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Agronomic performance of sweet potato with different potassium fertilization rates

Arthur B Cecílio Filho[1]; Sandra MC Nascimento[2]; Alexsandra SN Silva[2]; Pablo F Vargas[3]

[1]Universidade Estadual Paulista, Depto. Produção Vegetal (UNESP), Jaboticabal-SP, Brasil; rutra@fcav.unesp.br; [2]Instituto Federal do Maranhão (IFMA), São Luís-MA, Brasil; scostacruz@bol.com.br; alexsandra.nascimento@ifma.edu.br; [3]Universidade Estadual Paulista (UNESP), Registro-SP, Brasil; pablo@registro.unesp.br; pfvargas@cerat.unesp.br

ABSTRACT

Sweet potato is a vegetable with great potential due to its versatility of use, which covers human food, animal feed and biofuels. However, it is still little studied, especially regarding mineral nutrition and potassium. Thus, a study was conducted to evaluate potassium fertilizer doses (0, 30, 60, 90, 120 and 150 kg/ha K_2O) on mineral nutrition and yield of 'Beauregard' sweet potato in a typic Hapludult soil with low K level (0.3 $mmol_c/dm^3$). The experimental design was of randomized blocks with four repetitions. Harvest took place 123 days after seedling transplanting. Foliar K content, shoot, root and total dry matter, root total yield, root commercial yield, K accumulation, K content in the soil and K optimal economic dose were assessed. The highest foliar K content was observed at the dose of 100 kg/ha K_2O, with K value of 44.6 g/kg on leaf dry matter. In soils with low K availability, the highest yield (38 t/ha) was observed at the dose of 87 kg/ha K_2O. Maximum commercial yield (24.3 t/ha) was obtained at the dose of 85 kg/ha K_2O, and K accumulation of 150 kg/ha in the shoot and 57 kg/ha in the root, respectively, were observed (72.5 and 27.5%). Optimal economic production was of 71 kg/ha K_2O, which corresponds to 83% of the dose that maximized commercial production.

Keywords: *Ipomoea batatas*, potassium fertilization, economic dose.

RESUMO

Desempenho agronômico de batata doce sob diversos níveis de K

A batata doce é uma hortaliça com grande potencial devido a sua versatilidade de uso, podendo ser utilizada na alimentação humana, animal e biocombustível. Contudo, é uma cultura pouco estudada, principalmente no que diz respeita a nutrição mineral, especialmente o potássio. Desta forma, um estudo foi realizado objetivando avaliar doses de adubação potássica (0, 30, 60, 90, 120 e 150 kg/ha de K_2O) sobre a nutrição mineral e produtividade de batata doce 'Beauregard' em um Argissolo com baixo nível de K, 0,3 $mmol_c/dm^3$. O delineamento experimental foi de blocos ao acaso com quatro repetições. A colheita ocorreu 123 dias após o transplante das mudas. Foram avaliados teor foliar de K, matéria seca da parte aérea; matéria seca da raiz tuberosa; matéria seca total; produtividade total de raízes; produtividade comercial das raízes; acúmulo de K; teor de K no solo e dose ótima econômica de K. O maior teor foliar de K foi verificado na dose de 100 kg/ha de K_2O, com valor de 44,6 g/kg de K na matéria seca foliar. Em solos com baixa disponibilidade em K, a produção máxima (38 t/ha) foi verificada com a dose de 87 kg/ha de K_2O, e a máxima produção comercial (24,3 t/ha) foi obtida com a dose de 85 kg/ha de K_2O, sendo verificados acúmulos de 150 kg/ha de K na parte aérea e de 57 kg/ha de K na raiz tuberosa, respectivamente 72,5 e 27,5%. A produção ótima econômica foi de 71 kg/ha de K_2O, o que corresponde a 83% da dose que maximizou a produção comercial.

Palavras-chave: *Ipomoea batatas*, fertilização potássica, dose econômica.

