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SHORT COMMUNICATION

Productivity of potato seed submitted to different doses of potassium in hydroponic system

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ABSTRACT

The potato is one of the most economically important crops in Brazil, and among the items that most cost the production is seed potatoes. The deficiency of one nutrient can interfere with the absorption and accumulation of the others in plants. The aim of this work was to quantify the optimal potassium (K) dose for minituber basic seed potato yield in hydroponic system. The experiment was installed in a greenhouse with the Agata cultivar minitubers. The treatments consisted of five doses of K (0.0; 2.5; 5.0; 7.5 e 10.0 mmol L^{-1}) with four repetitions. The experimental design was a randomized block design. Data were submitted to analysis of variance and regression. The number of tubers, fresh mass, classification and dry mass were measured. The content of K and content other nutrients in the seed potato tubers were also evaluated. In the hydroponic systems, the maximum yield per plant was 48.41 tubers obtained with 6.15 mmol L^{-1} of K and maximum mass of fresh matter was 646.6 g.

Keywords: *Solanum tuberosum* L.; Agata; fertilization

INTRODUCTION

The production of potato (*Solanum tuberosum* L.) seed is a challenging step in the process of potato production in Brazil. Tuber of any size can be marketed as potato seed, but the term potato minituber is generalized in the seed segment of the basic category although it is not mentioned in the standards and standards for the production and marketing of potato propagation material in the Brazil (MAPA, 2012).

Regardless of the system used in the production of basic seed potatoes, it is almost always necessary to add potassium (K) to the medium. K deficiency may lead to reduced potato leaf dry matter accumulation (Cao and Tibbits, 1991), emergence and growth retardation, early senescence, dark green leaf (Chapman et al., 1992). followed by necrosis, thinner stems, shorter internodes, curved appearance and wilted foliage.

Several studies have evaluated the effect of potassium fertilization on potato crop productivity in the field, almost always indicating the need to apply K to obtain high productivity and quality of the tubers (Zorb et al., 2014; Silva and Fontes, 2016) increase the number of tubers (Mohr and Tomasiewicz, 2012; Singh and Lal, 2012), an essential characteristic in the production of minitubers of the basic category. There is little information on the multiplication of Agata minitubers, currently the main cultivar planted in Brazil.

For the correct management of fertilization, nutrient uptake and export studies are required to aid in fertilization programs, with the purpose of optimizing tuber production and reducing the excessive use of fertilizers (Cabalceta et al., 2005; Zobiole et al., 2010). According to Sancho (1999) and Bertsch (2003), nutrient extraction depends on external factors, which are related to the growing environment, but also on internal factors such as genetic potential and plant age.

The low productivity of potato crops is often related to nutritional limitations (Queiroz et al., 2014). And these limitations can begin when there is an imbalance of the nutrients accumulated in the seed tubers. Thus, a balance of nutrient concentrations in the tuber is essential, mainly

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for the production of seed tubers, since it is at the initial stage of development of the potato, which begins with the planting of the seed potato sprouted until the emergence of the main stems, which plant uses the nutrient reserve of the mother potato, since the root system has not yet developed (Mesquita et al., 2012).

The aim of this work was to to quantify the optimal dose of K on the productivity of seed potato minitubers in hydroponic system.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse of the Plant Mineral Nutrition Laboratory of the Plant Science Department of the Universidade Federal de Viçosa (UFV), Viçosa, MG, Brazil. The experiment was conducted between August and November 2012. The propagating material used was a minituber of the Agata cultivar, basic category G0, type VI (13-16 mm cross-sectional diameter, IMA, 2003) sprouting naturally with shoots approximately 0.5 cm the long.

The treatments consisted nutrient solution, with five doses of K (0.0, 2.5, 5.0, 7.5 and 10.0 mmol L^{-1}). The experimental design was completely randomized, with four repetitions. Each experimental unit consisted of a vessel with a plant. The sources of K used were potassium chloride (KCl -, with 60% of K_2O) and potassium nitrate (KNO_3 – with 44% of K_2O), and the doses used were determined according to Furlani (1998) modified. The control of the irrigation was automated, being realized by a digital timer programmed to activate the electric pump for two minutes at 7:00 a.m, 10:00 a.m., 12:00 p.m., 3:00 p.m. and 7:00 p.m.

