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ORIGINAL ARTICLE

Productivity and quality of sweet potato roots cultivation with and without chicken manure

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Abstract - Sweet potato (*Ipomoea batatas*) has cultural, social and economic importance due to its rusticity and wide climate adaptation, being cultivated in Brazil for human and animal food. However, cultivation is carried out mainly without fertilization and with Creole cultivars. The objective was to evaluate the yield and quality of roots of sweet potato cultivars with and without fertilization of chicken manure in an Oxisol. The experiment was carried out under field conditions in the 2015/16 and 2016/17 seasons in a randomized block design with three replications in 6 m^2 plots. Four sweet potato cultivars, BRS Rubissol, BRS Amélia, BRS Cuia and Crioula, were used. Root productivity, number, length and diameter of roots, and cracked roots were evaluated. In both cultivation conditions, the virus-free cultivars Rubissol, Amélia and Cuia showed higher average root yields, 43,941, 45,498 and 52,095 kg ha^{-1}, respectively, compared to the Crioula cultivar with 3,389 kg ha^{-1}. Fertilization with chicken manure does not increase the productivity, number, length and diameter of roots, but it does increase the number of cracked roots. The cultivation of virus-free sweet potato without fertilizer reduces cracked roots by an average of 51.4%.

Keywords: *Ipomoea batatas.* Alternative fertilizer. Chicken manure. Organic fertilizer.

Produtividade e qualidade de raízes de batata-doce cultivadas com e sem adubação de cama de frango

Resumo - A batata-doce (*Ipomoea batatas*) possui importância cultural, social e econômica devido sua rusticidade e ampla adaptação climática, sendo cultivada no Brasil para alimentação humana e animal. No entanto, o cultivo é realizado principalmente sem adubação e com cultivares crioulas. O objetivo foi avaliar a produtividade e qualidade de raízes de cultivares de batata-doce com e sem adubação de cama de frango em Latossolo vermelho. O experimento foi conduzido em condições de campo nas safras 2015/16 e 2016/17 em delineamento em blocos ao acaso com três repetições em parcelas de 6 m^2. Foram utilizadas quatro cultivares de batata-doce, BRS Rubissol, BRS Amélia, BRS Cuia e Crioula. Foi avaliada a produtividade, número, comprimento e diâmetro de raízes e raízes rachadas. Nas duas condições de cultivo, as cultivares livres de viroses Rubissol, Amélia e Cuia apresentaram maiores produtividades médias de raízes, 43.941, 45.498 e 52.095 kg ha^{-1}, respectivamente, comparado a cultivar Crioula com 3.389 kg ha^{-1}. A adubação com cama de frango não aumenta a produtividade, número, comprimento e diâmetro de raízes, porém aumenta a quantidade de raízes rachadas. O cultivo de batata-doce livre de viroses e sem adubação reduz em média 51,4% as raízes rachadas.

Palavras-chave: *Ipomoea batatas.* Fertilizante alternativo. Dejeto de frango. Adubação orgânica.

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Introduction

The production of sweet potato is part of the history of Brazil, as it is a plant originally from Latin America. The first adventurers who visited the country have already described the use of sweet potato by the people of Brazil from 1549 to 1557 (TOMCHINSKY; MING, 2019). In 2019, the sweet potato cultive area in Brazil was 54,123 hectares with an average production of 13,998 kg ha^{-1}, with the South and Northeast regions standing out with 16,329 and 23,126 hectares, respectively (IBGE, 2020).

Sweet potato has a wide adaptation to different environments, soil types and fertility conditions, being characterized by its rusticity, low production cost and cultivated mainly by small producers and without fertilization (ANDRADE JÚNIOR *et al.*, 2016). It is considered one of the most important cultures in the world, used as a source of family subsistence food, with high energy value, rich in vitamins and proteins (CAVALCANTE *et al.*, 2010). According to Akoetey, Britain and Morawicki (2017), sweet potatoes are an important source of carbohydrates consumed in different ways, especially, baked or boiled and in the manufacture of products such as starch, flour, canned goods and purees. In addition, mainly tethers can also be used in animal feed (ANDRADE JÚNIOR *et al.*, 2016), especially in dry seasons, where there is a shortage of pastures (VIANA *et al.*, 2011). In industry, in addition to food, it is used as a raw material for the production of fabrics, paper, cosmetics, fuel alcohol, among others (DÉSIRÉ; VIVIEN; CLAUDE, 2017).

