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Development of elephant grass in response to irrigation with different levels of domestic sewage[1]

Desenvolvimento do capim elefante em resposta a irrigação com diferentes proporções de esgoto doméstico

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ABSTRACT - The agricultural use of alternative water sources of inferior quality, such as reusing the water from domestic sewage, is seen as one way of increasing water availability, in addition to allowing the reuse of nutrients and organic matter, thereby helping to maintain the fertility and productivity of the soil. The aim of this study, therefore, was to evaluate growth, productivity and nutrition in elephant grass irrigated with different combinations of treated domestic effluent and well water. The experimental design was of randomised blocks, with six treatments and four replications, containing 10 plants in each plot. The treatments comprised five combinations of treated domestic effluent (TDE) and well water (WW): T1 (100% WW), T2 (25% TDE + 75% WW), T3 (50% TDE + 50% WW), T4 (75% TDE + 25% WW), T5 (100% TDE), and an additional treatment (T6) of 100% well water + a mineral fertiliser (NPK) recommended for elephant grass. The following variables were analysed: number of leaves, stem diameter, number of tillers, plant height, leaf area, fresh and dry weight of the leaves and stems, fresh and dry weight production, and the macronutrient content of the aerial part of the plant. The treatments applying the greatest levels of TDE had the closest mean values to those obtained under the conventional treatment, while the treatments applying 50% or more TDE were statistically equal by Tukey's test ($p < 0.05$) to the conventional treatment.

Key words: Water reuse. *Pennisetum purpureum*. Irrigation management. Semi-arid.

RESUMO - A utilização agrícola de fontes alternativas de água de qualidade inferior, tais como o reuso de águas de esgotos de origem doméstica, surge como opção para ampliar a disponibilidade hídrica, além de proporcionar o reaproveitamento de nutrientes e matéria orgânica, auxiliando na manutenção da fertilidade e produtividade do solo. Nesse contexto objetivou-se com este trabalho avaliar o crescimento, a produtividade e a nutrição do capim elefante irrigado com diferentes combinações de aplicação do esgoto doméstico tratado e água de poço. O delineamento experimental utilizado foi em blocos ao acaso, com seis tratamentos e quatro repetições, contendo 10 plantas em cada parcela. Os tratamentos consistiram em cinco combinações de aplicação do efluente doméstico tratado (EDT) e água de poço (AP): T1 (100% AP), T2 (25% EDT + 75% AP), T3 (50% EDT + 50% AP), T4 (75% EDT + 25% AP), T5 (100% EDT) e um tratamento adicional (T6) irrigado 100% com água de poço + adubação mineral (N-P-K) recomendada para o capim elefante. As variáveis analisadas foram: número de folhas, diâmetro do colmo, número de perfilhos, altura da planta, área foliar, massa fresca e seca da folha e do colmo, produtividades de massa fresca e seca, e o teor de macronutrientes na parte aérea da planta. Os tratamentos com maiores quantidades de EDT aplicado na irrigação foram os que mais se aproximaram das obtidas no tratamento cultivado convencionalmente, sendo os tratamentos com 50% ou mais de EDT estatisticamente iguais ao tratamento com cultivo convencional pelo teste de Tukey ($p < 0,05$).

Palavras-chave: Reuso de água. Pennisetum purpureum. Manejo da irrigação. Semiárido.

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INTRODUCTION

Brazil stands out in relation to water resources as it contains around 12% of the available freshwater on the planet. However, the natural distribution of this resource results in an imbalance between the different regions of the country, with the north holding approximately 68.5% of the total available water and only 8% of the population, whereas the southeast holds 6.0% of the country's water resources and 42.1% of the population, while the northeast concentrates 27.8% of the population and only 3.3% of the water (TRATA BRASIL, 2018).

It's important to note that the semi-arid region of the northeast is characterised by high rates of insolation, high temperatures and low thermal amplitudes. Total rainfall is low, with high temporal and spatial variability. Such factors contribute to high rates of evapotranspiration and a high water deficit (ZANELLA, 2014), including aspects that, due to a lack of moisture in the soil and pasture, favour adverse conditions for rainfed agriculture and animal husbandry at certain times of the year, (VALE; AZEVEDO, 2013).

In agriculture, replacing high-quality water with treated wastewater enables the farmer to economise on the high-quality water, increasing the availability of this resource for more-important purposes, such as human consumption (CUNHA *et al*., 2011), in addition to enabling agricultural production to develop in regions where there are problems of water scarcity during periods of drought.

Bressan *et al*. (2012) defines the liquid part of domestic sewage as a means of transporting the numerous organic and inorganic substances and microorganisms that are eliminated every day by humans, making the use of domestic sewage even more advantageous, as it is also a way of reusing nutrients (N, P, K, Ca, Mg) and organic matter, and of helping to maintain the fertility and productivity of the soil.

However, the application of effluent to irrigation must be planned and calculated based on the assimilative capacity of the soil-plant system, so as to control element reference levels in the soil and the plants (PINTO *et al*., 2013).

Several studies have been carried out to evaluate the performance of crops irrigated with effluent (NASCIMENTO; FIDELES FILHO, 2015; SARAIVA; KONIG, 2013; VALE; AZEVEDO, 2013). In each study, there was an increase in crop productivity when the lower-quality water was used, again demonstrating the viability of using treated domestic effluent for irrigation.

Elephant grass arrived in Brazil around 1920, and quickly spread due to its high nutritional value and production potential (FONTANELI *et al*., 2012). The forage has several advantages for biomass production compared to other forages grown in Brazil (MAZZARELLA; SEGUCHI; FERREIRA, 2015).

Leal *et al*. (2020) state that increasing the cutting age reduces nutritional quality in elephant grass cultivars, while irrigating during the dry season maintains the productivity of the forage and affords an increase in nutritional quality.

It is important to emphasise that even with all the above benefits, the use of wastewater requires proper management practices, as the inappropriate use of such water can cause problems for the health of consumers, for farmers, and for the soil. Therefore, the aim of this study was to evaluate the growth and productivity of elephant grass irrigated with different combinations of treated domestic effluent.

MATERIAL AND METHODS

The experiment was carried out in the experimental area of the weather station of the Federal University of Ceará, Pici Campus, in Fortaleza, Ceará (3º44' S, 38º33' W, altitude 19 m), from September to December 2018. According to the Köppen classification (1918), the region has a type Aw' climate, characterised as tropical rainy, very hot, with rainfall predominantly during the summer and autumn.

