ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

CRESCIMENTO E FITOMASSA DE BATATA-DOCE IRRIGADA COM ÁGUA RESIDUÁRIA TRATADA

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1 RESUMO

A utilização de água residuária tratada na irrigação de culturas agrícolas é apontada como uma alternativa para atenuar o problema da escassez hídrica. Assim, objetivou-se com o presente trabalho avaliar o crescimento e fitomassa de batata-doce irrigada com água residuária tratada. A pesquisa foi desenvolvida em ambiente protegido pertencente à unidade acadêmica de engenharia agrícola da Universidade Federal de Campina Grande, em delineamento de blocos casualizados em arranjo fatorial 3x2, com cinco repetições. Os fatores de variação consistiram em três qualidades de água (T1 = água de cisterna; T2 = água tratada por *wetland* e T3 = água tratada por UASB+*wetland*), e duas cultivares de batata-doce (Campina e Granfina). Avaliou-se ao final do ciclo de cultivo o número de folhas (NF), número de ramas (NR), área foliar (AF), diâmetro do caule (DC), fitomassa fresca de folhas (FFF), fitomassa fresca de ramas (FFR), fitomassa seca de folhas (FSF), fitomassa seca de ramas (FSR). Os resultados obtidos demonstram que as variáveis (NF), (NR), (AF), (FFF), (FSF) e (FSR) foram influenciadas de forma significativa pelas cultivares. A água residuária tratada na irrigação de batata-doce pode ser utilizada sem que haja perdas das características de crescimento e fitomassa.

Palavras-Chave: *Ipomoea batatas* L., reúso, gotejamento, efluente.

OLIVEIRA, R. C.; SILVA, P. F.; MATOS, R. M.; DANTAS NETO, J.; SABOYA; L. M. F.; FARIAS, M. S. S.
GROWTH AND PHYTOMASS OF SWEET POTATO IRRIGATED WITH TREATED WASTEWATER

Recebido em 16/11/2020 e aprovado para publicação em 21/01/2021
DOI: http://dx.doi.org/10.15809/irriga.2021v1n1p97-109

2 ABSTRACT

The use of treated wastewater in the irrigation of agricultural crops is indicated as an alternative to mitigate the problem of water scarcity. Thus, this study aimed to evaluate the growth and phytomass of sweet potatoes irrigated with treated wastewater. The study was conducted in a greenhouse belonging to the academic unit of agricultural engineering at the Federal University of Campina Grande, in a randomized block design and 3x2 factorial scheme, with five replications. The factors consisted of three water qualities (T1 = water from a cistern; T2 = water treated by wetland and T3 = water treated by UASB + wetland), and two sweet potato cultivars (Campina and Granfina). At the end of the cultivation cycle, the number of leaves (NF), number of branches (NR), leaf area (AF), stem diameter (DC), fresh leaf phytomass (FFF), fresh branch phytomass (FFR), dry leaf phytomass (FSF) and dry branch phytomass (FSR) were evaluated. The results obtained show that the variables (NF), (NR), (AF), (FFF), (FSF) and (FSR) were significantly influenced by the cultivars. Wastewater treated for irrigation of sweet potatoes can be used without loss of growth and phytomass characteristics.

Keywords: *Ipomoea batatas* L., reuse, drip irrigation, effluent.

3 INTRODUCTION

Water is one of the main limiting factors for agricultural production in the semiarid region of Northeast Brazil. The increase in population growth, combined with water misuse, affects the availability and quality of this resource (CASTRO et al., 2016). Owing to the limited availability of quality water, the use of treated wastewater for irrigation is a viable option to ensure the sustainability of water resources and crops.

In this sense, the use of treated wastewater in irrigated agriculture has been a relevant practice since it helps control environmental pollution, in addition to providing water and nutrients for crops, enabling savings in water and fertilizers and increasing agricultural production (MENDES; BASTOS; SOUZA, 2016).

Several studies have demonstrated the positive effects of wastewater on the growth and phytomass of crops such as lettuce, eggplant, beetroot, Sabil seedlings, basil, papaya seedlings, and cherry tomatoes (ALBUQUERQUE JÚNIOR et al., 2016; MEDEIROS et al., 2017; FERREIRA NETO et al., 2017; REBOUÇAS et al., 2018; ALVES et al., 2019; BEZERRA et al., 2019; SOUSA et al., 2019).