In Brazil, the cultivation of local and unimproved varieties is predominant, being one of the main reasons for the low root productivity, mainly due to the fact that the vegetative propagation of the crop takes place through branches (tears), resulting in plants with less vigor and productivity, which makes them susceptible to viruses (FERNANDES; DUSI, 2013). In this context, it is necessary to adopt more productive cultivars, taking into account commercially acceptable roots format, resistant to pests and diseases (AZEVEDO *et al.*, 2014; MASSAROTO *et al.*, 2014). The national average yield of sweet potato is low, around 11.8 t ha^{-1}, a value well below the potential of the crop, which can be higher than 40 t ha^{-1}, especially in improved and/or free from cultivars viruses (SILVA *et al.*, 2015). The northwest region of the State of Rio Grande do Sul (RS) is characterized by being essentially agricultural, which largely consist of small family farmers (TRENNEPOHL; MACAGNAN, 2008). Thus, the cultivation of sweet potato is very common in family properties in the region, where the culture is produced alone or in consortium with other species/crops (polycultures), mainly used for family subsistence.

Fertilization in the crop can favor greater root productivity, making it an important tool for studies, but in addition to chemical fertilization, more sustainable alternative sources, such as chicken manure, should be sought. The imminent scarcity of sources for chemical fertilizers, together with the atmospheric emissions of pollutants emitted by the burning of fossil fuels, are factors that lead to the increasingly imminent need to use other renewable sources that are less harmful to the environment (DALÓLIO *et al.*, 2017). The use of poultry manure, such as chicken manure, brings several benefits, as, for example, in addition to supporting the production of crops, it can positively change chemical properties, by providing nutrients, especially N, P and K, physical and biological of the soil (SANTOS L. *et al.*, 2014). Still, the use of chicken manure in plant fertilization is relevant, as it is an excellent supplier of organic matter for the soil (FERNANDES *et al.*, 2013),

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in addition to N (VALADÃO *et al.*, 2011), providing about 2% of N in its composition. It is public and technical-scientific knowledge that fertilization with poultry manure, when used correctly, promotes great potential for agricultural production and can be used in various cultures (CORRÊA; MIELE, 2011). According to Santos, Brito and Santos M. (2010), in economically poorer regions, the use of chicken manure can be a great alternative for fertilizing sweet potato, which can come from its own breeding. However, although there are reports of the use of chicken manure as an alternative source of fertilization in the sweet potato crop, research information is limited, especially regarding its efficiency.

Although the use of fertilization is efficient to increase the productivity of sweet potato roots, this scenario is not always advantageous, because, due to the rusticity of the crop, production under natural conditions of soil fertility, climate and without pest, disease and control weeds can be the best option for the rural producer. Allied to this, in the regional scenario, the sweet potato crop is still produced without major concerns with cultural treatment and management of the crop. Aiming to provide results that express data that collaborate with the reality of local agroecosystems, the present work aimed to evaluate the productivity and quality of roots of sweet potato cultivars with and without fertilization of chicken manure.

Material and Methods

The study was carried out in the experimental area of UERGS (Universidade Estadual do Rio Grande do Sul), unit in Três Passos, located in of Bom Progresso - RS, in a typical Red Oxissol (SANTOS H. *et al.*, 2018). The experiment was implemented under field conditions in an area with a history of growing annual crops in the spring/summer season in 6 m2 (2x3m) experimental plots and carried out for two experimental years, 2015/16 and 2016/17 crops. The two cultivation conditions, with and without fertilization of chicken manure, were carried out under natural climatic conditions and without irrigation (Figure 1). At the beginning of the experiment (2015/16 crop) soil samples were collected to characterize the chemical and physical properties of the soil (Table 1).