The plants emerged four to five days after planting. Until the emergence, the minitubers were irrigated with deionized water. After the emergency, irrigation was done with half of the concentration of nutrients described for each treatment and after seven days, solution with macro and micronutrients concentration was provided for each treatment. The different concentrations of K doses for each treatment are shown in Table 1. Have been added $NaNO_3$ concentration so that the proportion of nutrient loads (anions and cations) are in equilibrium in the nutrient solution (Martinez and Silva Filho, 2012).

Table 1: The amount of potassium (K) applied corresponding to each treatment

Fertilizer	Treatment (mmol de K)				
	0	2.5	5	7	10
$NaNO_3$	250	125	125	0	0
KNO_3	0	125	250	250	250
KCl		0	0	125	250

The amount expressed in mL of the mineral salts solution containing macro and micronutrients, for all treatments, added to the water in the formulation of the nutrient solution (50L) were: 630 of $Ca(H_2PO_4)_2$; 70 of NH_4NO_3; 79 of $MgSO_4$; 200 of CaSO4; 158,5 of $Ca(NO_3)_2$; 50 of Fe-EDTA; 50 of solution containing H_3BO_3; $CuSO_4$; $MnSO_4$; $ZnSO_4$ and $(NH_4)_6Mo_7O_{24}$.

The nutrient solution was monitored and adjusted to 5.5 ± 0.5, with 1 mol L^{-1} HCl or 1 mol L^{-1} NaOH, both once a day. The solution exchange was performed whenever the initial electrical conductivity had a reduction of 30%.

The monthly distribution of the average temperature during the period of conduction of the experiments was obtained by daily measurements, with a minimum 13.6; 14.2; 17.3 and 20.8 °C and the maximums 38.1; 40.5; 42.7 and 48.5°C, in the months of August, September, October and November, respectively.

Plants grown in hydroponics had a cycle of 81 days. After senescence of the shoot part, the tubers were harvested, washed and evaluated for number (NT), fresh mass (FMT) and classified. The tubers were classified according to the transverse diameter, according to the original proposition do Ima (2003). The classes and their diameters were: 0 (above 60 mm); I (50 to 60 mm); II (40 to 50 mm); III (30 to 40 mm); IV (23 to 30 mm); V (16 to 23 mm); VI (13 to 16 mm); VII (10 to 13 mm) e VIII (less than 10 mm).

After harvesting the tubers, the plants were separated into leaves, stems and roots. Afterwards, they were packed in paper bags and placed in a forced circulation oven at 70 ºC, until they reached a constant mass when the mass of the dry matter was determined.

Also were counted rotted tubers, attacked by pests and diseases and with defects (greening, smudging or cracking). The tubers were then cut into small pieces, placed in petri dishes and left on the laboratory table for partial drying. Subsequently, the samples were placed in a forced circulation oven at 70 ºC, where they remained until reaching constant weight, when the mass of the dry matter tuber (DMT).

After drying, the tubers were milled in a Wiley type mill, equipped with a 20 mesh screen, submitted to nitro-perchloric digestion and analyzed for K and P contents by flame emission photometry (Braga and Defelipo, 1974), Ca, Mg and S by atomic absorption spectrophotometry (Blanchar et al., 1965). The contents of K, P, Ca, Mg, and S were obtained by the multiplication of the dry mass of the tubers, by K, P, Ca, Mg, and S content in the tubers.

Data were submitted to analysis of variance and regression. The regression model was chosen based on the biological significance and significance of the regression coefficients, using the t test, adopting the level of up to 10% probability, and the coefficient of determination (R^2 = SQregression/ SQtration).

RESULTS

The plant development at 21 days after bud emergence and final tuber seed yield are shown in Fig. 1, according to the applied of K doses.

In the experiment, there was an effect of doses of K in relation to the number of tubers, represented by the equation of the quadratic type (Fig. 2A). The dose 6.15 mmol L^{-1} K productivity of minitubers 48.41 units $plant^{-1}$.

The behavior of FMT versus doses of K was similar to that presented by NT, and the dose that allowed the maximum FMT, 646.6 g $plant^{-1}$, was 6.13 mmol L^{-1} of K (Fig. 2B).

