

Growth and Production of Millet Irrigated With Dilutions of Treated Gray Water

Allana Rayra Holanda Sotero¹, Rafael Oliveira Batista¹, Mychelle Karla Teixeira de Oliveira¹,
Francisco de Assis de Oliveira¹, Ricardo André Rodrigues Filho¹, Héricck Claudino Mendes¹,
Wellyda Keorle Barros de Lavôr¹ & Audilene Dantas da Silva¹

¹ Universidade Federal Rural do Semi-árido, Mossoró, RN, Brazil

Correspondence: Francisco de Assis de Oliveira, Federal Rural University of the Semi-Arid, Mossoró, RN, Brasil.
E-mail: thikaoamigao@ufersa.edu.br

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Abstract

The present work aimed to analyze the effects of the application of dilutions of treated gray water (TGW) in well water (WW) on growth and production of millet cv. Ceará (*Pennisetum glaucum*). The experiment was carried out in a greenhouse, on the department of agronomic and forestry sciences, at the Federal Rural University of the Semi-Arid (UFERSA), Mossoró, RN, Brazil. The experimental design was randomized blocks with five treatments and six replications, totaling thirty plots. The experiment was carried out in vases with volume of 25L containing four plants per vase. The treatments consisted in five dilutions of TGW in WW: T1—100% WW plus 0% TGW; T2—75% WW plus 25% TGW; T3—50% WW plus 50% TGW; T4—25% WW plus 75% TGW and T5—0% WW plus 100% TGW. During the experiment it was analyzed the attributes of plant height, number of tillers, number of leaves, stem diameter and total fresh and dry matters. With the results, it was observed that the exclusive irrigation with TGW (T5) promoted better millet development. As the concentrations of TGW increased in dilutions, also increased plant height, number of leaves and tillers. The rise in the number of leaves is associated to the rise in height and tillers, and those are associated to the rise in stem diameter and fresh matter, resulting in better accumulations of dry matter and showing the viability of gray water use to improve forage production and increasing potable water availability to multiple uses.

Keywords: *Pennisetum glaucum*, forage, residual water, biomass, sustainability, reuse

1. Introduction

The way to increase availability of sources of water to irrigation is to rationalize its use (Santos Júnior et al., 2013), as well as to reuse water from different activities (Medeiros et al., 2010). The reuse of wastewater on forage production comes as a strategy to sustainable management of water, to reduce future problems of water scarcity. Beyond preventing water sources eutrophication, this technic when used correctly can improve food production because it has nutrients that allow to substitute in part or totally mineral fertilization to cultures, promoting benefits both economic and environmental.

Millet (*Pennisetum glaucum*) is an easy installing culture when compared to other because it requires less inputs due to its deep and vigorous roots, being efficient on water and nutrients use. According to Silva et al. (2015), millet has high productive potential in areas with low rainfall, being used in adverse conditions, showing to be a good alternative of forage in semiarid regions.

Residual water is being studies in many areas of reuse, presenting promising results (Santos et al., 2016; Alves et al., 2014; Deon et al., 2010). A study carried out in Campinas, SP, with treated domestic wastewater proved that its use promotes water and nutrients to fertilize soil and improve mays productivity (Javarez Júnior et al., 2010). Another study carried out in Apodi, RN, shown that treated domestic wastewater use to irrigate red rice promoted rise on some nutrients tax, such as nitrogen (Brito et al., 2014).

According to Baracuhy et al. (2015), water reuse is a way to reduce environmental pollution, providing water availability to forage irrigation, improving economic development on semiarid region. Among different sources of wastewater, it can be named the gray water, generated from urban and rural residences that come from showers, washbasins, kitchen sinks, tanks and washing machines. In its compositions there are elements from

soaps and cleaning products, being free from toilet effluents (Feitosa et al., 2011). It has been studying mainly by architecture and civil engineering branches to be reused with non-potable purposes (Guerra, 2016).

Rapoport (2004) states that gray water from kitchen sinks have oil, fat and human food particles in its composition.

In the long run, the use of wastewater can promote salts and heavy metals accumulation in soil to a harmful level to crops development and production (Rusan et al., 2007). Gray water dilutions in well water are done aiming to reduce salts concentration so water's electrical conductivity remain within standards established on COEMA's resolution n.2/2017 (Ceará, 2017) for agricultural and forestry purposes. A study carried out in Mossoró, RN, evaluated the effects of cotton irrigation with different dilutions of domestic sewage in two kinds of soil. It was observed that both soils presented increase in sodium content, which is harmful to soil's structure, dissipating soil particles and reducing its permeability (Andrade Filho et al., 2013).