Four sweet potato cultivars were used, three of which came from Embrapa Clima Temperado, which underwent clonal cleaning, free of viruses, BRS Amélia, BRS Cuia and BRS Rubissol, and a Crioula cultivar of purple pulp cultivated in the region covered by the present study. The sweet potato cultivars were subjected to two growing conditions: 1) Without fertilization, and 2) With fertilization. All cultivation conditions were carried out without pest, disease and weed control. The experiment was carried out in two adjacent areas, both in randomized blocks with three replications of each treatment: T1: Crioula, T2: Crioula + chicken manure, T3: BRS Rubissol, T4: BRS Rubissol + chicken manure, T5: BRS Amélia, T6: BRS Amélia + chicken manure, T7: BRS Cuia, T8: BRS Cuia + chicken manure.

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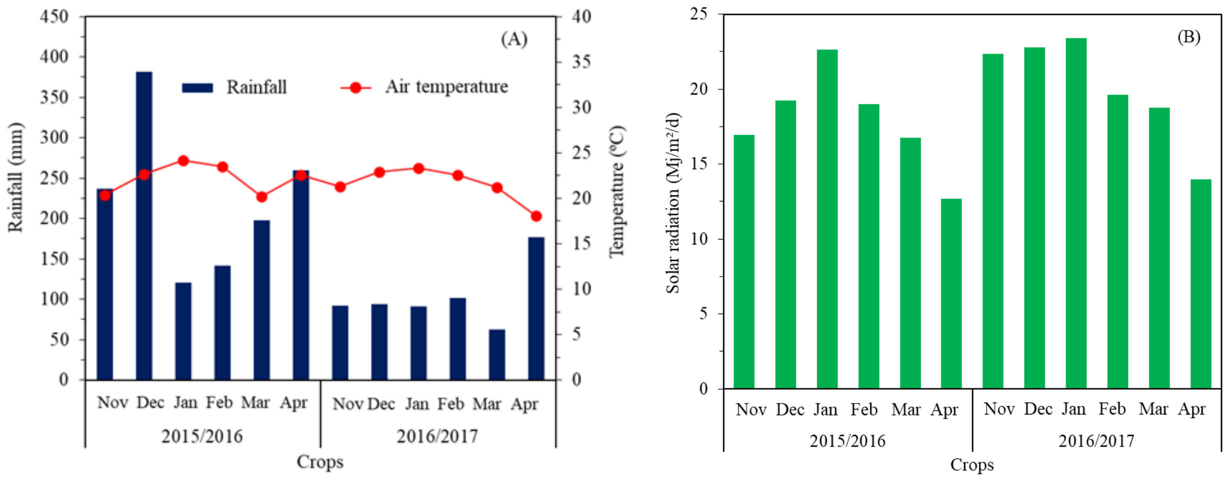

Figure 1. Rainfall, mean air temperature (A) and solar radiation (B) for the two conditions in the two seasons. Bom Progresso - RS.

Table 1. Chemical and physical properties of the soil in the area at the beginning of the experiment, 2015/16 season. Bom Progresso - RS.

Depth	pH[a]	V	SOM	Clay	Silt	Sand	Ca	Mg	Al	H+Al	P	K
- cm -	-- H_2O --	--- % ---					--- $mmol_c$ dm^{-3} ---				--- g kg^{-1} ---	
0 - 10	6.4	76.2	3.6	71.6	18.4	10.0	8.1	5.2	0.0	2.2	7.6	226.7
10 - 20	5.6	65.3	3.0	74.3	19.6	6.1	6.3	4.1	0.2	3.5	6.4	191.8

[a]pH: Hydrogen potential; V: Base saturation; MOS: Soil organic matter.

