leaves.

In the study performed by Rezende *et al.* (2017), both nitrogen and potassium fertigation have significantly influenced the number of commercial leaves per plant, with an increase in the N dose and an increase in the K_2O dose causing an increasing linear response of this variable. The same authors showed that for the increase of one commercial leaf per plant, 65.6 $kg\ ha^{-1}$ of N was necessary, whereas for K_2O the addition was 8.32 $kg\ ha^{-1}$. Araújo *et al.* (2011), observed a negative linear effect of nitrogen referring to the number of leaves per plant. Considering the treatment without the addition of nitrogen, the authors mention that organic matter in the soil met the need of cultivation to nitrogen, with no positive effect of nitrogenous chemical fertilizer.

According to the regression equation in Figure 6A, a linear increase in total productivity is observed of approximately 83 $kg\ ha^{-1}$ for each kilogram of K_2O applied in fertigation. The highest productivity was obtained using 75 $kg\ ha^{-1}$, in which it provided the productivity of 66,719 $kg\ ha^{-1}$; so the productive difference with dose 0 was 6,231 $kg\ ha^{-1}$, which means 9.34% increase.

As well as total productivity, the regression equation in Figure 6B, was based on the estimate of commercial productivity, considering 75,000

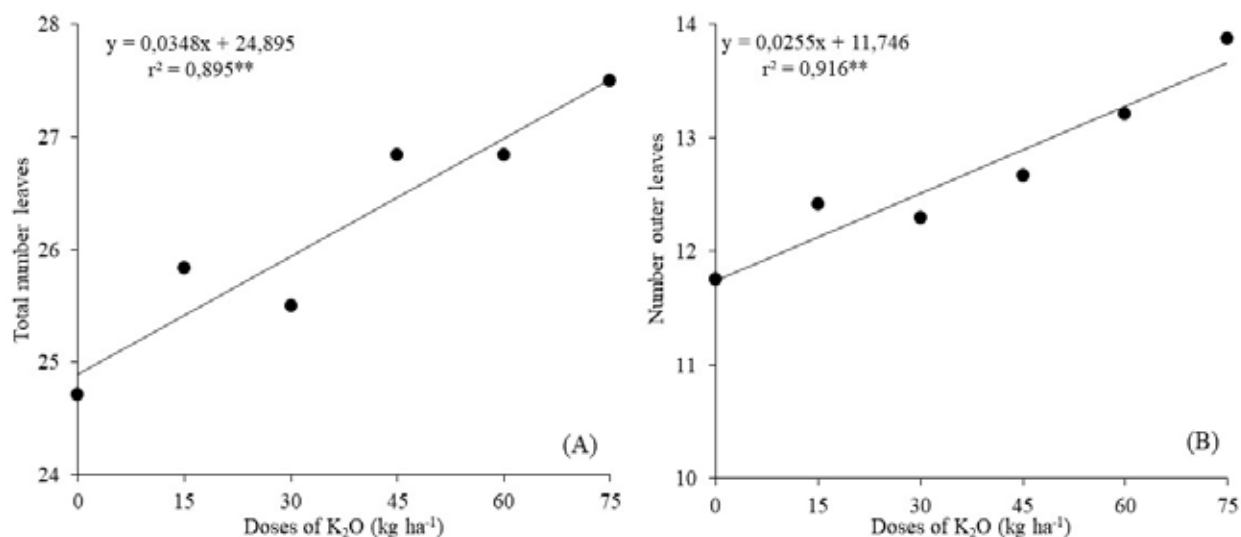


Figure 5. Total number of leaves (A) and number of external leaves (B) of Iceberg lettuce, cultivar Lucy Brown according to the potassium doses applied via fertigation. ** significant at 1% probability by the F test

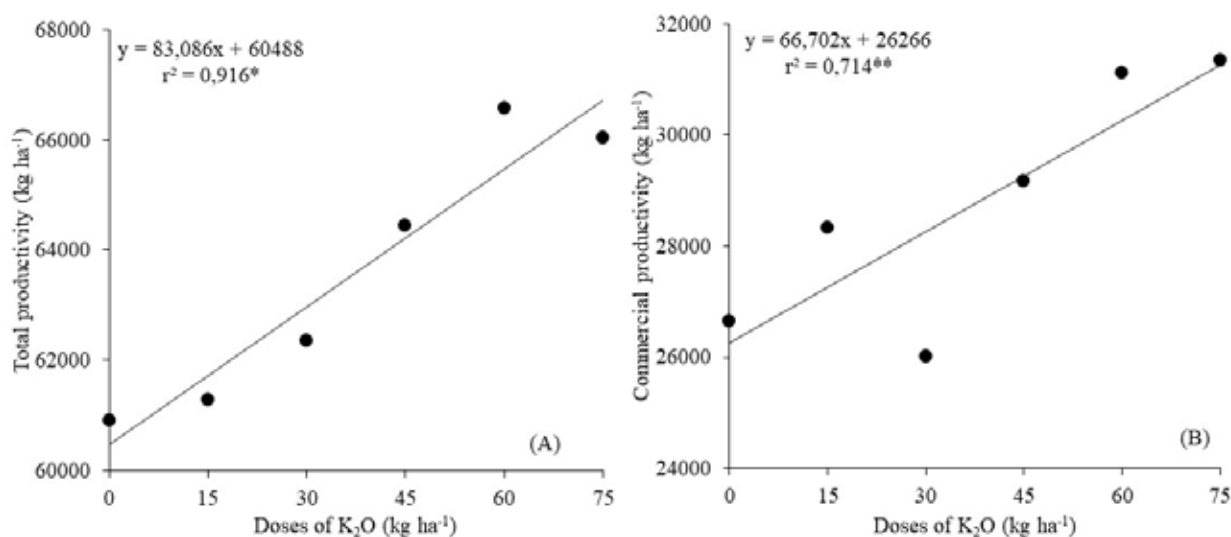


Figure 6. Total (A) and commercial (B) productivity of Iceberg lettuce, cultivar Lucy Brown according to the doses of potassium applied via fertigation. *, ** significant at 5% and 1% probability by the F test, respectively

plants ha⁻¹. The commercial productivity obtained using 125 kg ha⁻¹ was 31,342 kg ha⁻¹. The difference between the maximum and minimum productivity was 5,324 kg ha⁻¹, which means 17.63%. The average mass per head was approximately 417.89 g.

According to Koetz *et al.* (2006) the productivity as a function of potassium doses presented a quadratic regression model; therefore, it was possible to identify that the dose that provided the best productivity (optimal dose) was 119.36 kg ha⁻¹ of potassium (K₂O) or 198.93 kg ha⁻¹ of potassium chloride, for a productivity of 44,060 kg ha⁻¹.

CONCLUSION

- Most of the variables of the Iceberg lettuce cultivar Lucy Brown grown in Typic Hapludox adjust to the model of increasing linear regression as a function of K₂O doses, except the number of internal leaves.
- The K₂O dose that provides the highest value of the variables is 75 kg ha⁻¹, with the exception of the number of internal leaves that have no significant effect.

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