There are reports about wastewater reuse on forage production, for instance, studies developed with water from coffee processing (Fia et al., 2010) and livestock (Piccolo et al., 2013; Saraiva & Konig, 2013). On literature, studies point to wastewater reuse on forage production (Erthal et al., 2010; Andrade et al., 2014; Homem et al., 2016), however it is scarce studies on gray water reuse on millet development and production.

Thus, this work aimed to analyze the effects of application of treated gray water dilutions in well water on millet's cv. Ceará (*Pennisetum glaucum*) production and development.

2. Method

The experiment was carried out on greenhouse, on the department of agronomic and forestry sciences at the Federal Rural University of the Semi-Arid (UFERSA), Mossoró, RN, State Of Rio Grande do Norte, Brazil (05°12'03.9" S; 37°19'98" W). According to Köppen climate classification, the region's climate is classified as BSh, which is a country climate, semiarid, warm and dry, with low altitude and latitude, morphoclimatic domain caatinga, average annual rainfall lower than 650 mm and average annual temperature higher than 265 °C (Alvares et al., 2013). In this region the average annual rainfall is 673.9 mm, humidity of 65.9% (Dias et al., 2010) and average speed of wind is 3.32 m s⁻¹ (Morais et al., 2014).

The experimental design used was randomizes blocks with five treatments and six replications, totaling thirty plots. The experiment was carried out in vases with volume of 25 L containing four plants per vase. The treatments consisted in five dilutions of TGW in WW: T1—100% WW plus 0% TGW; T2—75% WW plus 25% TGW; T3—50% WW plus 50% TGW; T4—25% WW plus 75% TGW and T5—0% WW plus 100% TGW. Gray water dilutions are recommended to reduce salt concentration and to identify the most adequate dilution to culture development (Brito, 2014; Medeiros et al., 2015).

As substrate, it was used soil classified as Typic Rhodustuts (Rêgo, 2016), collected from the experimental farm Rafael Fernandes, Mossoro, state of Rio Grande do Norte, Brazil, whose chemical characteristics are presented on Table 1.

Table 1. Chemical characteristic of soil before irrigation with treated gray water dilutions in well water

Depth	pH	EC	OM	P	K ⁺	Na ⁺	Ca ²⁺	Mg ²⁺	Al ³⁺	(H+Al)	SB	T	CEC	V	ESP
cm	(H ₂ O)	dS m ⁻¹	-----	mg dm ⁻³	-----	-----	-----	-----	-----	cmol _c dm ⁻³	-----	-----	-----	-----	-----
0-20	6.10	0.41	3.31	1.90	26.90	4.70	1.10	0.70	0.00	1.49	1.89	1.89	3.37	56	1
20-40	4.80	0.03	2.07	1.70	26.90	4.70	0.40	1.00	0.15	1.98	1.49	1.64	3.47	43	1

Note. pH: Hydrogen potential, EC: electrical conductivity, OM: organic matter, P: phosphorus, K: potassium, Na⁺: sodium, Ca²⁺: calcium, Mg²⁺: Magnesium, Al³⁺: Aluminum, (H+AL): potential acidity, SB: Sum of bases, CEC: Cation exchange capacity, ESP: Exchange capacity, V: Base saturation, ESP: exchangeable sodium percentage.

Gray water was collected from a treatment station located on Monte Alegre I settlement (5°3'13.06" S; 37°27'23.27" W) in Upanema, state of Rio Grande do Norte, Brazil. The gray water produced in the residence is composed by shower, bathroom sink and laundry tanks. The house is inhabited by two people and they have three visitors on weekends, producing average of 80 L of gray water per day.

Table 2. Physico-chemical characteristics of treated gray water (TGW) and well water (WW) and its related average (A) and standard deviation (SD)