Data from the weather station at the Federal University of Ceará, show that the region has an average annual rainfall of 1,593 mm, average annual relative humidity of 77%, average wind speed of 3.7 m s^{-1}, average annual evapotranspiration of 1,791 mm, and annual minimum, average and maximum temperature of 23.6 °C, 26.9 °C and 30.5 °C, respectively.

The soil in the experimental area is classified as a Red-Yellow Argisol of a loamy-sand texture (EMBRWWA, 2006), with the following chemical characteristics in the 0-20 cm layer: PO_4^{3-} (20 mg dm^{-3}), K^+ (0.20 $cmol_c$ dm^{-3}), $Ca2^+$ (2.38 $cmol_c$ dm^{-3}), Mg^{2+} (0.91 $cmol_c$ dm^{-3}), Na^+ (0.05 cmolc dm^{-3}), Al^{3+} (ND), Cu^{2+} (0.5 mg dm^{-3}), Zn^{2+} (8.2 mg dm^{-3}), Mn^{2+} (4.6 mg dm^{-3}), Fe^{2+} (30 mg dm^{-3}), Bo (0.76 mg dm^{-3}), pH (5.7) and EC (0.30 dS m^{-1}).

The water used for irrigating the grass was pumped from a 40-m deep tubular well and transferred to a polyethylene water tank placed near the experiment. The results of the chemical analysis of the irrigation water showed the following values: $Ca2^+$ (1.00 $mmol_c$ L^{-1}), Mg^{2+} (1.70 $mmol_c$ L^{-1}), Na^+ (4.30 $mmol_c$ L^{-1}), K^+ (0.20 $mmol_c$ L^{-1}), Cl^- (3.80 $mmol_c$ L^{-1}), HCO_3^- (3.60 $mmol_c$ L^{-1}), pH (7.9), SAR (3.81) and EC (0.73 dS m^{-1}), with a C2S1 classification.

The experimental design was of randomised blocks, with six treatments and four replications, containing 10 plants in each plot (Figure 1). The treatments (T) consisted of five combinations of treated domestic effluent (TDE) and well water (WW): (T1 - (100% WW), T2 - (25% TDE + 75% WW), T3 - (50 % TDE + 50% WW), T4 – (75% TDE + 25% WW), T5 – (100% TDE), and a control treatment (T6) of 100% WW + recommended mineral fertiliser.

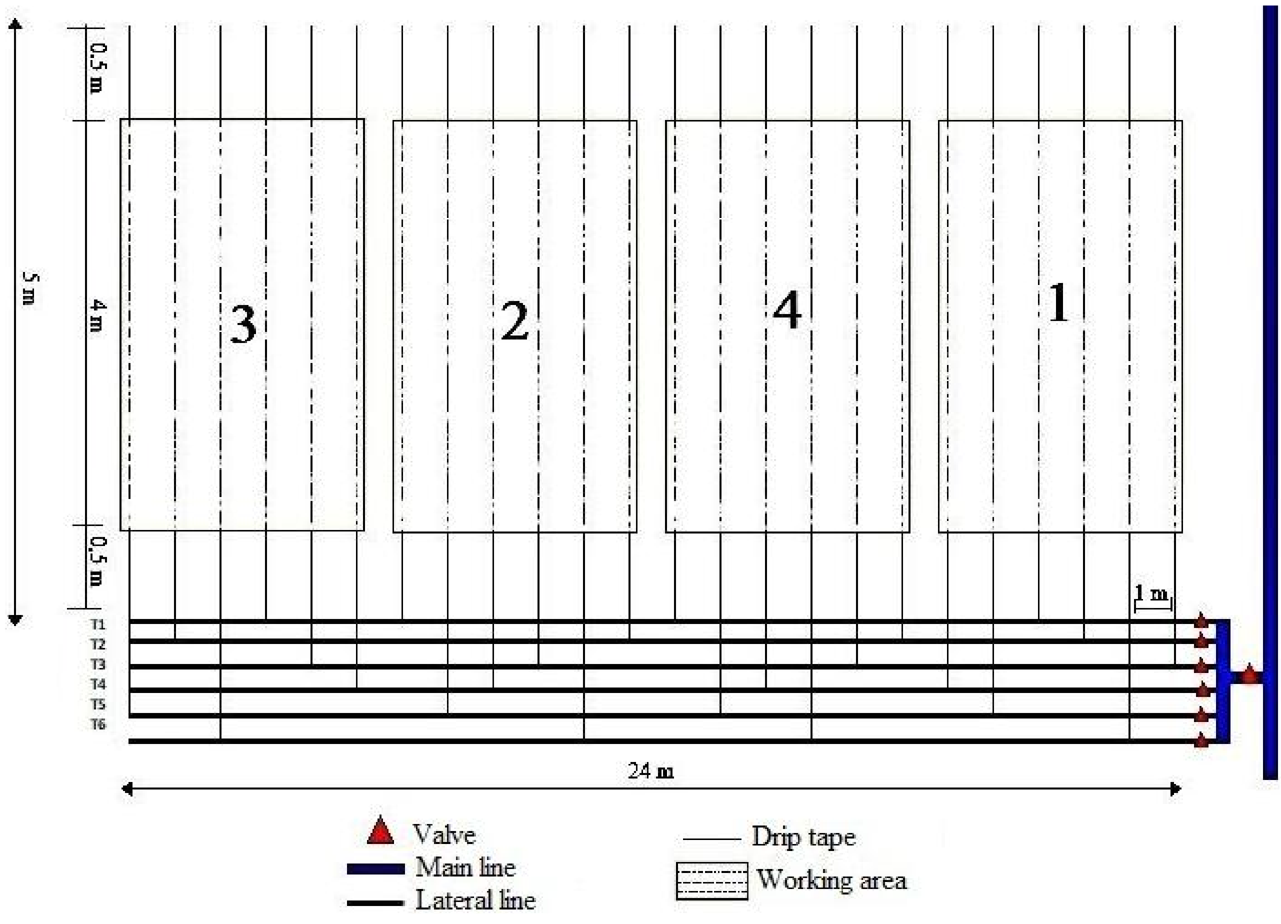
The reused water used in the treatments came from the sewage treatment plant of the Federal University of Ceará, Pici Campus, and was transported by water truck to the experimental site, where it was stored in a system of 2,000 and 5,000-L water tanks. The reused sewage water was analysed in the Soil and Water laboratory of the Federal University of Ceará, and presented the following values: Ca^{2+} (2.50 $mmol_c$ L^{-1}), Mg^{2+} (1.50 $mmol_c$ L^{-1}), Na^+ (4.70 $mmol_e$ L^{-1}), K^+ (0.60 $mmol_c$ L^{-1}), Cl^- (5.40 $mmol_c$ L^{-1}), HCO_{3-} (3.80 $mmol_c$ L^{-1}), pH (7.4), SAR (2.36) and EC (0.86 dS m^{-1}).