The use of treated wastewater as a water source for sweet potato irrigation can contribute to mitigating the degenerative effects of water scarcity in the Brazilian semiarid region (AMARO et al., 2017), in addition to providing nutrients to plants and exerting positive effects on soil quality, promoting improvements in physical, chemical and biological properties (SILVA et al., 2012).

Sweet potato (*Ipomoea batatas* (L.) Lam.) This vegetable is one of the main vegetables cultivated in Brazil because of its rusticity, wide climatic adaptation and high capacity to produce energy per unit of area and time, making it an important crop from an economic and social point of view (AMARO et al., 2017; SOUZA et al., 2015).

In 2019, Brazil produced 805.4 tons of sweet potato on 57.3 hectares. Among the Brazilian producing regions, the Northeast Region currently stands out, producing 317.3 tons of sweet potatoes annually, with the South Region being the second largest producer of sweet potatoes in the country, with 252.9 tons produced (IBGE, 2020). However, among the Brazilian regions, the Northeast Region has the lowest productivity for sweet potatoes, with a productivity of 11.5 kg ha $^{-1}$, whereas the Central-West Region has the highest productivity, with a productivity of 20.7 kg ha $^{-1}$ (SILVA et al., 2015).

The Northeast Region has been seeking new varieties of sweet potato with the aim of increasing its productivity; among the most planted cultivars are Campina and Granfina (SUASSUNA et al., 2017). The authors also state that the Campina cultivar, which has purple skin, has an average of 415 leaves per plant; in contrast, the Granfina cultivar, known for having white skin, has an average of 349 leaves per plant. This is due to the growth characteristics of each cultivar, considering that Campina has greater emission of secondary branches than do Granfina, 34 and 20, respectively.

Given the above, the present study aimed to evaluate the growth and phytomass of sweet potato cultivars irrigated with treated wastewater under the climatic conditions of the semiarid Northeast Region, aiming to expand the knowledge of water reuse in the irrigation of tuberous vegetables.

4 MATERIALS AND METHODS

The research was carried out between August and December 2017 in a protected environment belonging to the Academic Unit of Agricultural Engineering of the Center for Technology and Natural Resources (CTRN) of the Federal University of Campina Grande (UFCG), which is located in the municipality of Campina Grande, state of Paraíba, Brazil (latitude 7° 12' 88” S, longitude 35° 54' 40” W and altitude 532 m). On the basis of the Köppen classification, the municipality of Campina Grande is characterized by the climate type "As", tropical with a dry summer, a rainy season between March and July, with an average annual temperature of 28.2°C, a relative humidity of approximately 70% and an average precipitation of approximately 800 mm (ALVARES et al., 2013).

The protected environment covered with fiberglass tiles was 15 m long, 10 m wide and 3 m high.

The soil used was classified as a neosol of the clay–sandy loam textural class, whose physical and chemical characteristics at depths of 0.0–0.2 m are described in Table 1, according to the methodology proposed by Embrapa (2013).

Table 1 Physical and chemical characteristics of the soil.

Soil fertility										
pH	**P**	**K**	**In the**	**H + Al**	**Al**	**Here**	**Mg**	**SB**	**CTC**	**MO**
	--mg dm $^{-3}$ --		-------------------cmol $_c$ dm $^{-3}$ ---------------------							g kg $^{-1}$
4.3	6.9	112.0	1.7	5.4	0.2	0.9	0.8	3.6	9.1	25.0

Source: Soil Physics Laboratory, UFPB. SB - Sum of exchangeable bases; CEC - cation exchange capacity; MO - organic matter: Walkley-Black Wet Digestion.

The chemical and fertility characteristics of the organic fertilizer (worm humus) used are shown in Table 2.

Table 2 Characteristics of organic fertilizer (worm humus).

pH	P	K	In the	Here	Mg	Al	H+Al	SB	CTC	V	m	MO
	--mg dm $^{-3}$ --		-------------- cmol $_c$ dm $^{-3}$ ---------------							-- % --		g kg $^{-1}$
7.7	1658.0	2356.0	4.4	14.3	9.3	0	0.0	34.1	34.1	100	0	234.1

Source: Soil Physics Laboratory, UFPB. SB - Sum of exchangeable bases; CEC - cation exchange capacity; V - base saturation; m - Al+3 saturation; MO - organic matter: Walkley-Black Wet Digestion.