	08/21/2017		09/21/2017		10/16/2017		WW	TGW
	WW	TGW	WW	TGW	WW	TGW	A±SD	A±SD
Al (mg L ⁻¹)	0.213	0.125	0.084	0.099	0.053	0.133	0.117±0.085	0.119±0.018
As (mg L ⁻¹)	0.000	0.000	0.000	0.000	0.000	0.000	0±0	0.000±0.000
B (mg L ⁻¹)	0.512	0.366	0.415	0.244	0.350	0.412	0.426±0.082	0.341±0.087
Ba (mg L ⁻¹)	1.841	1.948	2.632	2.281	2.323	1.868	2.265±0.399	2.032±0.219
Cr (mg L ⁻¹)	0.064	0.105	0.012	0.000	0.013	0.004	0.030±0.030	0.036±0.060
Cu (mg L ⁻¹)	0.006	0.039	0.088	0.080	0.088	0.088	0.061±0.047	0.069±0.026
Mn (mg L ⁻¹)	0.029	0.377	0.062	0.177	0.061	0.124	0.051±0.019	0.226±0.133
Fe (mg L ⁻¹)	0.030	1.404	0.087	0.498	0.094	0.471	0.070±0.035	0.791±0.531
Ni (mg L ⁻¹)	0.081	0.053	0.012	0.000	0.015	0.028	0.036±0.039	0.027±0.027
Cd (mg L ⁻¹)	0.00	0	0.018	0.006	0.020	0.025	0.013±0.011	0.010±0.013
Pb (mg L ⁻¹)	0.06	0.049	0.002	0.043	0.001	0.04	0.021±0.034	0.044±0.005
Zn (mg L ⁻¹)	0.018	0.291	0.031	0.076	0.034	0.076	0.028±0.009	0.148±0.124
pH	7.1	7.5	7.12	7.59	7.05	7.97	7.090±0.030	7.693±0.242
EC (dS m ⁻¹)	0.5	1.4	0.42	1.33	0.52	1.70	0.467±0.050	1.477±0.197
K ⁺ (mmol _c L ⁻¹)	0.2	1.3	0.21	1.08	0.20	1.34	0.209±0.008	1.246±0.144
Na ⁺ (mmol _c L ⁻¹)	5.4	8.2	3.75	6.22	3.50	10.89	4.202±1.008	8.431±2.345
Ca ²⁺ (mmol _c L ⁻¹)	0.5	3.3	0.55	4.8	0.67	1.84	0.586±0.073	3.280±1.455
Mg ²⁺ (mmol _c L ⁻¹)	0.3	2.1	0.20	0.86	0.43	4.98	0.322±0.116	2.638±2.117
Cl ⁻ (mmol _c L ⁻¹)	2.9	8.5	1.20	5.40	2.00	6.40	2.022±0.834	6.778±1.600
CO ₃ ²⁻ (mmol _c L ⁻¹)	0.0	0.0	0.20	0.40	0.20	0.50	0.133±0.115	0.300±0.265
HCO ₃ ⁻ (mmol _c L ⁻¹)	2.6	7.8	1.30	2.60	2.50	7.50	2.144±0.734	5.967±2.919
N (mg L ⁻¹)				40.43		34.56		37.49±2.940
P (mg L ⁻¹)				4.74		2.54		3.640±1.100

The applications of gray water dilutions in well water was carried out through an irrigation system of microtubes with a PVC reservoir (60 L), an circulating pump Metalcorte/Eberle, self-ventilated, EBD250076 model, lateral lines of 16 mm and microtubes with average flow of 8.5 L h⁻¹. The irrigation system applied, daily, the needed volume of dilutions to increase soil humidity until its maximum water retention capacity.

On figure 1 are presented climate data collected inside the greenhouse during the experimental period, minimum (MinTem), medium (MedTem) and maximum (MaxTem) temperatures, minimum (MinRH), medium (MedRH) and maximum (MaxRH) relative humidity and global radiation. Temperatures varied from 26.8 to 29.1 °C; 27.6 to 29.8 °C; 28.3 to 30.6 °C, to minimum, medium and maximum, respectively (Figure 1A). For relative humidity, the variations were from 38.9 to 57.8% for MinRH, 41.8 to 60.3% for MedRH and 44.7 to 62.9% for MaxRH (Figure 1B). Solar radiation inside the greenhouse varied from 14.9 to 26.7 MJ m⁻² with average of 20.2 MJ m⁻² (Figure 1C).