The crop used in the experiment was elephant grass, whose main agronomic characteristics are plants with erect stems, which are arranged or not in clumps, and filled with a succulent and caespitose parenchyma. The grass is high, reaching from 3 to 5 metres, with wide, long (0.30 to 1.20 m) invaginated leaves of a dark or light green colour, and the abundant production of aerial and basal tillers.

The area was prepared by ploughing and cross harrowing. The holes were then dug using a hoe to a depth of 0.30 m, and spaced 0.5 m apart.

Planting was carried out using stems obtained from the Sector for Animal Science of the Federal University of Ceará, Pici Campus. Two stems were inserted per hole, each with 3 to 5 buds, at a spacing of 0.5 m between holes and 1.0 m between rows, to obtain a stand of 20,000 plants ha^{-1}. Before planting, the area was irrigated to increase the soil moisture to field capacity, with the aim of promoting adequate sprouting and ensure that the irrigation depths applied in each treatment would actually replace the water lost to evapotranspiration.

Figure 1 - Experimental layout detailing the treatments and blocks, Fortaleza, Ceará, 2021



Source: The author

The crop was irrigated by surface drip, using drip tapes (Ø = 16 mm) with self-compensating emitters spaced 0.3 m apart, with an individual flow rate of 1.6 L h^{-1}. The drip tapes were placed along the plant rows and spaced 1.0 m apart.

The treated domestic effluent and the well water were alternately pumped using a single centrifugal pump coupled to a 1/3 hp motor, to meet the requirements of the treatments under test. With the aim of better controlling the operating pressure of the irrigation system, and in order to avoid clogging the emitters, a control head comprising a filter and two pressure gauges was installed, located immediately after the motor pump set.

Irrigation management was based on replacing the crop evapotranspiration (ETc), estimated from the ETo. The ETo was estimated by the Penman-Monteith method (ALLEN *et al*., 1998) using climate data from the weather station on the Pici Campus, installed around 100 m from the experimental area.

After estimating the irrigation time (Ti), the irrigation depth was calculated for each treatment, which differed for TDE and WW based on the irrigation time.

In order to control the applied irrigation depth and the water source used for each treatment, ball valves were installed at the exits of the tanks and at the start of each lateral line; these were closed once the time required to replace the water depth for the treatment had been reached.

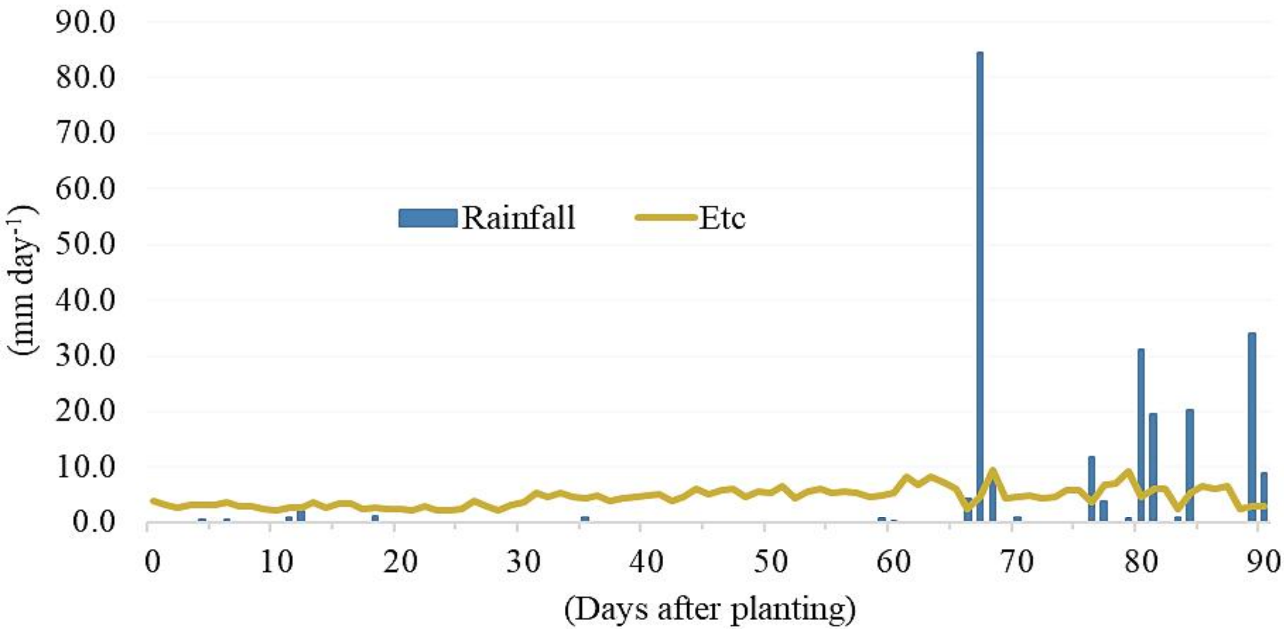
Initially, the valve to the tank containing well water was opened, starting irrigation for the treatments that required well water, and respecting the specific time of each treatment. The valve to the tank containing sewage water was then connected, using application times based on the water depth required for each treatment.

The cropping treatments basically consisted of the manual weeding of invasive plants and the application of ant killer whenever necessary. Chemical fertilisation using the principal macronutrients (N, P and K) was also carried out manually in the control plots, based on the requirements shown by the soil analysis and on the absorption rate of the crop, with P (40 kg ha^{-1} P_2O_5) incorporated into the soil before planting, while K (40 Kg ha^{-1} K_2O) and N (50 Kg ha^{-1} N) were added in furrows to the side of the rows after plant emergence. The selected fertilisers were urea, phosphoric acid and potassium chloride, using amounts recommended by Vilela *et al*. (2002).

For the purposes of irrigation management, the rainfall and crop evapotranspiration as estimated by the Penman-Monteith method were monitored daily from September to December 2018.