For the plants cultivated in hydroponics there were effect of the K doses for the dry matter tuber (DMT), leaf matter (DML) and stem (DMS) variables. The variables evaluated and the equations representative of the relationship between dose of K and these variables are in Table 2.

In the experiment in hydroponic system, 592 tubers were harvested. Of these, 55.4% were abnormal. Of these abnormal tubers, 5.24% were totally rotten; 2.53% had dark patches on the epidermis; 24.32% were sprouted; 22.47% were malformation and 0.84% had some type of defect. The highest proportion of abnormal tubers (73.47%) was observed in the treatment with 2.5 mmol L^{-1} K where of the 24.5 tubers produced per plant, 18 were abnormal.

There were tubers with larger diameter, but the percentage was not expressive, being 2.36% of type II, 7.77% of type III and 42.42% of types IV, V and VI. Additionally, there was a predominance of smaller tubers with 11.99% classified as type VII and 35.64% as type VIII (Table 3).

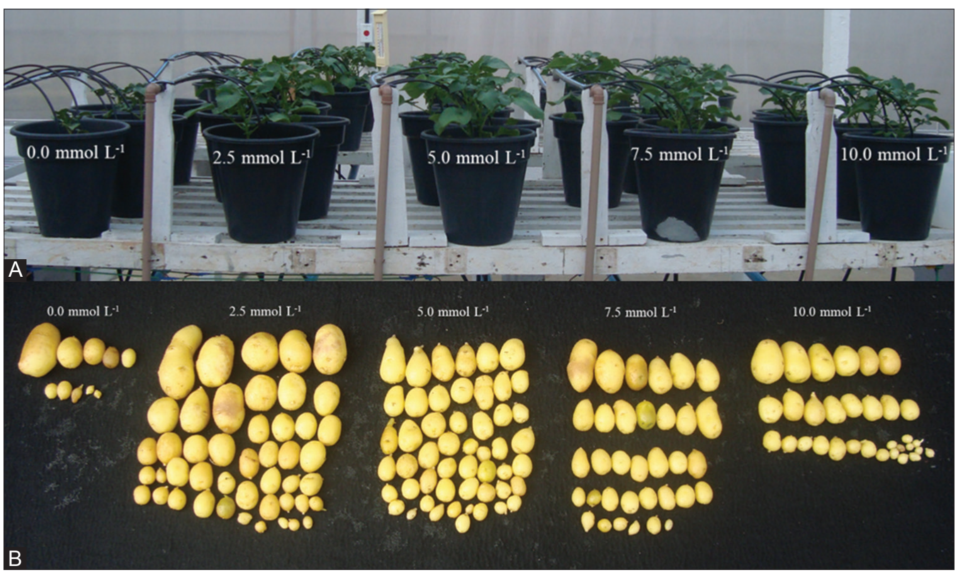

Fig 1. Potato plant development after 21 days after emergence (A) and final seed potato production (B) in plants grown on hydroponics doses of potassium (K).

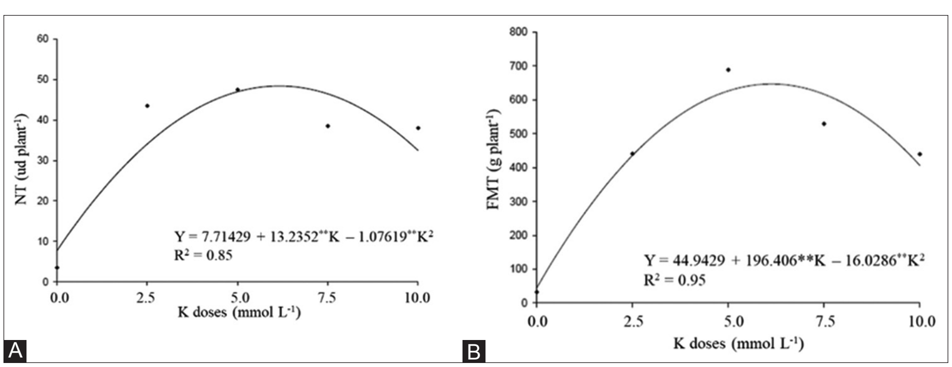

Fig 2. Number of tubers (NT) (A) and fresh mass of tubers (FMT) (B) in plants grown on hydroponics doses of potassium (K).