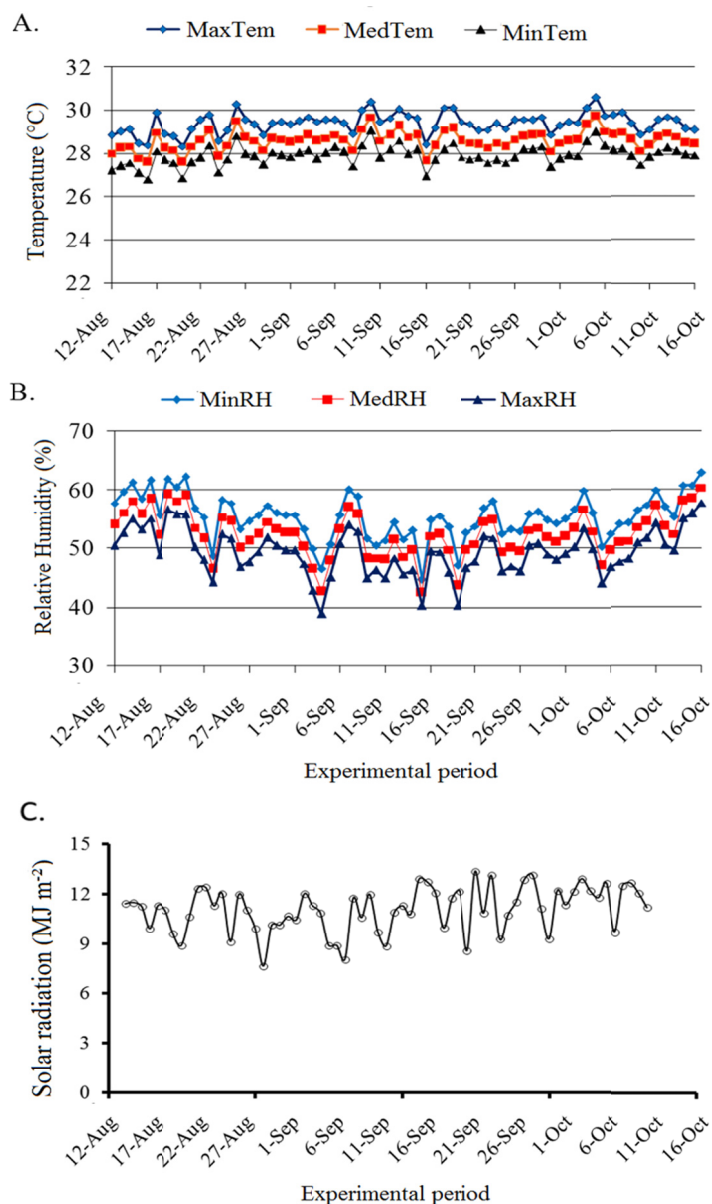


Figure 1. Climate data (A: temperature; B: Air relative humidity; C: solar radiation) obtained during the experimental period

On Table 3 it is presented the volume of water applied during the experiment, showing that it was applied a total volume of 159.4 L per vase in the end of the experiment for all treatments. Considering that treatments T4 and T5 received higher volumes of treated gray water, there was economy of 75 and 100% of well water for forage production, higher than forage production of treatment T1, that only used well water.

Table 3. Volume in liters of treated gray water (TGW) dilutions in well water (WW) and applied during the experimental period

Treatments	1-20 DAS		21-40 DAS		41-65 DAS		Accumulated		Total
	WW	TGW	WW	TGW	WW	TGW	WW	TGW	
----- Liters per vase -----									
T1	71.30	0.00	30.80	0.00	57.30	0.00	159.40	0.00	159.40
T2	71.30	0.00	23.10	7.70	43.00	14.30	137.40	22.00	159.40
T3	71.30	0.00	15.40	15.40	28.65	28.65	115.45	44.05	159.40
T4	71.30	0.00	7.70	23.10	14.30	43.00	93.30	66.10	159.40
T5	71.30	0.00	0.00	30.80	0.00	57.30	71.30	88.10	159.40

Note. DAS: Days after sowing; T1: 100% WW plus 0% TGW; T2: 75% WW plus 25% TGW; T3: 50% WW plus 50% TGW; T4: 25% WW plus 75% TGW and T5: 0% WW plus 100% TGW.

Non-destructive evaluations of growth were weekly done through the variables: plant height, number of leaves, number of tillers and number of panicles. At the end of the cycle, it was evaluated development characteristics: height, number of leaves and tillers, stem diameter, number and length of panicles, fresh and dry matter.

The material was collected manually on October 16th of 2017, 65 days after sowing. Plants were cut 0.05 m above the soil taking all its leaves. The fresh matter of the forage was obtained after cutting, when the material was putted in paper bags and weighted. Then, the material was sent to hothouse with forced air circulation on 65 °C until it gets to constant weight and then it was weighted again to obtain dry matter. Later the material was milled in Willey Mill and kept in plastic bags to go to laboratory analysis.

Data of millet development and production were submitted to analysis of variance, using test F with 5% of probability. The means were compared though Tukey test with 5% of probability. Regression models were chosen based on determination coefficient values and regression equation coefficients, using test F with 5% of probability. Statistical analysis of data was carried out with aid of SISVAR program developed by Ferreira (2011).

3. Results and Discussion

It was observed that while increase TGW proportion on treatments, plants acquired higher amount of biomass with increase in height, number of leaves and tillers. For height, it was observed no significant difference on the first four weeks and after that plants started to express treatment effects with 5% of significance and 1% of significance from fifth week on (Table 4). The better treatment was the one with 100% of TGW (T1), which presented average height of 112.87 cm while treatment T1 presented average height of 92.04 cm (Figure 2A).