The physical–chemical parameters of the three water qualities used in the research are shown in Table 3.

Table 3 Water quality parameters of cistern (T1), *wetland-treated wastewater (T2), and UASB+ wetland*-treated wastewater (T3)

Parameters	T1	T2	T3
Potential of Hydrogen (pH)	7.71	8.09	8.09
Electrical Conductivity (dS m $^{-1}$)	0.246	7.69	8.31
Calcium (meq L $^{-1}$)	0.92	3.59	2.86
Magnesium (meq L $^{-1}$)	0.4	4.07	4.34
Sodium (meq L $^{-1}$)	0.25	5	5.7
Potassium (meq L $^{-1}$)	0.07	0.36	0.43
Carbonates (meq L $^{-1}$)	0	1.12	5.28
Bicarbonates (meq L $^{-1}$)	1.57	2.42	2.15
Chlorides (meq L $^{-1}$)	0.72	8.25	6.85
Sulfates (meq L $^{-1}$)	Presence	Presence	Presence
Sodium Adsorption Ratio (RAS)	0.31	3.31	3.22
Water Class	C1S1	C4S1	C4S1

Source: Irrigation and Salinity Laboratory (LIS), UFCG. C1S1 (low salinity and low sodium content); C4S1 (very high salinity and low sodium content).

The experimental design was randomized blocks in a 3x2 factorial arrangement, with the first variation factor consisting of three irrigation water qualities (T1 = cistern water; T2 = *wetland-treated water*; and T3 = UASB+ *wetland-treated water*) and the second of two sweet potato cultivars (Granfina and Campina), with five replicates, totaling 30 experimental units. The treatments were arranged in 30 pots with a capacity of 11 L spaced 0.5 m between plants and 1.0 m between rows, corresponding to the experimental unit.

The pots were filled with approximately 16.7 L of soil and 3 kg of organic fertilizer (Table 2). Each pot had a hole at the bottom. A 1 cm layer of gravel No. 1 was added over the hole and covered with a geotextile blanket to facilitate drainage.

All the treatments were fertilized with nitrogen (N), phosphorus (P), and potassium (K) according to the results of the soil analysis and the recommendations of Novais, Neves, and Barros (1991). As a source of N, 0.65 g pot^{-1} urea was applied; for P, 5.48 g pot^{-1} simple superphosphate was applied; and for K, 0.4872 g pot^{-1} potassium chloride was mixed with the soil that composed the pots.

The water used for irrigation was rainwater stored in a cistern and reclaimed water treated by *wetland* and UASB systems. The rainwater was stored in a cistern located at the Federal University of Campina Grande, while the reclaimed water came from the *wetland* and UASB (*upflow anaerobic sludge blanket*) effluent treatment systems installed on the campus. These treatment systems receive wastewater from the Bodocongó stream, which runs through the UFCG main campus and receives domestic sewage effluent from the Monte Santo and Bodocongó neighborhoods. The *wetland system* was installed with distribution and discharge devices.

The sweet potato cultivars used were obtained from small-scale vegetable growers in the upper Sertão region of Paraíba. They are named Campina and Granfina, with pink and white external colors, respectively. These cultivars are widely cultivated in the state of Paraíba. These plants are vigorous, low-growth plants with deep green leaves and uniform roots. Harvest begins 90 to 130 days after planting. One vine with 10 buds per pot was planted.

A drip irrigation system with self-compensating emitters with a nominal flow rate of 2.3 $L\ h^{-1}$ coupled to 16 mm polyethylene irrigation lines was used. These were pressurized by three individual 0.5 HP centrifugal motor pumps, one for each treatment, which were manually operated at different start and end times for each application. To prevent the entry of suspended particles into the system, a 1" screen filter with a flow capacity of 5 $m^3\ h^{-1}$ and a 120-mesh mesh was used. Valves and water meters were installed at the beginning of each lateral line to control and totalize the water volume applied per irrigation line.

