Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
https://periodicos.ufersa.edu.br/index.php/caatinga

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)
http://dx.doi.org/10.1590/1983-21252023v36n421rc

Biomass and nutrient contents in *Panicum maximum* cultivars irrigated with fish farming effluent

Biomassa e teor de nutrientes em cultivares de *Panicum maximum* irrigadas com efluente da piscicultura

Daianni A. da C. Ferreira[1], Marcelo T. Gurgel[1], Nildo da S. Dias[1], José F. de Medeiros[1], Francisco V. da S. Sá[1]*

[1]Center of Agrarian Sciences, Universidade Federal Rural do Semi-Árido, Mossoró, RN, Brazil.

ABSTRACT - Wastewater reuse is an alternative for irrigated agriculture in semi-arid regions, due to water support and nutritional supply. Thus, the objective was to evaluate biomass production and nutrient contents in three cultivars of *Panicum maximum* irrigated with fish farming effluent. The experiment was carried out in a greenhouse, with a complete randomized block design in a split-split-plot scheme. The plot consisted of three types of irrigation management (public-supply water (control), control + conventional fertilization, and irrigation with fish farming effluent). The subplot consisted of three cultivars of *P. maximum* (Tanzania, Mombasa, and Massai). The sub-subplot consisted of four cutting times (45, 90, 135, and 180 days after sowing). At each cutting time, biomass production and nitrogen, phosphorus, potassium, calcium, magnesium, sodium, iron, copper, manganese, and zinc contents were determined. Irrigation with fish farming effluent increases sodium content in all *P. maximum* cultivars and causes reduction in biomass production. The salinity of fish farming effluent increased calcium, magnesium, iron, manganese, and zinc contents in the tissues.

Keywords: Fertilization. Massai. Mombasa. Water reuse. Tanzania.

RESUMO - O reuso de águas residuárias é uma alternativa para a agricultura irrigada em regiões semiáridas, devido ao suporte hídrico e aporte nutricional. Assim, objetivou-se avaliar a produção de biomassa e a concentração de nutrientes em três cultivares de *Panicum maximum* irrigadas com efluente da piscicultura. A pesquisa foi conduzida em casa de vegetação, com delineamento em blocos casualizados completos em esquema de parcelas sub-subdividida no tempo. A parcela foi constituída por três manejos de irrigação (água de abastecimento (testemunha), testemunha + adubação convencional e irrigação com efluente da piscicultura). A sub-parcela foi constituída por três cultivares de *P. maximum* (Tanzânia, Mombaça e Massai). A sub-subparcela foi composta por quatro tempos de corte (45, 90, 135 e 180 dias após a semeadura). Em cada tempo de corte foram determinadas a produção de biomassa e as concentrações de nitrogênio, fósforo, potássio, cálcio, magnésio, sódio, ferro, cobre, manganês e zinco. A irrigação com efluente da piscicultura aumenta o teor de sódio de todas as cultivares de *P. maximum*, o que acarretou redução na produção de biomassa. A salinidade do efluente da piscicultura aumentou os teores de cálcio, magnésio, ferro, manganês e zinco nos tecidos.

Palavras-chave: Adubação. Massai. Mombaça. Reuso de água. Tanzânia.

Conflict of interest: The authors declare no conflict of interest related to the publication of this manuscript.

This work is licensed under a Creative Commons Attribution-CC-BY https://creativecommons.org/licenses/by/4.0/

Received for publication in: August 2, 2022.
Accepted in: March 2, 2022.

***Corresponding author:**
<vanies_agronomia@hotmail.com>

INTRODUCTION

Management of water resources is one of the biggest problems faced by humanity, mainly due to the process of urbanization, industrial growth and irrigated agriculture (VÖRÖSMARTY et al., 2015). However, the random nature of these resources, which undergo changes caused by both climate change and human activities, makes them even more precious (PEDRO-MONZONÍS et al., 2015).