Table 4. Summary of analysis of variance to height during miller experiment produced with treated gray water

Variation sources	DF	Mean square							
		10DAS	17DAS	24DAS	31DAS	38DAS	45DAS	52DAS	59DAS
Gray water	4	27.16 ^{ns}	18.67 ^{ns}	610.70 ^{ns}	393.7 [*]	696.0 ^{**}	387.23 ^{**}	426.3 ^{**}	471.0 ^{**}
Blocks	5	23.82 ^{ns}	31.97 ^{ns}	51.73 ^{ns}	289.1 ^{ns}	330.5 [*]	92.74 ^{ns}	410.7 ^{**}	201.4 ^{**}
Error	20	24.79	13.13	234.92	115.4	115.6	7.70	37.84	38.81
CV (%)		41.39	18.01	38.54	18.02	13.40	9.72	6.65	6.29

Note. *, **: significant at 5% and 1% of probability, respectively, for F test. ns: non-significant for F test. DAS: days after sowing.

The tillers started to show from the beginning of dilutions application, showing significant difference of 1% on treatments from the 31th day after sowing (Table 5). The treatment with 100% of TGW presenter better number of tillers, promoting higher biomass with average of 11.5 tillers while the treatment T1 obtained average of 1.5 tiller (Figure 2C).

Table 5. Summary of variance analysis for the number of tillers during millet experiment produced with treated gray water

Variation sources	DF	Mean square							
		10DAS	17DAS	24DAS	31DAS	38DAS	45DAS	52DAS	59DAS
Gray water	4	-	-	-	3.85**	4.15**	5.64**	31.62**	46.75**
Blocks	5	-	-	-	2.46*	2.12**	1.92*	1.19 ^{ns}	4.17 ^{ns}
Error	20	-	-	-	0.78	0.32	0.64	1.39	2.04
CV (%)					52.66	32.30	39.80	39.55	38.11

Note. *, **: significant at 5% and 1% of probability, respectively, for F test. ns: non-significant for F test. DAS: days after sowing.

The number of leaves on the main stem were not significant during part of the experiment, being significantly different from the 7th week (Table 6). On average, the number of leaves on the main stem was bigger in the treatment T1 (7 leaves) and smaller on treatment T5 (3.4 leaves) (Figure 2E).

Table 6. Summary of variance analysis for the number of leaves on the main stem during millet experiment produced with treated gray water

Variation sources	DF	Mean square							
		10DAS	17DAS	24DAS	31DAS	38DAS	45DAS	52DAS	59DAS
Gray water	4	-	0.55 ^{ns}	2.75 ^{ns}	2.26 ^{ns}	0.19 ^{ns}	3.79 ^{ns}	18.89**	14.85**
Blocks	5	-	1.64*	1.61 ^{ns}	3.53 ^{ns}	2.84**	4.92 ^{ns}	2.88 ^{ns}	3.01 ^{ns}
Error	20	-	0.44	1.32	2.32	0.61	3.47	1.46	2.57
CV (%)			13.02	20.70	21.24	9.17	24.20	17.55	26.08

Note. *, **: significant at 5% and 1% of probability, respectively, for F test. ns: non-significant for F test. DAS: days after sowing.

Despite the number of leaves on main stem do not present big difference during the experiment, the difference can be noticed on the number of total leaves per plant, that increased as increased the number of tillers. This variable presented significant difference of 1% from the 3rd week after sowing (Table 7) with bigger number of leaves on treatment T5 with average of 53.67 leaves per plant, while on treatment T1 there were 14.09 leaves (Figure 2D).

Table 7. Summary of variance analysis for the number of total leaves during millet experiment produced with treated gray water

Variation sources	DF	Mean square							
		10DAS	17DAS	24DAS	31DAS	38DAS	45DAS	52DAS	59DAS
Gray water	4	-	0.55 ^{ns}	120.81**	110.02*	206.80**	317.85**	2717.4**	591.54**
Blocks	5	-	1.61*	11.44 ^{ns}	106.33*	126.36**	103.82 ^{ns}	390.0 ^{ns}	56.64 ^{ns}
Error	20	-	0.45	11.74	31.75	17.87	42.27	481.9	46.77
CV (%)			13.15	32.71	37.04	37.69	29.63	67.53	28.96

Note. *, **: significant at 5% and 1% of probability, respectively, for F test. ns: non-significant for F test. DAS: days after sowing.

Panicles started to emerge from the 5th week. With the rise in tiller, more panicles emerged, showing significant difference of 1% from the 6th week after sowing (table 8) with greater number of panicles the treatment T5 with mean of 8.46 panicles while treatment T1 had 1.3 panicles per plant (Figure 2B).

Table 8. Summary of variance analysis for the number of panicles during millet experiment produced with treated gray water

Variation sources	DF	Mean square							
		10DAS	17DAS	24DAS	31DAS	38DAS	45DAS	52DAS	59DAS
Gray water	4	-	-	-	-	0.15 ^{ns}	2.66 ^{**}	5.56 ^{**}	45.12 ^{**}
Blocks	5	-	-	-	-	0.13 ^{ns}	1.54 [*]	0.90 [*]	3.10 ^{ns}
Error	20	-	-	-	-	0.09	0.48	0.23	3.31
CV (%)		-	-	-	-	95.36	36.50	17.55	44.45

Note. *, **: significant at 5% and 1% of probability, respectively, for F test. ns: non-significant for F test. DAS: days after sowing.