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The sweet potato (*Ipomoea batatas*), originated from America, is a species with great versatility, which can be used in human food, animal feed and industrial production, leading to biofuels, flakes, starch and powder.

Currently, China is the world's largest producer of this crop, with 788 million tons per year and an average yield of 22.43 t/ha. Brazil is the 20th largest producer, achieving 54.4% of China's equivalent yield (12.28 t/ha) (FAO, 2014).

This vegetable crop is among the seven main food crops in the world (Nsa *et al.*, 2013) and among the top five crops in 50 countries (Thume *et al.*, 2013). In many developing countries, the sweet potato is a staple food for producing large amounts of energy per area/time (Li *et al.*, 2014).

It is considered a rustic crop (Erpen *et al.*, 2013), as it is highly resistant to pests and diseases and has good response to fertilizer application, growing in low fertility and even degraded soils (Mantovani *et al.*, 2013). Despite these characteristics and multiple use possibilities, this vegetable has not been exploited properly (Figueroa *et al.*, 2011) and has been little studied (Azevedo *et al.*, 2014).

As it is traditionally cultivated by small farmers and most of its production is intended for the local market or for own consumption, the sweet potato has not been receiving much attention by Brazilian agricultural researchers, notably with regard to knowledge of its nutrition demands and fertilization recommendation criteria (Thumé *et al.*, 2013).

Low yield of this crop may be due to factors such as lack of appropriate crop practices, use of obsolete cultivars, susceptibility to pests and diseases (Azevedo *et al.*, 2014) and inadequate plant nutrition.

Among soil factors, fertility is the most important for sweet potato production (Nsa *et al.*, 2013). Due to soil variability in sweet potato producing regions, its chemical and physical characteristics differ. Therefore, crop fertilization recommendations are also variable.

Among the nutrients, potassium (K) stands out, which is the second most absorbed and extracted nutrient by this crop (Echer *et al.*, 2009). This nutrient participates directly and indirectly in numerous biochemical processes involved in carbohydrate metabolism, photosynthesis and respiration (Costa *et al.*, 2004).

Despite the existence of studies evaluating potassium influence in sweet potato roots development and production, these were not carried out in all sweet potato producing regions. Soil type and environmental conditions influence potassium availability dynamics in soil. Thus, there is the need to know the influence of this nutrient in each production environment.

Given the above, the objective of this study was to evaluate the agronomic performance of sweet potato in relation to potassium fertilization levels.

MATERIAL AND METHODS

The experiment was carried out from 1 July to 31 October 2011, in the Federal Institute of Maranhão, Maracanã Campus, located in the municipality of São Luis (2°36’35’’S, 44°15’52’’W, elevation of 34 m). Climate, according to Thornthwaite’s classification, is of B1 WA type, characterized as humid with moderate water deficiency in the winter, between June and September. During the study, average maximum temperatures of 32.81°C and average minimum temperatures of 24.32°C were observed, with rainfall of 156 mm.

The soil of the area is a typic Hapludult of Itapecuru formation (Embrapa, 2006). Chemical characteristics and soil texture were measured prior to study installation through soil samples collected at the 0-20 cm layer. These samples were sent to the Soil Chemistry and Fertility Laboratory of Maranhão State University. Analysis showed soil texture with 6, 8 and 86% clay, silt and sand, respectively. Chemical analysis showed 4.8 pH ($CaCl_2$), 14 mg/dm^{3}organic matter, 14 g/dm^3 P (resin) and K, Ca, Mg, Na, Al, Al+M and CEC of 0.3, 3.0, 4.0, 0.4, 0.0, 24.0, 31.7 mmol$_c$/dm^3, respectively, with base saturation of 24%.

The study was conducted through a randomized blocks design with six treatments (0, 30, 60, 90, 120 and 150 kg/ha K_2O) and four repetitions. The experimental unit area was 2.4 m wide and 3.5 m long, comprising three rows with 80 cm spacing between each other, with ten plants spaced at 35 cm. Data were collected only in the eight central plants of the plot central line, which is the plot useful area, while the other plants were considered borders.