Figure 2 shows the daily behaviour of the rainfall and crop evapotranspiration as estimated by the Penman-Monteith method, monitored throughout the experiment from September to December 2018. There was a considerable increase in rainfall volume from 1 December (67 th day of cultivation), where 84.4 mm was seen in 24 hours, giving an accumulated total of 224.7 mm by the day of collection (90 th day of cultivation). It is important to point out that the historical average rainfall in the area for December is 37.3 mm and that, therefore, the month was atypical. The accumulated evapotranspiration remained close to the historical monthly average throughout the period.

Figure 2 - Behaviour of crop evapotranspiration and daily rainfall during the experiment



The plant variables under analysis were the number of leaves (NL), number of tillers (NT), leaf area (LA), stem diameter (SD), plant height (PH), leaf fresh weight (LFW), stem fresh weight (SFW), leaf dry weight (LDW), stem dry weight (SDW), fresh weight production (FWPROD), dry weight production (DWPROD), and macronutrient content in the aerial part of the plant.

The data of the response variables were submitted to analysis of variance by F-test at a significance level of 5% and 1%. When significant, the mean data were compared using Tukey's test to verify the existence of significant differences between treatments, or submitted to regression analysis to find the equation that best represented the relationship between the variables under analysis and the study factor.

The Microsoft Office Excel (2019) and ASSISTAT v7.7 software (SILVA; AZEVEDO, 2016) were used to carry out the statistical analysis.

RESULTS AND DISCUSSION

For the growth variables under study, there was a significant difference at 1% for SD and LA, and at 5% for PH; while NL and NT showed no significant difference at 90 DAP for the different levels of sewage (Table 1).

Among the variables that showed a statistical difference, the treatments that used 75% and 100% TDE to irrigate the elephant grass stand out. For SD and LA, irrigating exclusively with sewage afforded an increase of 36% and 135%, respectively, compared to plants irrigated with well water only and with no mineral fertiliser (Table 2). The mean diameters found in this study (12.87 to 17.50 mm) encompass the measurements presented by Santos et al. (2014), who studied three genotypes of elephant grass under nitrogen fertiliser, and found a mean value of 15.33 mm per stem.

Larger measurements were found for PH when using 75% TDE and 25% well water, achieving a mean height of 135.75 cm. Greater values for height were found by Saraiva and Konig (2013), who, cultivating purple elephant grass irrigated daily with treated domestic effluent in the semi-arid region of Potiguar, obtained values between 1.5 and 2.0 m at 90 DAP.

It can also be seen that each treatment that used 50% or more TDE for irrigation did not differ statistically by Tukey's method ($p > 0.05$) from the conventional treatment (well water + mineral fertiliser).

Table 1 - Summary of the analysis of variance for number of leaves (NL), stem diameter (SD), number of tillers (NT), plant height (PH) and leaf area (LA) in elephant grass as a function of the treatments under test, Fortaleza, Ceará, 2020

SV	DF	Mean Square				
		NL	SD	NT	PH	LA
Treatment	5	185.47 (ns)	14.15**	3.57 (ns)	1,096.27*	109,667,424.24**
Block	3	1,755.22**	14.88**	2.94 (ns)	4,592.11**	459,761,463.15**
Residual	15	175.49	1.19	1.54	286.91	11,899,726.22
Total	23	-	-	-	-	-
CV (%)	-	22.58	6.91	28.14	14.08	20.34

** significant at 1% by F-test; * significant at 5% by F-test; (ns) not significant by F-test. SV - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation

Table 2 - Mean values for stem diameter (SD), plant height (PH) and leaf area (LA) in elephant grass as a function of the treatments under test, Fortaleza, Ceará, 2020

Treatment	Variable		
	SD	PH	LA
	(mm)	(cm)	(cm^2 plant^{-1})
0% TDE	12.87 c	89.00 b	9017.25 c
25% TDE	14.18 bc	116.25 ab	13565.75 bc
50% TDE	15.99 ab	126.25 ab	16077.50 abc
75% TDE	17.18 a	135.75 a	18510.75 ab
100% TDE	17.50 a	127.50 ab	21217.25 ab
Control	17.08 a	127.25 ab	23376.25 a
Mean	15.80	120.33	16960.79

Mean values followed by the same letter in a column do not differ by Tukey's test, $p < 0.05$

In order to determine the most suitable level of TDE for growth in elephant grass, analysis of variance was carried out only for the treatments that used TDE for irrigation, thereby excluding the conventional treatment. Table 3 shows ANOVA for the growth variables under study, where a significant difference can be seen for stem diameter, plant height and leaf area, while number of leaves and number of tillers show no statistical difference at 90 DAP for the different levels of sewage applied in irrigation.

Analysing stem diameter and plant height, the regression equations showed increasing linear performance as a function of the different levels of sewage (Figure 3), with a maximum mean diameter of 17.50 mm for the treatment that used 100% TDE and a minimum mean diameter of 12.87 mm for the treatment with no TDE. For mean plant height, the lowest value was also seen in the treatment with 0% TDE (89.0 cm); however the highest value was seen in the treatment with 75% TDE (135.75 cm), representing an increase of approximately 53% in relation to the smallest mean height.

Evaluating the leaf area showed increasing values estimated by the regression equation, starting from 9,017 cm^2 $plant^{-1}$ when irrigated exclusively with well water, and reaching 21,217 cm^2 $plant^{-1}$ for the treatment that used 100% TDE (Figure 4). This increase in leaf area may express the great potential of using domestic sewage water for the production of elephant grass, generating biomass for animal feed in regions with problems of water scarcity, and/or reducing the pressure of using of good-quality water.

It was found that, with the exception of LFW, each of the production variables responded significantly to the different levels of treated domestic effluent applied in irrigation (0, 25, 50, 75 and 100% TDE; and WW + mineral fertiliser) at 90 DAP (Table 4). There was a significant difference for SDW and DWPROD at 1%, and for LFW, SFW and FWPROD at 5%.