Each pot was considered a drainage lysimeter, thus facilitating daily irrigation management and enabling the determination of crop evapotranspiration (Etc) through the average water balance of water input and output throughout the crop cycle. Etc was calculated according to Equation 1, described by Reichardt (1990).

$$ET_c = I - D \quad (1)$$

where Etc = crop evapotranspiration in mm day^{-1};
I = irrigation depth in mm day^{-1};
D = drainage depth in mm day^{-1}.

The effects of the treatments on the following variables were evaluated 110 days after planting (DAT): number of leaves (NF), number of branches (NR), leaf area (AF), stem diameter (DC), fresh leaf mass (FFF), fresh branch mass (FFR), dry leaf mass (FSF), and dry branch mass (FSR). The number of leaves and branches was determined via direct counting on each plant, whereas the leaf area was obtained via Equation 2.

$$AF = C * L * f \quad (2)$$

where AF = Leaf area, in cm^2;
C = Length of the leaf, in cm;
L = width of the sheet, in cm; and
f = Correction factor for sweet potato (0.57), dimensionless. Determined by analyzing the correlation between C and L.

The stem diameter was measured via a digital caliper. The fresh mass of leaves and branches was obtained by weighing them immediately after harvest on a 0.01 g precision scale. For dry mass analysis, the leaves and branches were placed in properly labeled paper bags and then placed in a forced-air oven at 65 °C, where they were dried until they reached a constant weight. After drying, the samples were weighed on an analytical balance with a precision of 0.01 g.

The variables were statistically analyzed via the F test, with the analysis performed whenever the interaction was significant. The qualitative factors related to the two cultivars and water qualities were statistically analyzed via the Tukey test for comparison of means via Sisvar software (FERREIRA, 2011).

5 RESULTS AND DISCUSSION

A summary of the analysis of variance results for the variables number of leaves (NF), number of branches (NR), leaf area (AF) and stem diameter (DC) as a function of water quality and cultivar at 110 DAT is presented in Table 4.

Table 4 Analysis of variance for the number of leaves (NF), number of branches (NR), leaf area (AF), and stem diameter (DC) of the sweet potato crop as a function of cultivar and water quality at 110 days after planting.

Source of Variation	**GL**	**Mean square**			
		NF	**NR**	**AF (cm²)**	**DC (mm)**
Cultivars (C)	1	172672.53**	367.50**	204227563.45**	0.21 ns
Types of Water (A)	2	9038.03 ns	54.93 ns	13926599.31**	22.81 ns
Interaction (C)*(A)	2	18935.63 ns	30.40 ns	1192928.66 ns	5.16 ns
Block	4	24404.53	41.88	1068092.03	21.6
Residue	20	12924.67	18.78	971833.66	18:31
CV%	-	17.39	19.21	15.96	32.12
Overall Average	-	376.47	22.57	6178.61	13.32

GL: degree of freedom; CV (%): coefficient of variation; ns - not significant at $p < 0.05$ according to the F test; ** and * - significant at $p < 0.01$ and $p < 0.05$, respectively, according to the F test.

The analysis of variance for the cultivar factor (C) revealed a significant difference ($p < 0.01$) in the number of leaves (NF), number of branches (NR) and leaf area (AF), whereas for the stem diameter (DC) variable, no significant difference was detected.

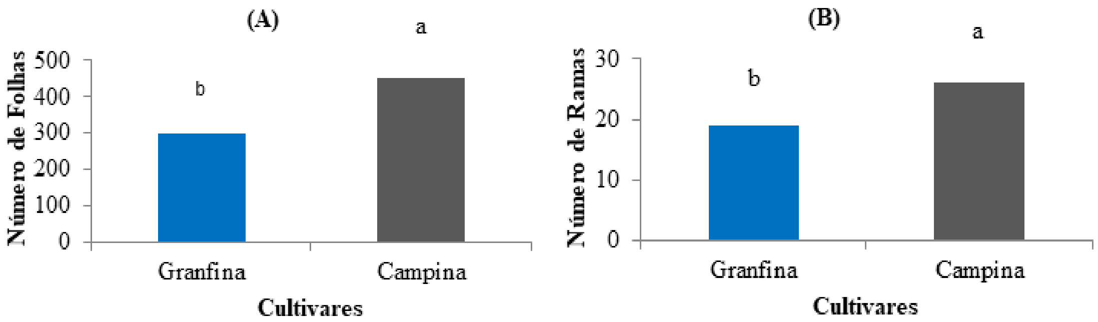
For the source of variation in water type (A), there was a significant difference ($p < 0.01$) only for the leaf area (AF). In terms of the number of leaves (NF), number of branches (NR) and stem diameter (DC), there was no significant effect ($p < 0.01$; $p < 0.05$) according to the F test.