Liming was conducted in total area with limestone containing 32% CaO, 15% MgO and RNV (relative neutralizing value) of 95%, in order to increase soil saturation to 60% and Mg content to at least 10 mmol$_c$/dm^3 (Casali, 1999). This operation was followed by plowing and harrowing, in order to incorporate the input.

Sixty days after liming, 20 cm deep furrows were opened, 30 kg/ha N (urea), 180 kg/ha P_2O_5 (triple superphosphate) and 10 t/ha cattle manure were applied. The potassium source used was potassium chloride. Thus, each plot was fertilized according to the experimental design, receiving all potassium fertilizer at planting. Then, plots were raised manually through hoes.

‘Beauregard’ sweet potato was used, which is an American cultivar developed by Louisiana Agricultural Experiment Station. It was introduced in Brazil by the La Papa International Center (CIP), Peru. This cultivar has a vegetative cycle of 90 to 130 days, elongated and uniform roots and red-purple peel with smooth surface. Internally, it has an intense orange color, indicating high beta-carotene content.

Stems containing four gems were removed from the apical part of matrix plants from the Embrapa experimental field, Coroatá-MA, and were placed in polystyrene trays of 50 cells containing organic substrate. After 25 days, transplantation to the plots was conducted.

Irrigation was carried out according to crop needs. Topdressing was conducted by applying 30 kg/ha N from urea source at 30 days after transplanting (DAT) (Casali, 1999).

Pest control (whitefly and mealybug) was conducted chemically. Invasive plants control was carried out through three manual weeding, with two occurring in the plots at 30 and 60 DAT and another one occurring between plots at 45 DAT.

At 60 DAT, (a) Foliar K content (TFK) was evaluated, in which leaves from the sweet potato shoot middle third, i.e., the newest fully developed leaves were taken from the eight plants of the experimental unit useful plot (Lorenzi *et al.*, 1997). Collection was held at the beginning of the day, between 6 and 7 a.m. Once collected, leaves were washed with tap water and deionised water, in order to remove impurities. After excess water removal with a paper towel, samples were placed in paper bags, identified and taken to dry in an oven with forced air circulation at 65°C, until reaching constant matter. Then, each sample was grounded in a Wiley mill. Extract preparation for K content reading was carried out according to the methodology by Battaglia *et al.* (1983).

At 123 DAT, sweet potato roots were harvested, through which the following parameters were evaluated: (b) Shoot dry matter (SDM): leaves and shoots of the plot useful area were harvested, washed, deposited in paper bags and placed in an oven with forced air circulation at 65°C, until reaching constant matter; later, they were weighed and converted to g/m^2. (c) Tuberous root dry matter

(TRDM): two roots from the useful area were weighed, cut into small slices, placed in paper bags and put to dry in an oven with forced air circulation at 65°C, until reaching constant matter; later, they were weighed and converted to g/m^2. (d) Total dry matter (TDM): calculated by adding the SDM + TRDM. (e) Root total yield (TY): roots were harvested from the eight plants of the useful area, washed and dried for one day; afterwards, they were weighed and converted to kg/m^2. (f) Roots commercial yield (CY): harvested roots were considered commercial if weighing between 80 and 800 g (Miranda *et al.*, 1995); these were weighed and values were converted to kg/m^2. (g) K accumulation: during harvest, plant SDM and TRDM P content were analyzed using the methodology by Battaglia *et al.* (1983); through content results and the respective dry matters of parts from which it was determined, accumulated amounts of these nutrients in every plant part were obtained. The total amount accumulated in the plant was obtained by adding SDM and TRDM amounts, while nutrients export corresponded to TRDM amounts. (h) Soil K content (SKC): after experiment completion, the central cultivation row (furrow) of each plot was sampled at five points; simple samples were mixed to obtaining a composite sample, in which K content (resin) was evaluated. (i) K optimal economic dose: the optimal economic dose for commercial roots production was determined according to the methodology by Natale *et al.* (1996). Equivalence ratio (ER) of 2.5 was obtained, which was found through the ratio between the average price of 1 kg of K_2O (R$ 3.75/kg) and the average price of 1 kg of sweet potato (R$ 1.50/kg) marketed in CEASA-São Luís, in 2012. ER was equated with the first derivative of the regression model adjusted for sweet potato commercial root production and K_2O dose.