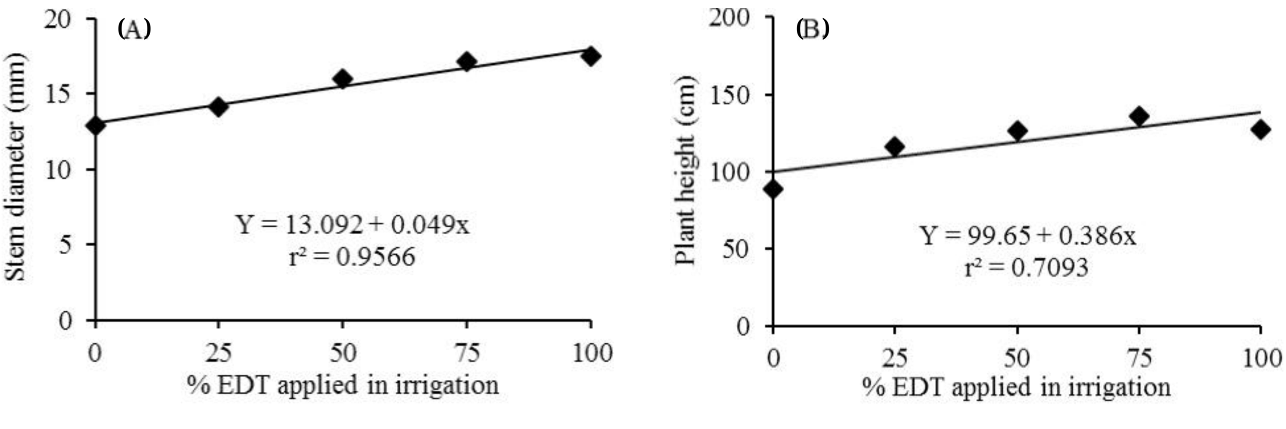
When examining the mean values of the production parameters, it can be seen that the treatments applying the greatest amount of TDE came closest to the values obtained under the conventional treatment; the treatments applying 50% or more TDE were statistically equal to the control by Tukey's test ($p < 0.05$) (Table 5).

Table 3 - Summary of the analysis of variance for number of leaves (NL), stem diameter (SD), number of tillers (NT), plant height (PH) and leaf area (LA) in elephant grass as a function of the treatments under test, Fortaleza, Ceará, 2020

SV	DF	Mean Square				
		NL	SD	NT	PH	LA
Treatment	4	224.82$^{(ns)}$	15.71**	3.45$^{(ns)}$	1,312.93*	87,694,553.55**
Block	3	1,773.65**	7.50**	2.80$^{(ns)}$	3,494.32**	317,512,250.73**
Residual	12	182.69	0.35	1.88	268.36	8,803,040.32
Total	19	-	-	-	-	-
CV (%)	-	22.85	3.78	29.83	13.77	18.92

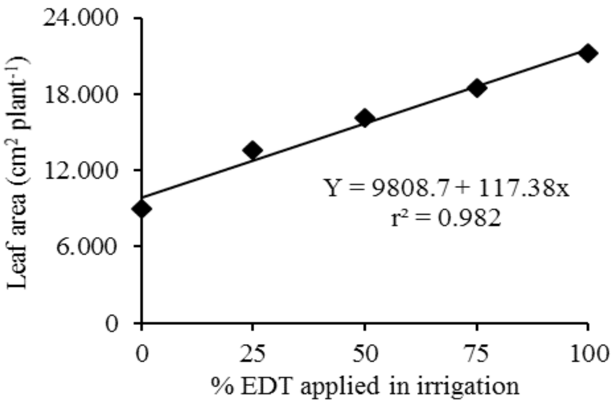
** significant at 1% by F-test; * significant at 5% by F-test; (ns) not significant by F-test. SV - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation

Figure 3 - Regression analysis for the mean values for stem diameter (A) and plant height (B) in elephant grass as a function of the level of treated domestic effluent (TDE) applied in irrigation, Fortaleza, Ceará, 2020



The greatest absolute production of both fresh and dry weight was, respectively, 28.04 and 6.73 Mg ha^{-1} in the control treatment, with a reduction of 76% in the weight of the material after drying. Santos et al. (2014), found 51.77% DM from elephant grass 'Cameron' grown with a base fertiliser of nitrogen, it is important to note that in the second study, the harvest took place at 180 DAP, a period during which the plant is more lignified and with a greater accumulation of dry matter.

Figure 4 - Regression analysis for mean leaf area in elephant grass as a function of the level of treated domestic effluent (TDE) applied in irrigation, Fortaleza, Ceará, 2020



The treatment that used only TDE for irrigation resulted in a fresh weight production of 26.83 Mg ha^{-1} and dry weight production of 5.58 Mg ha^{-1}. Figueira (2016), evaluating elephant grass 'Pioneer', harvested when the residue was at varying heights, obtained a fresh weight production of 41.51 Mg ha^{-1}, when harvested after 3 months cultivation with a residue height of 30 cm, higher values than those found in this study. Vale and Azevedo (2013) found a reduction in productivity when comparing elephant grass irrigated with groundwater as opposed to desalination waste, presenting 19.1 and 14.5 Mg ha^{-1} fresh weight, and 3.9 and 2.9 Mg ha^{-1} dry weight for the treatments with water and wastewater, respectively.

Table 4 - Summary of the analysis of variance for leaf fresh weight (LFW), stem fresh weight (SFW), leaf dry weight (LDW), stem dry weight (SDW), fresh weight production (FWPROD) and dry weight production (DWPROD) in elephant grass as a function of the treatments under test, Fortaleza, Ceará, 2020

SV	DF	Mean Square					
		LFW	SFW	LDW	SDW	FWPROD	DWPROD
Treatment	5	21,468.39**	190,830.48**	1,720.68$^{(ns)}$	15,116.11*	129.78**	10.64*
Block	3	124,032.20**	1,512,390.33**	13,514.30**	85,439.51**	1,000.11**	66.33**
Residual	15	4,117.45	3,6605.55	610.74	3,906.20	21.54	2.94
Total	23	-	-	-	-	-	-
CV (%)	-	21.99	23.00	33.30	40.92	20.65	37.78

** significant at 1% by F-test; * significant at 5% by F-test; (ns) not significant by F-test. SV - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation

Table 5 - Mean values for leaf fresh weight (LFW), stem fresh weight (SFW), leaf dry weight (LDW), stem dry weight (SDW), fresh weight production (FWPROD) and dry weight production (DWPROD) in elephant grass as a function of the treatments under test, Fortaleza, Ceará, 2020

Treatment	Variable				
	LFW	SFW	LDW	FWPROD	DMPROD
	(g plant^{-1})	(g plant^{-1})	(g plant^{-1})	(Mg ha^{-1})	(Mg ha^{-1})
0% TDE	146.58 b	485.61 b	74.49 b	12.64 b	2.43 b
25% TDE	290.69 ab	768.17 ab	93.36 b	21.18 ab	2.93 ab
50% TDE	311.55 a	714.19 ab	151.13 ab	20.51 ab	4.44 ab
75% TDE	336.29 a	946.21 a	170.61 ab	25.65 a	5.13 ab
100% TDE	333.48 a	1008.19 a	185.68 ab	26.83 a	5.58 ab
Control	332.28 a	1069.73 a	241.28 a	28.04 a	6.73 a
Mean	291.81	832.02	152.75	22.48	4.54

Mean values followed by the same letter in a column do not differ by Tukey's test, $p < 0.05$

In each of the treatments, stem weight was superior to leaf weight both before and after drying, with a mean share of 74% in FWPROD and 66% in DWPROD. The smaller share in the second case can be explained by the higher concentration of water in the stem in relation to the leaves. Furthermore, according to Figueira (2015), the share of the stem in dry weight production was around 50% on average for the different heights.