With respect to the interaction between the factors cultivar (C) and water type (A), no significant effect ($p < 0.01$; $p < 0.05$) was detected via the F test for any of the variables analyzed (Table 4).

Dantas et al. (2014), who studied the effects of domestic effluent reuse on radish crops, did not observe significant effects of irrigation water quality on growth and phytomass variables. These results are consistent with those observed in the present study; this fact may be associated with the nutritional characteristics present in the water, as shown in Table 3.

Notably, the highest average number of leaves was obtained for cultivar Campina, which presented 452.33 leaves per plant, which was 50.48% greater than that of cultivar Granfina, which presented 300.6 leaves per plant (Figure 1A). These values were greater than those obtained by Queiroga et al. (2007), who analyzed the sweet potato cultivars 'ESAM 1', 'ESAM 2' and 'ESAM 3' and reported average values for the number of leaves ranging from 77.67--108.53 leaves per plant.

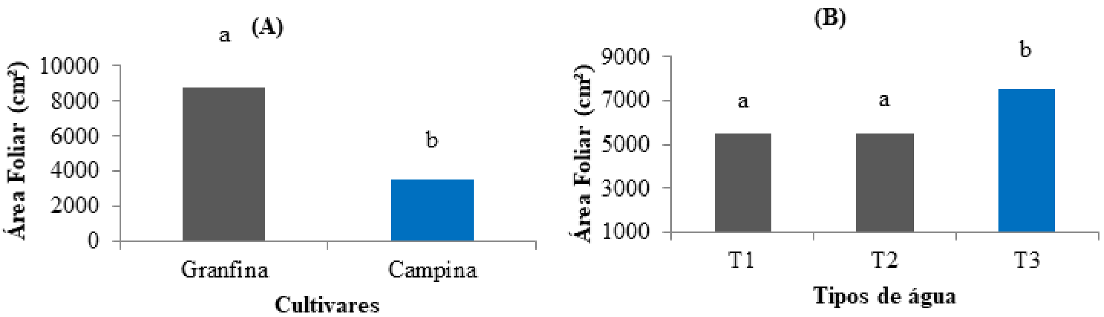
Figure 1 Number of leaves (A) and branches (B) according to the sweet potato cultivar at 110 days after planting.



The Campina cultivar also stood out in terms of the number of branches, with 26.07 branches per plant, whereas the Granfina cultivar presented 19.07 branches per plant (Figure 1B). This result corroborates those obtained by Suassuna et al. (2017), who, when studying the Campina and Granfina cultivars, reported that the Campina cultivar has a greater number of branches than the Granfina cultivar does.

The leaf area (LA) was significantly influenced ($p < 0.01$) by the individual factors cultivar (C) and water type (A) (Figure 2A and B).

Figure 2 Averages for leaf area according to cultivar (A) and water type (B) of sweet potato cultivated 110 days after planting.



The average leaf area values obtained for the sweet potato cultivars Granfina and Campina were 8787.75 cm² and 3569.48 cm², respectively (Figure 2A). This difference of approximately 40% may be related to the fact that the Granfina cultivar has wider leaves, despite having a smaller number of leaves and branches, which possibly influenced the leaf area values of the Granfina cultivar to be greater than those of the Campina cultivar.

The results obtained in this study for the leaf area of the sweet potato cultivars Granfina and Campina are superior to those reported by Queiroga et al. (2007), who evaluated the cultivars ESAM 1 and ESAM 2 and reported leaf area values of 3223.90 and 2667.83 cm², respectively. This fact may be related to the number of leaves per plant, which in the present study was much greater than that reported by Queiroga et al. (2007). According to Taiz and Zaiger (2017), leaves are primarily responsible for capturing solar energy and producing organic material through photosynthesis. Therefore, the larger the leaf area of a plant is, the more photoassimilates will be converted to the roots.