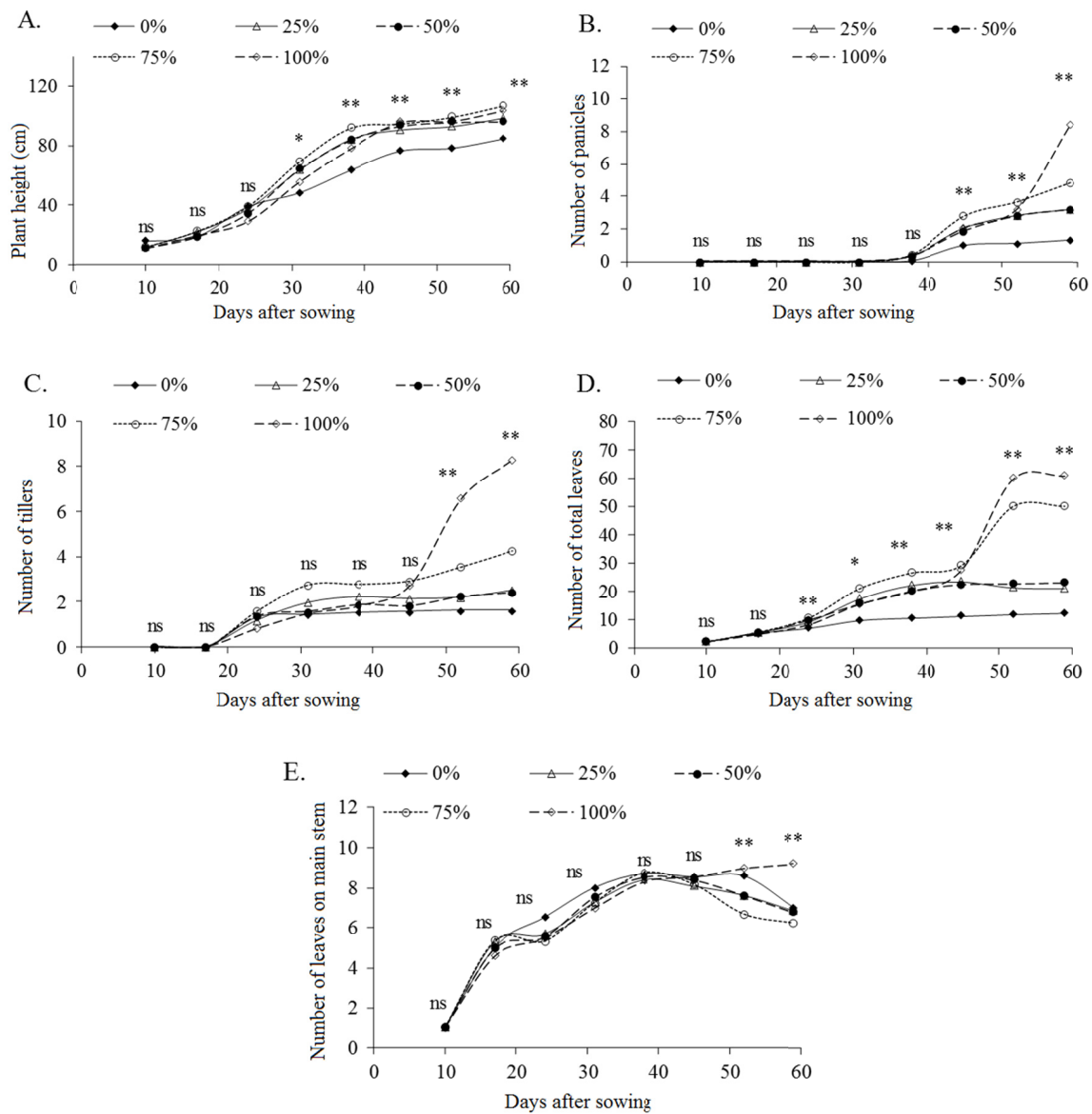


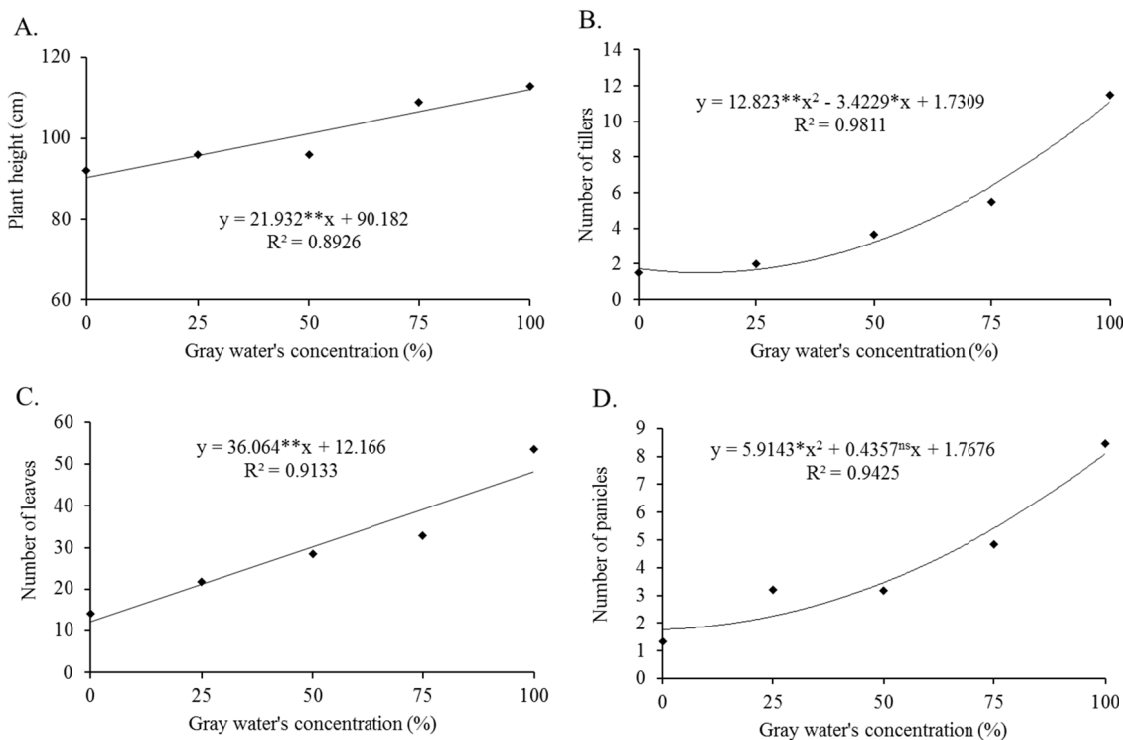
Figure 2. Plant height (A), number of panicles (B), number of tillers (C), number of total leaves (D) and number of leaves on main stem (E) of millet produced with treated gray water

The analyzed variables were strongly influenced by treatments applied with significant difference of 1% (tables 9), except panicle length, that did not present significant difference. With these results, it can be identified that gray water application is benefic to growth and development of millet.

Table 9. Summary of variance analysis for fresh matter (FM), dry matter (DM), height (H), number of total leaves (NL), number of tillers (NT), number of panicles (NP), stem diameter (SD), panicle length (PL) fresh panicle matter (FPM) and dry panicle matter (DPM) of millet produces with treated gray water 65 days after sowing

Variation sources	DF	Mean square					
		FM	DM	H	NL	NT	
Gray water	4	2028.67**	251.99**	459.11**	545.86**	40.25**	
Blocks	5	124.47 ^{ns}	24.81*	187.88*	73.41 ^{ns}	3.59 ^{ns}	
Error	20	81.02	8.33	56.60	33.78	1.83	
CV (%)		25.58	20.77	7.67	24.12	33.93	
		SD	NP	PL	FPM	DPM	
Gray water	4	1.40**	43.80**	2.41 ^{ns}	173.37**	48.82**	
Blocks	5	8.75 ^{ns}	2.84 ^{ns}	1.97 ^{ns}	7.94 ^{ns}	8.78 ^{ns}	
Error	20	0.28	3.02	2.12	14.72	3.59	
CV (%)		16.02	41.72	15.12	35.18	29.12	

Despite the number of leaves on the main stem present graph with decreasing quadratic behavior with treatments, the number of leaves on tillers presented inverse behavior, culminating to linear growth on number of total leaves. The other variables presented linear growth (height) and quadratic growth (number of tillers, panicles and stem diameter). Panicle length did not present significant difference with treatments (Figures 3 and 4).