With the average data of evaluated characteristics, analysis of variance (F test) was performed according to the proposed design, in addition to polynomial regression analysis, and the equation with the most significant adjustment was chosen. Agroestat statistical program was used, which was developed by the Department of Mathematical Sciences, Faculty of Agricultural and Veterinary Sciences, Unesp, Jaboticabal Campus.

RESULTS AND DISCUSSION

Soil K content, foliar potassium content and sweet potato roots total and commercial yields were significantly influenced by potassium doses applied to the soil.

There was linear regression model adjustment for soil K content (Figure 1). Proportional increases in soil K content were observed with increasing K doses application. K content, which was rated as very low prior to experiment application (Raij *et al.*, 1997), reached only 0.8 mmol$_c$/dm^3 even at the highest evaluated dose, remaining in the level class considered low (0.7 to 1.5 mmol$_c$/dm^3).

Failure to increase soil K possibly occurred due to K loss by leaching due to soil texture (sandy) and its low CEC. According to Werle *et al.* (2008), K losses are usually intense in sandy soils with low K retention capacity.

As for foliar K content, there was quadratic equation adjustment to the averages. Foliar content increase was observed until the 100 kg/ha K_2O dose, when 44.6 g/kg K was observed on leaf dry matter. Higher doses provided lower levels, and leaf content was of 38.5 g/kg K when the highest K_2O (150 kg/ha) dose was applied. This leaf content was also obtained with 48 kg/ha K_2O, and as lower doses were applied, leaf content also reduced, with 21.5 g/kg when K was not applied in the soil (Figure 1). With the provision of at least 25 kg/ha K_2O, foliar K content remained in the range of levels considered adequate by Lorenzi *et al.* (1997), which is from 31 to 45 g/kg.

Sweet potato roots total yield (TY) and commercial yield (CY) averages were adjusted to the second degree model (Figure 2). Maximum sweet potato TY (38 t/ha) was obtained with the estimated dose of 87 kg/ha K_2O, and maximum CY (24.3 t/ha) was achieved with the estimated dose of 85 kg/ha K_2O. From the doses aforementioned, there was yield decrease as the dose was increased (Figure 2).

Commercial sweet potato roots maximum yield obtained in this study exceeded sweet potato yield averages from the state of Maranhão, estimated at 2.8 t/ha, and the average of the Brazilian Northeast region, 7.5 t/ha (IBGE, 2014).

The results of this experiment corroborate Raij (2011), who explained that potassium fertilizer response by crops is especially pronounced in