The planting of sweet potato cultivars was carried out in early November with seedlings of 3-4 leaves, in holes 15 cm deep, with a spacing of 75 cm between rows and 25 cm between plants in the planting row. In the condition without fertilization, the plants were managed without any fertilization. In the condition with fertilization, the cultivation was carried out according to the needs of the soil and established in the Manual de Adubação e Calagem para os Estados do RS e de SC (CQFRS/SC, 2016). The chicken manure used consisted of four batches of broilers, totaling 16,000 kg ha^{-1}, divided into two parts, half in planting and the other half in coverage after 45 days of planting. In the cultivation with fertilizer, spontaneous growth plants were controlled weekly with manual weeding or weeding and pest and disease control was carried out with fortnightly applications of neem oil.

Productivity and quality of sweet potato roots were determined 180 days after planting the seedlings, that is, at the physiological maturation stage of the roots. For this purpose, the manual harvest of the roots of six plants per experimental plot was carried out. These were washed under running water, weighed and evaluated for diameter, length and presence of cracks. Through the weight of roots and the presence of cracks,

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the productivity of roots and the number of cracked roots were determined. Still, the remaining roots of the experiment were harvested and the total number of roots in each plot was determined. The data obtained were subjected to analysis of variance (ANOVA), followed by Tukey's test ($p \leq 0.05$). The comparison between the cultivation conditions, without and with fertilization, was carried out with the T test ($p \leq 0.05$). Both analyzes were performed using Sisvar software (FERREIRA, 2011).

Results and Discussion

The statistical analysis of the data showed no difference between the experimental years for the analyzed variables. This shows that the sweet potato crop is little influenced by annual variations of climatic factors, showing due cultivation stability, according to Andrade Júnior *et al.* (2016), rusticity and easy adaptation. In the first experimental year, greater precipitation was observed, but less solar radiation, inversely to the second year (Figure 1), even so, not reflecting in performance difference in sweet potato cultivation (Table 2).

Table 2. Root yield of sweet potato cultivars under cultivation conditions with and without chicken manure fertilization. Bom Progresso - RS.

Cultivars	With fertilizer (Kg/ha)	Without fertilization (Kg/ha)
Amélia	48613 abc* ns	42383 cd
Rubissol	46198 bcd ns	41684 d
Cuia	53333 a ns	50857 ab
Crioula	3622 e ns	3156 e

*Equal lowercase letters in the columns, among the sweet potato cultivars, for each fertilization condition do not differ statistically by the Tukey 5% test. ns = Not significant in the lines, between the fertilization conditions, for each cultivar, test T 5%.

The cultivation of sweet potato with and without fertilization of chicken manure did not show any statistical difference, probably due to the average level of soil fertility (Table 1). However, Santos, Brito and Santos M. (2010), observed an increase in root production when the crop was fertilized with chicken manure. According to Ros, Narita and Hirata (2014), sweet potato responds to the addition of chicken manure as fertilizer mainly in low fertility soils. It can be seen that the three genetically improved, more productive, healthy and virus-free cultivars had much higher root productivity when compared to the Crioula cultivar. According to Montes, Paulo and Montes R. (2015), cultivars infected with viruses tend to limit root development and, consequently, restrict productivity, in addition to forming roots that will be classified as belonging to the group with the lowest commercial value.

Cultivar BRS Cuia had the highest root yield with 53,300 kg ha^{-1} in the cultivation with fertilization of chicken manure, followed by 50,800 kg ha^{-1} without fertilization, 4.69% lower, but with no statistical

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difference between the fertilization conditions. Cultivar BRS Amélia in the cultivation with fertilization produced 48,600 kg ha^{-1}, not differing statistically from the cultivar BRS Cuia in the two cultivation conditions, however, with a lower production when under conditions without fertilization with 42,400 kg ha^{-1}. Cultivar BRS Rubissol did not show difference in productivity compared to cultivar BRS Amélia, however, cultivar BRS Rubissol with the addition of chicken manure showed lower statistical results only compared to BRS Cuia. Silva *et al.* (2015), identified in a study carried out in Canoinhas - SC, with six cultivars and with the use of chemical fertilization, that BRS Rubissol was one of the cultivars with the highest root yield, and BRS Cuia and BRS Amélia with intermediate yields, which differs from this study, in which BRS Cuia presented the best results. Similar root productivity of cultivar BRS Cuia was found by Castro *et al.* (2011), which also under field experiment conditions, obtained an average productivity of 40 to 60 ton ha^{-1}. The present result indicates that the virus-free sweet potato cultivars (BRS Amélia, BRS Cuia and BRS Rubissol) have superior production stability, even when produced under natural conditions of climate, soil fertility and without pest, disease and weeds, with a small increase in productivity when chicken manure was added as fertilizer, but not statistically different.