For Meinerz *et al*. (2011), the nutritional value of elephant grass as forage is associated with the leaf blade/stem+sheath ratio. The greater share of the stem in this study is due to the harvest being carried out close to the ground, and including the most luxuriant part of the stem.

In order to determine the most satisfactory level of TDE for cultivating elephant grass, an analysis of variance was carried out only for the treatments that included a level of TDE, thereby excluding the treatment under conventional cultivation. Table 6 shows the ANOVA for the production variables under study, where it can be seen that among the parameters, only LDW showed no significant difference. LFW was significant at 1%, while the other variables differed at 5% by F-test at 90 DAP, for the different levels of sewage applied in irrigation.

In the regression analysis that was based on the model found for the levels of TDE applied in irrigation, a linear increase was seen in SFW, SDW, FWPROD and DWPROD at 90 DAP as a function of the increase in TDE (Figures 6 and 7); the exception was LFW, for which the second-order polynomial model was a better fit (Figure 5). It was also possible to determine the point of maximum LFW as corresponding to the application of 75.4% TDE and 24.6% WW, representing 346.59 g plant^{-1} fresh weight.

The greatest production of stem fresh weight (Figure 6A) and stem dry weight (Figure 6B) was 1008.19 and 185.68 g plant^{-1}, respectively, in the treatment that used 100% TDE. While the lowest values, 485.61 and 74.49 g plant^{-1} SFW and SDW, respectively, were seen in the absence of TDE.

The effect of the level of TDE on the production of fresh and dry weight in elephant grass can be seen in Figure 7 (A and B). The greatest dry-weight production achieved in this study (5.58 Mg ha^{-1}), obtained when irrigating exclusively with TDE, was slightly superior to the results of Meinerz et al. (2011), who studied the conventional and agroecological cultivation of elephant grass, and obtained results of 4.71 and 2.63 Mg ha^{-1}, respectively, three months after beginning the study.

Table 7 shows the results of the analysis of variance for the levels of phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca) and nitrogen (N) in the elephant grass at 90 DAP, as a function of conventional cultivation and the application of different levels of treated domestic effluent (0%, 25%, 50%, 75% and 100% TDE, and WW + mineral fertiliser). From the results, it was found that the different levels of treated domestic effluent applied in irrigation had a significant effect on the potassium (K), magnesium (Mg) and nitrogen (N) content at the level of 1% probability, and on phosphorus (P) at the level of 5% probability by F-test, while the levels of calcium (Ca) did not differ statistically.

Observing the levels of macronutrients in the elephant grass (Table 8), it can be seen that, as with the production variables, the treatments with the greatest amounts of TDE applied in irrigation came closest to the values obtained under the conventional treatment, with the treatments with 50% or more TDE being statistically equal to the control by Tukey's test ($p < 0.05$) (Table 8).

The most abundant nutrient found in the grass was K, reaching 5.19% of the composition of the plant material when grown conventionally. This is followed by N, which makes up 3.06% of the plant material obtained under the same treatment.

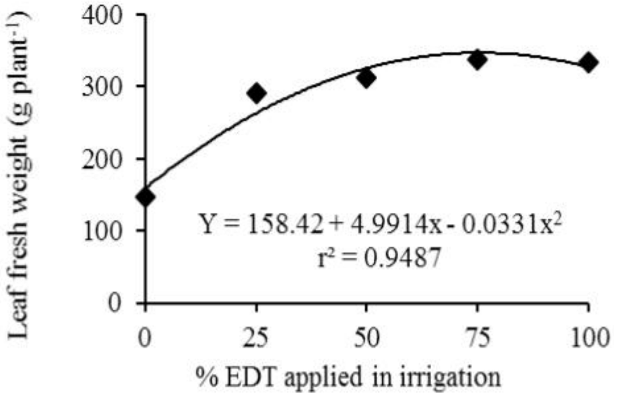
Table 6 - Summary of the analysis of variance for leaf fresh weight (LFW), stem fresh weight (SFW), leaf dry weight (LDW), stem dry weight (SDW), fresh weight production (FWPROD) and dry weight production (DWPROD) in elephant grass as a function of the level of treated domestic effluent applied in irrigation, Fortaleza, Ceará, 2020

SV	DF	Mean Square					
		LFW	SFW	LDW	SDW	FWPROD	DWPROD
Treatment	4	24,870.75**	170,729.42*	1,614.26$^{(ns)}$	9,492.10*	125.08*	7.53*
Block	3	102,076.35**	1,198,629.19**	8,872.14**	51,608.87**	797.34**	41.06**
Residual	12	4,256.50	41,232.47	539.93	2,464.74	25.08	2.05
Total	19	-	-	-	-	-	-
CV (%)	-	23.00	25.88	33.21	36.76	23.44	34.91

** significant at 1% by F-test; * significant at 5% by F-test; (ns) not significant by F-test. SV - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation

The values for Mg found in this study agree with those presented by Andrade et al. (2000), who evaluated potassium and nitrogen fertiliser in elephant grass and obtained mean levels of between 10 and 20 g Kg^{-1}. In the present study, when evaluating the export of these macronutrients at harvest, which depends on their levels in the aerial part of the plant and on the dry-matter production, the amount of exported macronutrients was found to have the following behaviour: K > N > Mg > Ca > P.

Figure 5 - Regression analysis for mean fresh leaf weight in elephant grass as a function of the level of treated domestic effluent (TDE) applied in irrigation, Fortaleza, Ceará, 2020



The high values for P seen in this study can be explained by its general abundance in domestic effluent, and its characteristic of low mobility in the soil, where it becomes available to the plant through mineralisation of the organic matter present in the sewage applied to the soil.