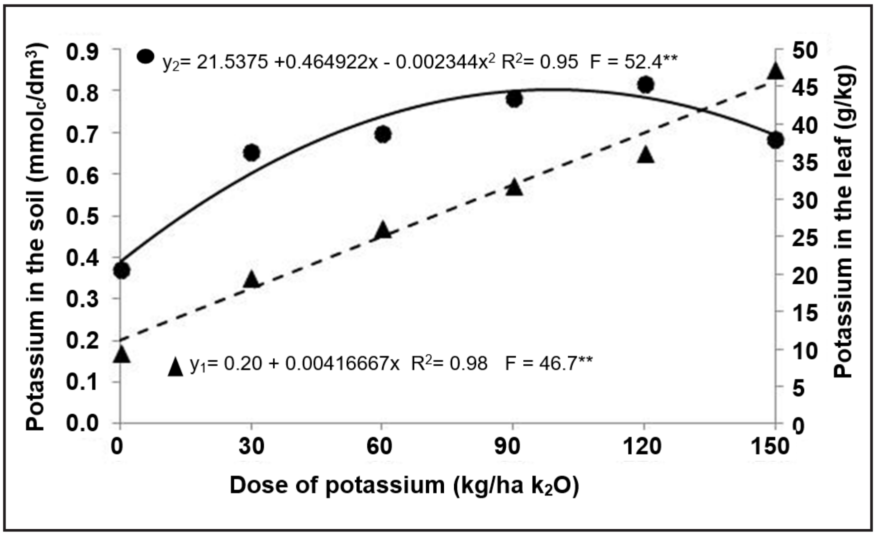


Figure 1. Potassium content in the soil (y1) and leaf (y2) of sweet potato, depending on dose of potassium {teor de K no solo (y1) e na folha (y2) de batata-doce, em função da dose de K}. Jaboticabal, UNESP, 2014.

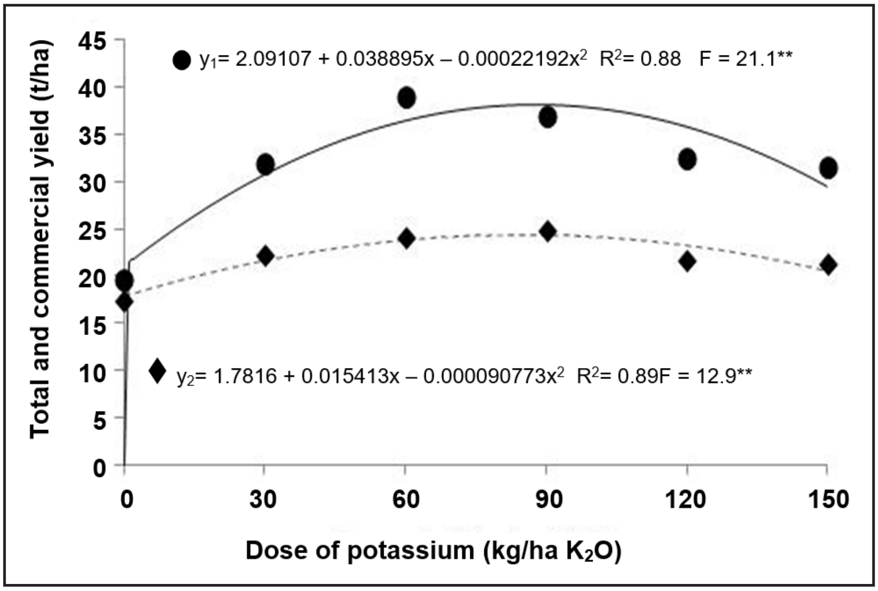
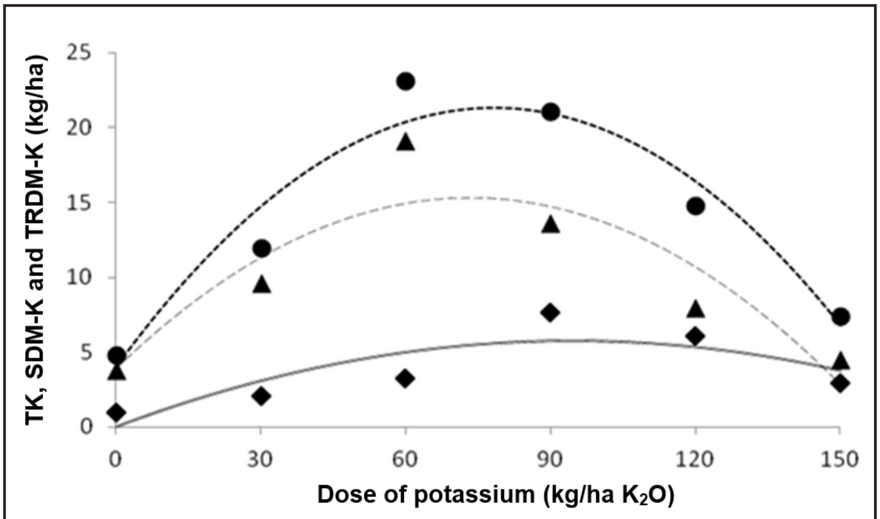


Figure 2. Total (y1) and commercial yield (y2) of sweet potato roots depending on dose of potassium {produtividade total (y1) e commercial (y2) de raízes de batata-doce em função de dose de K}. Jaboticabal, UNESP, 2014.