As for cultivar Crioula, root production was much lower, with an average of 3,389 kg ha^{-1}. The low productivity of cultivar Crioula, 71.3% below average (SILVA *et al.*, 2015) in both growing conditions can be associated with the incidence of viruses, a common feature in creole cultivars that have not undergone clonal cleaning. Visual and proven observations with tissue analysis in the plants of this cultivar, from 30 days after planting, evidenced the presence of viruses, with, for example, withered leaves and mats on the plants. Castro and Couto (2011), relate the fact of the low productivity of sweet potato crops to the low quality of the seedlings used, as the culture is very susceptible to fungal and bacterial diseases and, especially, viruses. Martins *et al.* (2014), point out that although sweet potato has a great productive potential in Brazil, it is often common to find low yields, resulting mainly from the use of degenerate genetic materials, most of which are susceptible to pests and diseases. Therefore, it is possible to understand why cultivar Crioula had lower sweet potato root yield. Thus, the maximum productive potential of the cultivar Crioula, a cultivar with medium productivity, was not reached, and it may be associated with the low health of the seedlings and its great genetic variability. According to Montes, Paulo and Montes R. (2015) it is important to check the health of sweet potato seedlings, because when infected with viruses they present low production and lower commercial value. Martins *et al.* (2014), showed that sweet potato presents high genetic diversity among its clones, varying from the place of origin of the material and due to the occurrence of natural crossings of the materials, intensifying the disease problems.

Sweet potato crop is highly responsive to the supply of K, so the equivalent productivity between crops with and without fertilization may be linked to the high availability of K existing in the soil (Table 1). Cecílio Filho *et al.* (2016), observed that species that accumulate reserves in roots, such as sweet potato, K favors the formation and translocation of carbohydrates and improves root production. According to Thumé *et al.* (2013), the contents of N, P and K in the roots varied significantly depending on the doses of these nutrients, with K being the nutrient with the highest accumulation.

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Fertilization with chicken manure, on average, did not significantly increase the number (10.6/m^2), length (13.6 cm) and diameter of roots (21.9 cm), although a greater number of associated roots was not observed. to conditions without fertilization (Table 3). The non-addition of fertilizer resulted in the lowest mean number of cracked roots (51.4%), with the cultivar Amélia having the lowest amount and Crioula without cracked, in both growing conditions.

Table 3. Yield and qualitative evaluation of the roots of sweet potato cultivars in the two cultivation conditions, with and without chicken manure fertilization. Bom Progresso - RS.

Cultivars	With chicken manure				Without chicken manure			
	Roots (nº 6 m^2)	Cracks (nº)	Length (cm)	Diameter (cm)	Roots (nº 6 m^2)	Cracks (nº)	Length (cm)	Diameter (cm)
Amélia	20.9 A a*	4.3 B a	16.0 B a	25.5 B a	29.7 A a	2.3 B b	12.2 B a	21.7 B a
Rubissol	22.7 A a	5.7 A a	22.0 A a	21.0 B a	26.7 A a	3.0 A b	19.2 A a	26.4 B a
Cuia	26.4 A a	8.3 A a	13.1 B a	30.4 A a	29.8 A a	3.3 A b	10.2 B a	34.6 A a
Crioula	7.0 B a	0.0 C a	8.7 C a	7.2 C a	6.0 B a	0.0 B a	6.7 B a	8.2 C a

*Equal uppercase letters in the columns, among the sweet potato cultivars, for each variable do not differ statistically by the Tukey 5% test. Equal lowercase letters in the lines, between the fertilization conditions, for each cultivar, do not differ from each other by the T test 5%.