In order to better evaluate the behaviour of the macronutrient content in the aerial part of elephant grass as a function of the applied levels of TDE, analysis of variance was carried out only for the treatments that used TDE for irrigation, thereby excluding the treatment under conventional cultivation. Table 9 shows the ANOVA for the macronutrient content, where it can be seen that, with the exception of Ca (which showed no significant difference), each of the other macronutrients responded significantly ($p < 0.01$) at 90 DAP to the applied level of TDE applied in irrigation.

Figure 6 - Regression analysis for mean stem fresh weight (A) and mean stem dry weight (B) in elephant grass as a function of the level of treated domestic effluent (TDE) applied in irrigation, Fortaleza, Ceará, 2020

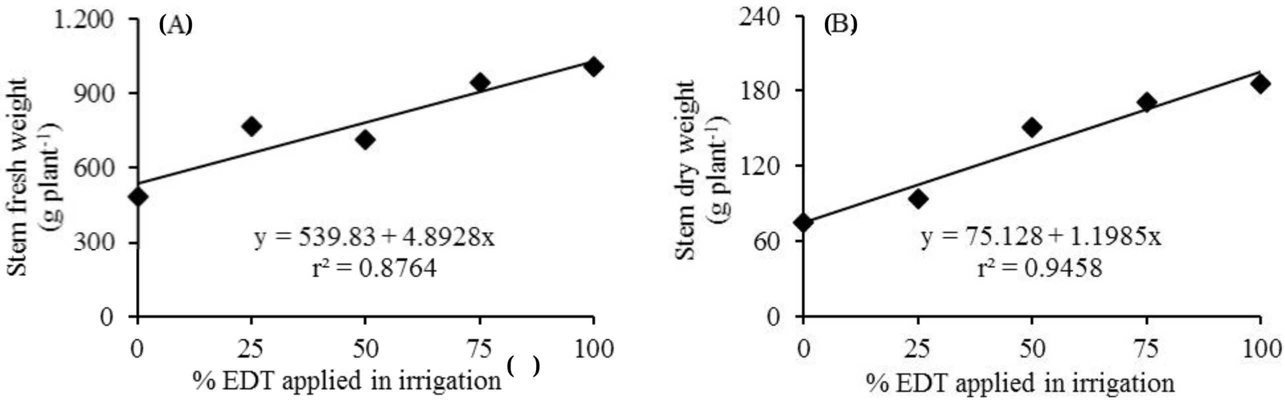


Figure 7 - Regression analysis for mean productivity in elephant grass as a function of the level of treated domestic effluent (TDE) applied in irrigation, Fortaleza, Ceará, 2020

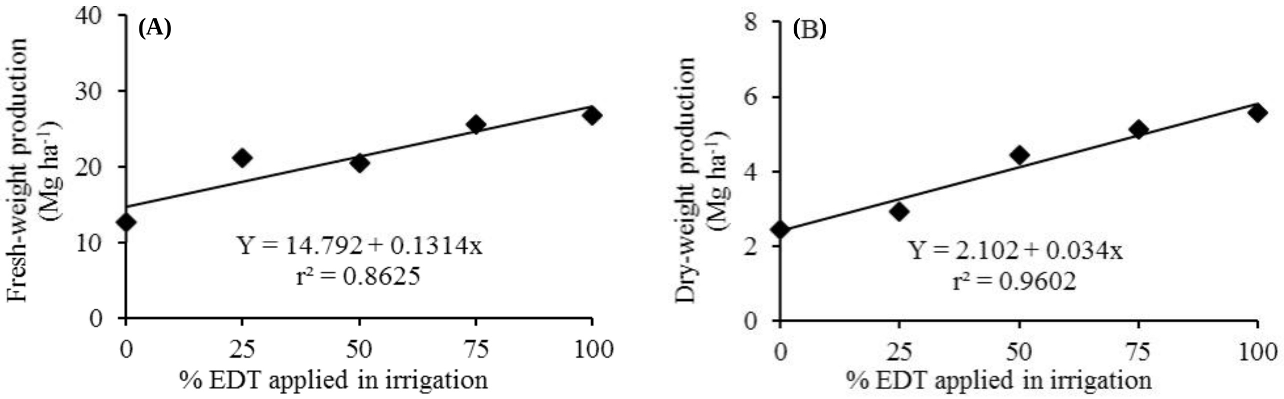


Table 7 - Summary of the analysis of variance for the levels of phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca) and nitrogen (N) in elephant grass as a function of the treatments under test, Fortaleza, Ceará, 2020

SV	DF	Mean Square				
		P	K	Mg	Ca	N
Treatment	5	37.11*	188.43**	56.75**	1.65(ns)	19.02**
Block	3	15.41(ns)	107.48**	72.69**	40.43**	38.17**
Residual	15	11.49	18.91	6.14	5.41	2.06
Total	23	-	-	-	-	-
CV (%)	-	29.15	9.84	14.06	21.15	5.06

** significant at 1% by F-test; * significant at 5% by F-test; (ns) not significant by F-test. SV - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation

Table 8 - Mean values for phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca) and nitrogen (N) in elephant grass as a function of the level of treated domestic effluent applied in irrigation, Fortaleza, Ceará, 2020

Treatment	Variable			
	P	K	Mg	N
	(g Kg^{-1})	(g Kg^{-1})	(g Kg^{-1})	(g Kg^{-1})
0% TDE	8.53 b	33.72 c	12.71 c	24.45 b
25% TDE	9.22 ab	38.47 bc	14.30 bc	27.83 a
50% TDE	10.34 ab	44.47 ab	16.32 abc	28.33 a
75% TDE	11.71 ab	47.72 ab	19.33 ab	28.73 a
100% TDE	13.13 ab	48.73 a	21.71 a	30.08 a
Control	16.83 a	51.93 a	21.42 a	30.63 a
Mean	11.63	44.17	17.63	28.34

Mean values followed by the same letter in a column do not differ by Tukey's test, $p < 0.05$

Table 9 - Summary of the analysis of variance for the levels of phosphorus (P), potassium (K), magnesium (Mg), calcium (Ca) and nitrogen (N) in elephant grass as a function of the level of treated domestic effluent applied in irrigation, Fortaleza, Ceará, 2020