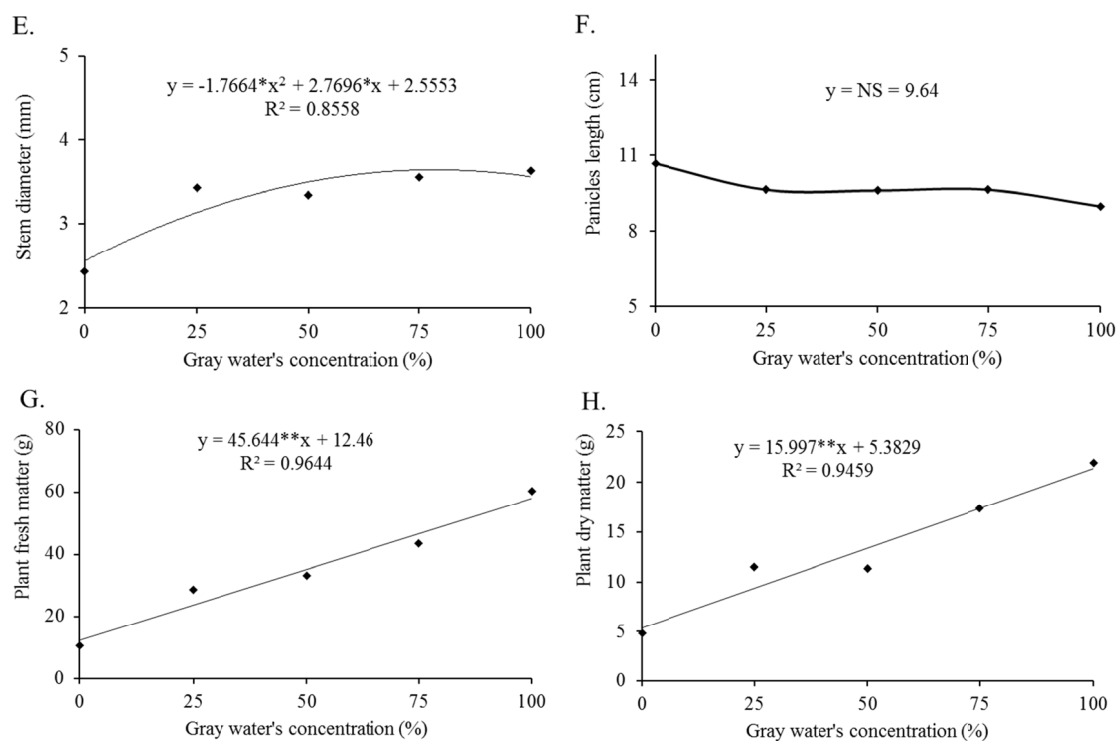


Figure 3. Plant height (A), number of tillers (B), Number of leaves (C), number of panicles (D), stem diameter (E), panicles length (F), plant fresh matter (G) and plant dry matter (H) of millet produced with treated gray water

Millet totally irrigated with treated gray water presented higher values of fresh and dry matter than millet irrigated only with well water. That can be explained by the fact that the gray water presented higher content of macronutrients than well water (600% of K^+ , 570% of Ca^{2+} and 850% of Mg^{2+}). Gray water also presents significant amounts of nitrogen and phosphorus that favor millet development. Kumar et al. (1985) obtained better biomass of millet with application of nitrogen and zinc. The results are like the results of Javarez Junior (2010) and Santos (2016) that got better productivity of mays and cotton with domestic wastewater.

Nitrogen is a macronutrient with structural function in plant and it is present in gray water in ammoniacal form, from urine not descendent from toilet. Its continuous availability for plant allows it to approximate from its productive potential on growth and production variables.

As increase gray water concentration on treatments dilution, it increased plant height, leaves emission and tiller, and higher values were found on treatment T5 with 100% of gray water, with height 22.6% superior to treatment T1, leaves emission 380% superior and tiller 767% superior. As the irrigation with gray water only begun on the 20th day after sowing, it can be inferred that differences in plant height were strongly influenced by the treatments, as well as the number of leaves and tillers, that presented significant difference from the 24th and 52nd days on, respectively. Malafaia et al. (2015), Lira (2016), and Santos (2016) found similar results to mays, sorghum and cotton irrigated with domestic wastewater, respectively, promoting higher values of height and stem diameter in all the experiments, as well as rise in biomass in sorghum and cotton and increase in panicle number in sorghum.

The rise in number of leaves is associated to the rise in height and number of tillers and those are associated to the rise in stem diameter and fresh biomass, resulting in better accumulation of dry mass and showing gray water's viability to forage production. With the rise in tiller number, also occurred rise in panicle number, that did not present significant differences in its length.

4. Conclusion

From the results obtained, it can be concluded that irrigation exclusively with treated gray water promoted greater biomass production of millet cv. Ceará (*Pennisetum glaucum*) being benefic its application to forage production aiming animals feeding.

It can be concluded that irrigation with gray water increased the nutritional production, obtaining greater production and increasing the availability of water for other purposes.

The results obtained in this scientific study promote the formation of knowledge for the mitigation of water uses for reuse purposes in sustainable agriculture, increasing the availability of drinking water, as well as, if further studies are necessary in this line of research, to evaluate the cumulative effect of the use of gray water on agricultural crops.

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