However, among the virus-free sweet potato cultivars, there was no statistical difference for the number of roots; Rubissol and Cuia had a greater number of cracks; Longest rubissol and gourd with the largest diameter. Cultivar Crioula produced the smallest number, size, length of roots and cracked roots, regardless of the cultivation condition. Montes, Paulo Montes R. (2015) report that cultivars without clonal cleaning of viruses have low productivity, related to the smaller number and weight of roots, limiting production and, consequently, the commercial value due to a greater amount of small and deformed roots. According to Santos (2015), the reduction in production and quality of sweet potato roots are related to environmental conditions of climate and soil. Azevedo *et al.* (2014) observed that the shape of the roots was more irregular with late harvest, probably due to greater exposure to environmental factors such as temperature and soil moisture. Santos (2015) observed that depending on the cultivar, in addition to the possibility of nematode attack, the longer time the roots remain in the field, especially with high availability of water in the soil, allows greater absorption, causing great internal pressure and cracking of the epidermis of the roots. Furthermore, the use of N can favor shoot growth at the expense of roots, in addition to favoring cracking because the epidermis does not follow the growth of the roots. Thus, the greater availability of N in the soil with application of chicken manure (64 kg/ha), in our study, can explain the production of smaller roots, and mainly, a greater number of cracks roots.

To choose the sweet potato cultivar for planting, in addition to productivity, it is necessary to observe the size and cracking of the roots, in order to meet the demands of the consumer market. According to Filgueira (2007), the most demanding markets prefer potatoes with a length of 13-15 cm, unit weight of 200 to 400g, smooth, free from damage or physiological anomalies. This statement is corroborated by Goto (2010) who reports that 70% of the decision to purchase fruit and vegetables is based on appearance. Thus, according to our results, virus-free sweet potato cultivars cultivated without poultry manure, in addition to maintaining productivity, the roots have a size with better acceptance in the consumer market due to the good average length ratio (12.07 cm) and diameter (22.72 cm), in addition to less cracked roots, when compared to cultivation with fertilization.

In this sense, cultivation of sweet potatoes, practiced mainly on small rural properties without fertilizer, can be an important food and income alternative in family farming. Santos, Brito and Santos M. (2010) also highlight that the use of chicken manure from family farms can reduce the cost of production, compared to crops with chemical mineral fertilizer, providing a healthy and cheap source, as the use of chicken manure reduces the use of mineral sources of nutrients, even with less contamination of the environment. Finally, we emphasize that the good root yield of sweet potato cultivars under natural conditions of climate and soil fertility or with fertilization of chicken manure are related to the use of healthy seedlings that have undergone phytosanitary quality control. Thus, it can be seen that the highest yields were found in sweet potato cultivars in which the seedlings underwent clonal cleaning processes, thus showing the importance of using healthy seedlings, and that there are several factors that can affect its productivity and quality, affecting its acceptance or not by the consumer market.

Thus, the virus-free sweet potato cultivars BRS Amélia, BRS Cuia and BRS Rubissol show higher root production, even when produced under conditions without fertilizing chicken manure, being highly recommended in relation to the cultivar Crioula. The Crioula cultivar sweet potato has low root productivity, even with chicken manure fertilization. The cultivation of virus-free sweet potato and without fertilization of chicken manure reduces, on average, 51.4% the occurrence of cracks roots.

Conflict of interest

The authors declare that the research was conducted in the absence of any potential conflicts of interest.

Ethical statements

The authors confirm that the ethical guidelines adopted by the journal were followed by this work, and all authors agree with the submission, content and transfer of the publication rights of the article to the journal. They also declare that the work has not been previously published nor is it being considered for publication in another journal.

The authors assume full responsibility for the originality of the article and may incur on them, any charges arising from claims, by third parties, in relation to the authorship of the article.

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