There was a dose effect of K on the phosphorus and calcium content in the tubers. In the experiment there was also an effect of the dose of K on potassium and sulfur contents. The variables evaluated and the equations representative of the relationship between dose of K and these variables are in Table 4.

There was a dose effect of K on sulfur in the experiment. The variables evaluated and the equations representative of the relationship between dose of K and these variables are in Table 5.

DISCUSSION

In the present experiment we have chosen to express the number of tubers produced since the systems used are apparently more appropriate for the production of minituber potato seed of the highest quality basic category, which are usually marketed in units. While in the experiment the response of the NT to the doses of K increased until the maximum point, when it started to decline.

The K doses were insufficient, optimal or deleterious, depending on the amount of K applied. The negative dose action of K on the NT was possibly determined by the increase in the electrical conductivity of the solution of the medium and/or the negative effect of the accompanying ion of K.

The difference in the dose value of K that provides the maximum yield of tubers can be attributed to several factors, such as methodological differences, year, planting season, management, heterogeneity of the organic constituents of the substrate associated to the mineral fertilizer added by the manufacturer. Medeiros et al. (2002), in a hydroponic system experiment, were able to produce from 8.6 to 49.6 tubers plant^{-1} and the average fresh tuber mass of 3.3 to 15.4 g, depending on the cultivar, propagation material and hydroponics system, including different ionic concentrations in nutrient solutions, such as 183 and 298 mg L^{-1} of K, for example.

Table 2: Adjusted equations for the dry mass of dry tubers (DMT), leaves (L), stems (S), roots (R) and whole plant (WP) dried at harvest, as a function of potassium (K) plants grown in hydroponic systems

Variables	Adjusted equations	R^2
DMT	$\hat{Y}$ = 45.35435*K+4.21237K^2	0.55
DML	$\hat{Y}$ =7.45626+13.0412*K – 0.870606**K^2	0.98
DMS	$\hat{Y}$ = 1.87308+1.52930*K	0.83
DMR	$\hat{Y}$ = 9.21	-
DMWP	$\hat{Y}$ = 118.51	-

*and** - significant at 1 and 5% probability by the "t" test, respectively

The results obtained in experiments, as well as those obtained by Medeiros et al. (2002), show a more qualified performance of these system (hydroponic system) in relation to seed potato production when compared to soil multiplication, which is 3 to 5 tubers per plant (Daniels et al., 2000). The superiority may be due to the lower incidence or absence of pathogens in the environment, a more appropriate control of plant nutrition, especially when nutrient solution is used, because through it is possible to maintain the concentration of nutrients near the roots and to make adjustments when necessary (Medeiros et al., 2002), to control the pH of the solution in bands that optimize nutrient uptake (Martinez and Alvarez, 1993), in addition to focusing on obtaining a larger number of tubers of lower mean mass.

For example, in the field, Bansal and Trehan (2011) obtained an increase in size only and not in the number of potato tubers with the application of K. Singh and Lal (2012) verifying the behavior of nutrients N and K in cultivated potato crop (39.83 t ha^{-1}), with 225 and 150 kg ha^{-1} of N and K_2O, respectively, were observed in the soil. The two nutrients increased the production of the larger tubers and decreased the yield of smaller tubers.

However, in the protected environment, there are few studies evaluating the effect of K doses on the production of basic seed potatoes. Usually, a single dose is used, for example, in the multiplication of minitubers in the soil and in a greenhouse, where Farran and Mingo-Castel (2007) using 0.75 g per K_2O plant, obtained 95 g plant^{-1} of fresh mass of tubers and 4.5 tubers plant^{-1}.

In hydroponics, using organic substrate and seedlings originating from tissue culture, Favoretto (2005) obtained 6.7 minitubers with 23 mm of greater diameter and fresh mass of 16.10 g, harvested 53 days after the transplant.