The leaf area according to the type of treated wastewater differed statistically by the Tukey test at the 5% probability level, and in the water treated with the UASB+ *wetland* (T3), the average leaf area was 7541.26 cm², which differed from those of the other types of water, which were 5504.26 and 5490.31 cm² for the treatments with *wetland* (T2) and saltwater (T1), respectively (Figure 2B).

Sousa Neto et al. (2012) and Alves et al. (2009), analyzing the viability of using wastewater in cotton cultivation, reported that plants irrigated with wastewater from urban sewage had a larger leaf area than those irrigated with supply water, a result similar to that found in this study for sweet potato crops (Figure 2B).

According to Oliveira et al. (2010), leaf area is a determining factor in production, since its reduction implies less absorption of radiant energy and consequently less intense photosynthesis, thus reducing biomass production. Therefore, the increased area provides greater production of photoassimilates and consequently more translocation to the roots.

From the analysis of variance, a significant effect of cultivar (C) ($p < 0.01$) was observed for fresh leaf phytomass (FFF), dry leaf phytomass (FSF) and dry branch phytomass (FSR). No significant difference was detected ($p < 0.01$; $p < 0.05$) for the variable fresh branch phytomass (FFR) (Table 5).

Table 5 Summary of analysis of variance for fresh leaf mass (FFF), fresh branch mass (FFR), dry leaf mass (FSF) and dry branch mass (FSR) of sweet potato cultivation according to cultivar and water quality at 110 days after planting.

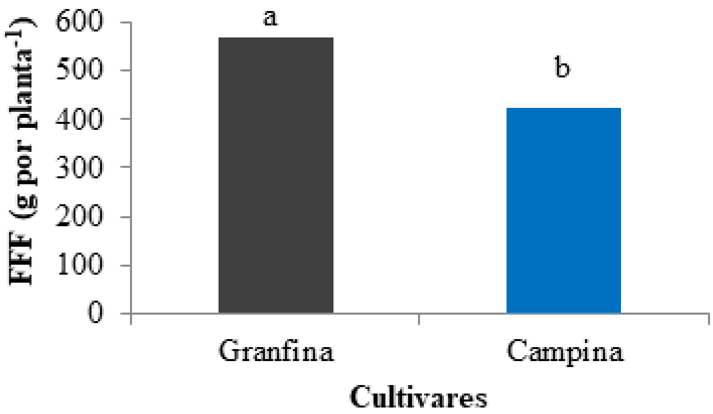
Source of Variation	**GL**	**Mean square**			
		FFF (g plant $^{-1}$)	**FFR (g plant $^{-1}$)**	**FSF (g plant $^{-1}$)**	**FSR (g plant $^{-1}$)**
Cultivars (C)	1	158122.80**	5768.53 ^{ns}	1230.08**	2322.14**
Types of Water (A)	2	14767.43ns	13385.83 ^{ns}	109.56 ^{ns}	58.37 ^{ns}
Interaction (C)*(A)	2	10206.70ns	2426.03 ^{ns}	237.98 ^{ns}	43.52 ^{ns}
Block	4	19872.22	11946.33	209.92	92.85
Residue	20	24607.99	7027.05	100.56	218.03
CV%	-	31.56	23.05	18.52	26.59
Overall Average	-	497.07	363.67	54.15	55,54

GL: degree of freedom; CV (%): coefficient of variation; ns - not significant at $p < 0.05$ according to the F test; ** and * - significant at $p < 0.01$ and $p < 0.05$, respectively, according to the F test.

For the source of variation in water type (A) and the interaction between the cultivar (C) and water type (A) factors, there was no significant effect ($p < 0.01$; $p < 0.05$) on any of the phytomass variables analyzed (Table 5).

The variable fresh leaf phytomass (FFF) was significantly influenced ($p < 0.05$) by the cultivar factor (C). An analysis of the average fresh leaf phytomass (FFF) according to cultivar (Figure 3) revealed that the highest value was obtained for the Granfina cultivar, which presented an average value of 569.67 g plant $^{-1}$, whereas the Campina cultivar presented an average value of 424.47 g plant $^{-1}$.