In some areas of the Brazilian semi-arid region, the low availability of good-quality water for irrigation has stimulated the use of lower-quality water, especially saline water (SILVA et al., 2014). In most cases, both surface and subsurface waters have high concentrations of salts (PRAXEDES et al., 2022). The great challenge is to develop proper management of these waters with high salt concentrations because, when managed incorrectly, they cause problems of soil salinization and desertification of areas (SÁNCHEZ; NOGUEIRA; KALID, 2015).

Among the alternatives of irrigation with saline water, the reuse of fish farming effluent is technically feasible for the cultivation of plants that are moderately tolerant to salinity, such as forage grasses, maize and bean (SIMÕES et al., 2016; SILVA et al., 2018a). Some studies have shown that drip irrigation with fish farming effluent in a differentiated management promotes segregation in the generating sources, minimizes environmental effects and maximizes social and economic benefits for rural communities (SOUZA et al., 2022).

Among the main advantages related to the reuse of fish farming effluent, the most prominent are the high organic content and saving in plant water demand, with probable reduction in soil chemical fertilization, which may result in increments in biomass production and yield of crops, enabling low-cost agricultural production, especially in regions affected by water scarcity problems (SALGADO et al., 2018).

The reuse of lower-quality water can meet the water requirement of plants, increasing nutritional supply and reducing the environmental impact caused by the release of this nutrient-rich effluent into the groundwater (MOURA; LOPES; HENRY-SILVA, 2014). However, water salinity greater than 2.0 dS m^{-1} significantly reduces the biomass production of *P. maximum*, mainly due to specific ions such as Na^+ and Cl^- (DIAS et al., 2019; PRAXEDES et al., 2019; SILVA et al., 2020).

Given the importance of developing technologies that allow the reuse of saline water in agriculture and a production system that can benefit small farmers, the objective of this study was to evaluate biomass production and nutrient contents in three cultivars of *P. maximum* irrigated with fish farming effluent.

MATERIAL AND METHODS

The study was conducted in a greenhouse, located in the Department of Agronomic and Forestry Sciences of the Federal Rural University of the Semi-Arid Region (UFERSA), East campus, in Mossoró, RN, Brazil, from July 2019 to January 2020. The greenhouse had metal structure, transparent plastic material cover and 50% shade net walls, with area of 126 m² and ceiling height of 4.0 m. The values of air temperature and relative humidity, monitored inside the greenhouse with a digital thermo-hygrometer (MINIPA©) during the experimental period, are presented in Figure 1.

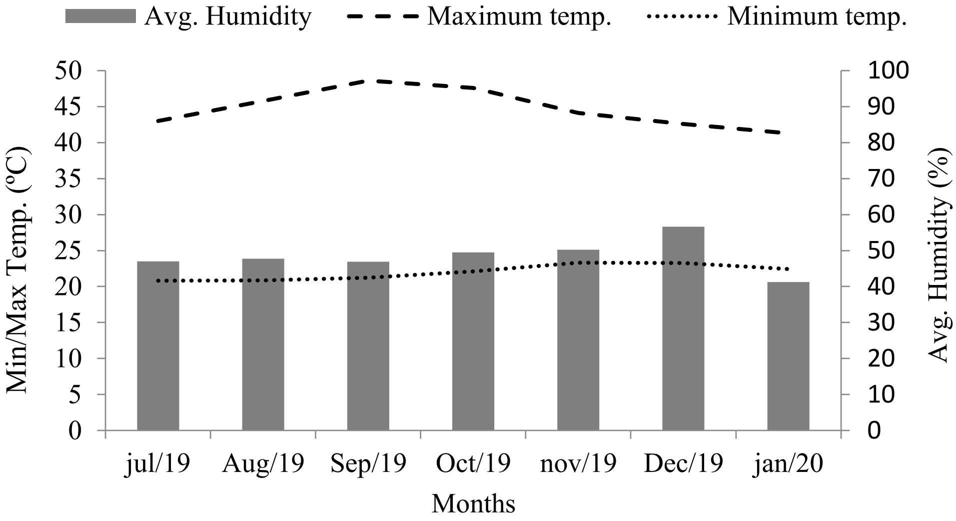

Figure 1. Temperature and relative humidity recorded inside the greenhouse during the experimental period.