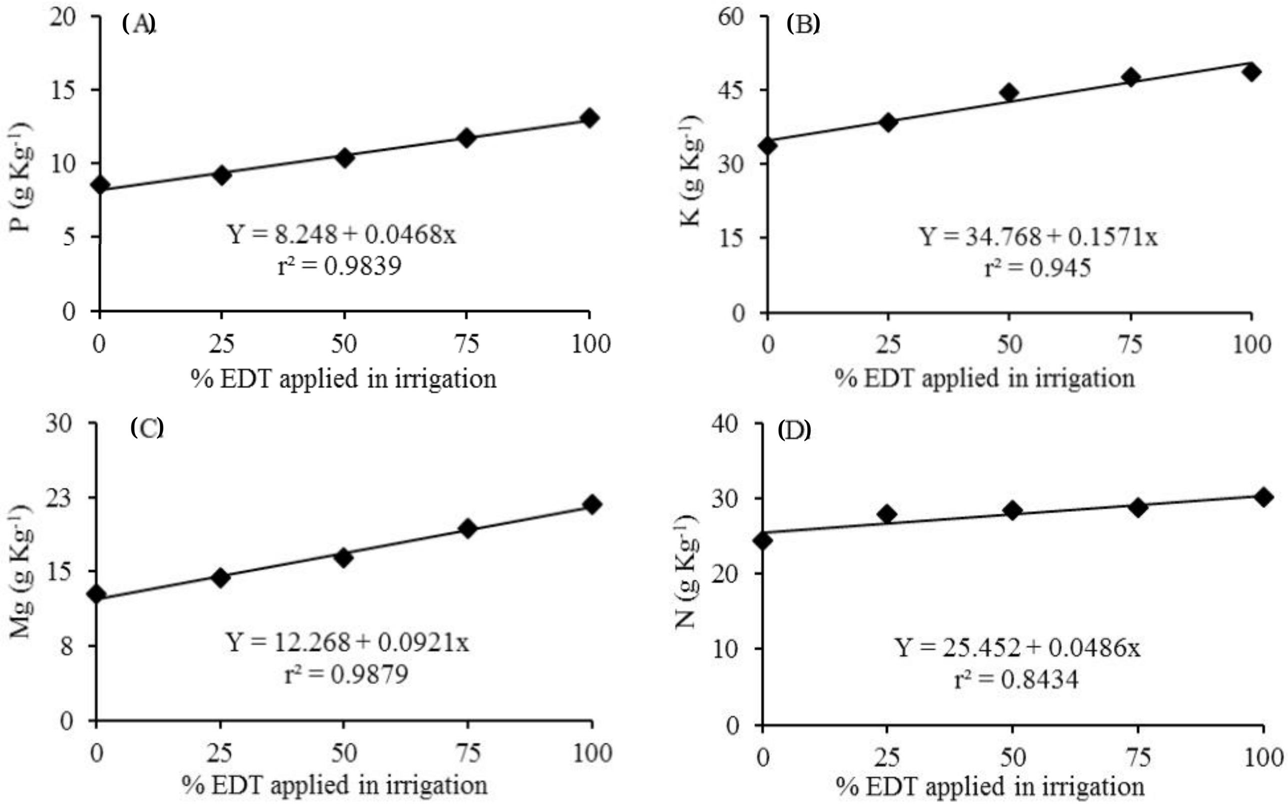
SV	DF	Mean Square				
		P	K	Mg	Ca	N
Treatment	4	13.90**	163.28**	53.71**	2.06(ns)	17.50**
Block	3	5.19*	95.69*	55.48**	44.85**	38.70**
Residual	12	1.41	23.24	6.17	3.84	1.92
Total	19	-	-	-	-	-
CV (%)	-	11.20	11.31	14.72	17.82	4.96

** significant at 1% by F-test; * significant at 5% by F-test; (ns) not significant by F-test. SV - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation

For the levels of phosphorus (P), potassium (K), magnesium (Mg) and nitrogen (N) in the aerial part of the elephant grass at 90 DAP as a function of the amount of treated domestic effluent applied in irrigation, it was found using regression analysis, that the linear model best fitted the data. In each case, irrigating exclusively with TDE afforded an increase of at least 20% in the nutrient content compared to the treatment that received only well water.

The values for P found in this study agree with those presented by Moreira et al. (2006), who, evaluating phosphate fertiliser and its methods of application, found values between 7.0 and 17.0 g Kg^{-1} DM. The authors infer that the greater the number of roots in contact with the fertilised soil, the better the use of the available P, corroborating the method of fertilizer (TDE) application used in this experiment.

Figure 8 - Regression analysis for the mean levels of phosphorus (A), potassium (B), magnesium (C) and nitrogen (D) in the aerial part of elephant grass as a function of the level of treated domestic effluent (TDE) applied in irrigation, Fortaleza, Ceará, 2020



The K content found in this study is far greater than that presented by Santos *et al*. (2012) for three varieties of elephant grass in the presence and absence of gypsum. However, in the above experiment the cutting age was 213 DAP, while in the present experiment it was 90 DAP, a period during which the plant is still developing and showing a higher rate of nutrient absorption.

The linear increase in the mean K content had no effect on the increase in the mean Mg content, which was greater than that found by Oliveira et al. (2011). Inverse levels of these two elements are often found in crops due to the competitive absorption of these elements. This can also be seen in other studies (ANDRADE et al., 2000; PAULA *et al*., 2011).

The mean nitrogen content in the aerial part of the plants showed increasing linear behaviour, where the lowest concentration was seen in the treatment with no TDE, and the highest concentration was obtained in the treatment where only TDE was applied, 24.45 and 30.08 g Kg^{-1}, respectively. Greater maximum values were found by Xu *et al.* (2015), who investigated the potential of elephant grass to extract nutrients from domestic sewage water, and found a maximum accumulation of 57.01 g Kg^{-1} in the aerial part of the plant.

The results of this research show that the use of treated domestic effluent as a source of water and fertiliser afforded an increase in the growth and production variables under study, with the plants making good use of the nutrients in the residue, helping their development.

CONCLUSIONS

1. The production of elephant grass irrigated with combinations of water and treated domestic effluent proved to be viable as long as there is a minimum level of 50% TDE, since under these conditions, production and the accumulation of macronutrients in the plant were statistically equal to those obtained under conventional cultivation;
2. The use of treated domestic effluent as a source of water and nutrients proved to be a viable alternative for the production of elephant grass, allowing quality feed to be maintained even during periods of drought, better-quality water to be conserved for more-important purposes, and the use of chemical fertilisers to be reduced.

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