Figure 3 Averages for fresh leaf phytomass (FFF) according to sweet potato cultivar at 110 days after planting.

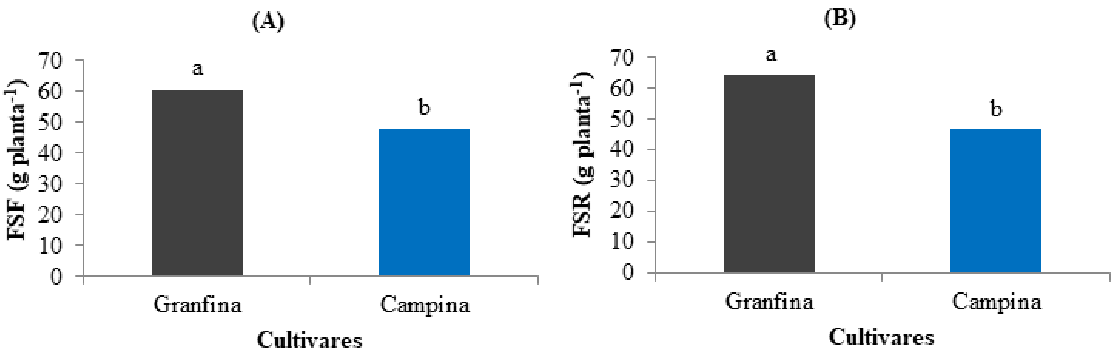


The Granfina cultivar presented greater fresh leaf phytomass due to its larger leaf area. According to Erpen et al. (2013), the leaf area of sweet potato is considered a determining variable of production, since a smaller leaf area implies less energy absorption and consequently lower intensity photosynthesis, causing a reduction in the production of fresh leaf phytomass.

Rosado (2016), when studying, under field conditions, the growth and production of sweet potato as a function of nitrogen dose, spacing and number of branches per hole, obtained, 100 days after the Campina cultivar was planted, an average value of fresh leaf phytomass (FFF) of 973.6 g for one branch per hole. However, when two branches were used per hole, the value of fresh leaf phytomass was equal to 211.8 g. These results differ from those obtained in this study, which may be related to the crop management conditions.

The leaf dry matter (FSF) and branch dry matter (FSR) variables were significantly influenced ($p < 0.05$) by the cultivar factor (C) (Figure 4).

Figure 4 Averages for leaf dry matter (A) and branch dry matter (B) according to sweet potato cultivar at 110 days after planting.



The highest averages for leaf dry matter and branch dry matter were obtained for the Granfina cultivar, which presented averages of 60.55 g plant-1 and 64.34 g plant-1, respectively. The Campina cultivar presented averages of 47.75 g plant-1 and 46.74 g plant-1 for leaf dry matter and branch dry matter, respectively. The influence of the cultivar factor was also verified by Conceição, Lopes, and Fortes (2004), who reported that the production of leaf and branch dry matter differed between the Abóbora and Da Costa cultivars.

Notably, the Granfina cultivar was more efficient in terms of phytomass production, which was probably due to the greater production of photoassimilates as a result of its larger leaf area than that of the Campina cultivar.

This behavior was also verified by Gomes (2010), who, when analyzing the production of two sweet potato cultivars with wide commercial acceptance in the state of Paraíba under different planting densities and amounts of phosphorus, reported that the Granfina cultivar presented greater production of fresh and dry phytomass than did the Ciciliana cultivar.

The accumulation of dry matter in plants reflects the rate of net photosynthesis observed throughout the crop cycle, which is influenced by the cellular concentrations of nutrients such as nitrogen, phosphorus, potassium, magnesium and sulfur, which actively participate in the metabolic processes of generating photoassimilates (SILVA et al., 2016).

6 CONCLUSION

Treated wastewater can be used to irrigate sweet potatoes without loss of growth or phytomass characteristics.

7 ACKNOWLEDGMENTS

To the National Council for Scientific and Technological Development (CNPq) for granting scholarships and to the Federal University of Campina Grande (UFCG) for the support and opportunity to develop the research.

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