● TK= 3.9965 + 0.4432269x – 0.002830714x²; R²= 0.92; F= 272.1**

▲ SDM-K= 3.907045 + 0.3111916x – 0.002118358x2; R²= 0.81; F= 157.4**

♦ TRDM-K= 0.009982143 + 0.1216939x – 0.0006442956x²; R²= 0.69; F= 265.2**

Figure 3. Total accumulation of potassium in the plant (TK), in the dry matter of shoots (SDM-K) and root dry matter (TRDM-K) of sweet potato depending on dose of potassium {acúmulo total de K na planta (TK), na matéria seca da parte aérea (SDM-K) e na matéria seca de raízes (TRDM-K)}. Jaboticabal, UNESP, 2014.

sandy soils with low fertility. In species that accumulate reserves in tuberous roots, potassium favors carbohydrates formation and translocation and improves commercial roots production.

Some authors found higher doses to obtain maximum yields. Foloni *et al.* (2013) obtained sweet potato maximum CY (23.4 t/ha) with 120 kg/ha K_2O, and Brito *et al.* (2006) verified need for 194 and 173 kg/ha K_2O to maximize TY (14.8 t/ha) and CY (8.4 t/ha), respectively, in soils with low K content (37 mg/dm^3). Several factors influence soil potassium dynamics and its availability to the plant, as well as the plant need for the nutrient. Thus, we observed that the Beauregard cultivar may be less demanding regarding potassium fertilization than Canadense and Rainha Branca cultivars, used in the studies mentioned above.

Total and commercial yield reductions with doses higher than 87 and 85 kg/ha K_2O, respectively, may be attributed to a possible soil salinity increase near the plant root area, besides the reduction of absorptions of other cations. According to Marschner (1997), high salinity of some fertilizers, mainly KCl, damages root growth and distribution, as well as nutrients and water absorption, as it decreases the osmotic potential near the rhizosphere, hindering ion movement to the roots. Moreover, excessive fertilization with potassium may reduce Ca and Mg absorption, promoting crop yield reduction (Pereira & Fontes, 2005). Thus, in order to obtain high yields and good quality products, sufficient and balanced quantities are needed (Malavolta, 2005).

The optimum economic dose, valid for the 2.5 ratio, obtained through the ratio between fertilizer price and sweet potato price, was of 71 kg/ha K_2O, corresponding to 83% of the dose responsible for commercial root maximum yield. That dose was lower than those proposed by Casali (1999) and Lorenzi *et al.* (1997) for sweet potato crops in soils with low K content.

Potassium accumulation in shoot dry matter and in tuberous root, which are equivalent to potassium export, and total potassium accumulation in the plant were significantly influenced by K doses applied to the soil, having quadratic equation adjustments for characteristic means (Figure 3).

With the dose that maximized commercial productivity, 85 kg/ha K_2O, accumulations of 150 kg/ha K in the shoot and 57 kg/ha K in the tuberous root were found (Figure 3), totaling 72, 5 and 27.5%, respectively, of the total K accumulated by sweet potato plant. Therefore, the highest absorbed K percentage was found in leaves, followed by tuberous roots. These results corroborate those obtained by Echer *et al.* (2009), who also found that most of K absorbed by the plant was present in sweet potato leaves.

We concluded that Beauregard cultivar (a) had its commercial yield increased by potassium fertilization until the 85 kg/ha K_2O dose in soils with low K availability. In addition, (b) the optimal potassium fertilizer economic dose was of 71 kg/ha K_2O, which corresponds to 83% of the dose that maximized commercial yield.

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