Table 3: Number of tubers harvested by classes in each treatment as a function of potassium (K) doses according to the transverse diameter (mm) in plants grown in hydroponic systems

Treatment	Class of tubers/transverse diameter (mm)						
Doses of K mmol L^{-1}	II 40-50	III 30-40	IV 23-30	V 16-23	VI 13-16	VII 10-13	VIII<10
0.0	0.25	1.75	1.25	0.25	-	-	-
2.5	0.25	1.25	2.25	2.75	4.75	2.75	10.50
5.0	1.00	4.00	6.25	6.00	4.00	5.75	13.50
7.5	1.00	1.75	4.50	5.50	7.00	2.75	15.50
10.0	1.00	2.75	7.25	5.00	5.75	6.50	13.25

Table 4: Adjusted equations for the variables expressed in g kg-1, for potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg) and sulfur (S) in the tuber, as a function of doses of potassium (K) in hydroponic systems

Variables	Adjusted equations	R^2
K	$\hat{Y} = 1.15550+0.237600^{*}K - 0.136000^{*}K^2$	0.99
P	$\hat{Y} = 0.605286 - 0.0365286^{**}K+0.0214286^{***}K^2$	0.95
Ca	$\hat{Y} = 1.35071 - 0.0470714^{***}K+0.0545714^{**}K^2$	0.85
Mg	$\hat{Y} = 18.6$	-
S	$\hat{Y} = 0.0048094 - 0.00057861^{*}K+0.0004181^{*}K^2$	0.94

*,** and*** - significant at 1, 5 and 10% probability by the "t" test, respectively

Table 5: Adjusted equations for the variables expressed in g plant-1 for the contents of potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg) and sulfur (S) in tubers, potassium (K) in hydroponic system, and the respective determination coefficients

Variables	Adjusted equations	R^2
K	$\hat{Y} = 1.5337$	-
P	$\hat{Y} = 0.3531$	-
Ca	$\hat{Y} = 0.9727$	-
Mg	$\hat{Y} = 1.4254$	-
S	$\hat{Y} = 0.000075791 - 0.000012744^{*}K +0.000000836362^{***}K^2$	0.98

*,** e*** - significant at 1, 5 and 10% probability by the "t" test, respectively

Such values indicated in the work correspond to the total productivity of 469 minitubers and 1127 g m^{-2} of fresh mass. With these treatments, the total quantities available in each bag for a potato plant through the nutrient solutions during the experimental period were 912; 1434; 1694; 2085 and 2476 mg $plant^{-1}$ of K, respectively. In each bag was planted a tuber of Asterix cultivar, at a density of 4.4 pots m^{-2} and the experiment was closed at 73 days after planting. The study showed that there were no significant effects of the addition of K on the number, 7 and 16 commercial and total tubers and on the fresh mass of tubers, 755 g $plant^{-1}$ (Cogo et al., 2006). Precise control of the number and size of potato tubers still remains a challenge for researchers (Levy and Veilleux, 2007).

The tuber is a stem and presents epidermis, peridermis, cortex (50%), vascular rings (30%) and medulla (Fontes 2005). When immature, it releases the film, dehydrates easily and is easily damaged and penetrated by microorganisms. The occurrence of tuber defective in the experiment can be attributed in part to the high temperature inside the greenhouse during the period in which the experiments were conducted. The temperature determines the occurrence of physiological disturbances and the growth rate of most of the pathogens that cause rot in the tubers.

In the potato, there are variations in the amount of nutrients accumulated by the tubers, influenced, mainly, by factors related to the production and dry matter partition for them. It may also be related to the amount of an element for the plant. In the present work K interferes with the absorption and accumulation of other elements such as P, Ca, Mg and S.

Balanced concentrations of nutrients in the potato tuber is important for a good initial development of the plant, this may interfere with the plant's future productivity. Since the potato plant uses the reserves accumulated in the seed tubers for their initial growth, root emission and stems. Fernandes et al. (2011) found that due to the reduction of dry mass and remobilization of nutrients to the growing regions, the amounts of N, P, K, Mg and S accumulated in the seed tubers decreased. Thus, among the nutrients accumulated by potato Malavolta and Dantas (1980) found that 80 to 94% of P, 68 to 74% of N, 32.5 to 57.8% of S, 25.5% of Mg, 19 to 20% of K and 2.8 to 3.6% of Ca are exported by the tubers.

CONCLUSION

For hydroponic cultivation the dose of 6.15 mmol L^{-1} of K is the optimal dose to produce basic seed potatoes in a three-phase system.

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Author's contributions

In this research, all authors contributed effectively. Camila, Carla e Marialva designed and achieved experiments and wrote the paper; Paulo Cezar was involved in manuscript preparation and supervised the research project.

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