The experiment was conducted in a complete randomized block design, with eight replicates, in a scheme of split-split plots in time. The plot consisted of three types of irrigation management (IM), which were: public-supply water (IM1-control), control + conventional fertilization (IM2) and irrigation with fish farming effluent (IM3). The subplot consisted of three cultivars of *P. maximum*, which were: Tanzania (C1), Mombasa (C2) and Massai (C3). The sub-subplot consisted of four cutting times (cycles), at 45, 90, 135 and 180 days after sowing.

Panicum maximum grass was cultivated in a *Latossolo Vermelho Amarelo distrófico argissólico* (Oxisol) (SANTOS et al., 2018), with sandy loam texture, collected in the 0.0-30.0 cm layer at the Rafael Fernandes Experimental Farm, belonging to UFERSA, located in the Lagoinha district, rural area of the municipality of Mossoró, RN, and its physical-chemical characteristics (TEIXEIRA et al., 2017) are presented in Table 1.

Soil preparation consisted of air drying and sifting, to remove impurities such as roots and gravel. Before planting the crop, liming was performed by applying calcium hydroxide ($CaOH_2$), according to the base saturation obtained in the soil analysis, with 54% calcium. The soil was corrected to increase base saturation to 90%. After 15 days of acidity correction, the soil under IM2 was fertilized according to the recommendations of Holanda et al. (2017), applying 600 mg of $P_2O_5^-$, 600 mg of K_2O, and 600 mg of N per pot, through fertigation, using monoammonium phosphate, potassium chloride and urea, respectively. After the first cutting, a top-dressing application was made in the IM2 treatment (public-supply water + fertilization), with the dose of 40 and 20 kg ha^{-1} of N and K_2O, respectively.

The plants were grown in lysimeters (plastic pots) with 20 dm^3 of soil, perforated at the base, which received a 3-cm-thick layer of crushed stone no. 1 and 2-mm-mesh nylon screen. The experimental unit consisted of one lysimeter, and the spacing was 0.50 m between pots and 1.0 m between rows. *Panicum* cultivars were manually sown on July 15, 2019, by placing approximately 20 seeds per pot at a depth of 1.0 cm. The seeds showed a germination power of 90% after 7 days and, when they reached 5.0 cm in height, thinning was performed, leaving only one plant per pot.

During the experimental period, daily irrigations were carried out, in the morning, based on the drainage lysimetry method using a drip irrigation system, formed by a Metalcorte/Eberle self-venting circulation motor-pump unit, actuated by a single-phase motor, with 210 V voltage and 60 Hz frequency, installed in a 60-L reservoir, with spaced emitters of 16-mm-diameter lines and flow rate of 2.5 L h^{-1}. Two types of water were used for irrigation, one from the supply network (PSW) of UFERSA's Central Campus, from the Water and Sewage Company of Rio Grande do Norte (CAERN), and the other consisting of fish farming effluent (FFE), collected in the Aquaculture Sector of UFERSA's East campus. Public-supply water was stored in a 1000-L water tank and the fish farming effluent was stored in two 2000-L water tanks. The chemical characterization of the water used in the experiment is presented in Table 2.

Table 1. Chemical and physical attributes of the soil used in the experiment.

pH	OM	P	K$^+$	Na$^+$	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al	SB	t	T	V	ESP
	(%)	---------- (mg dm^{-3}) --------			----------------------------- (cmol$_c$ dm^{-3}) -----------------------							-------- % -------	
5.30	1.67	2.1	54.2	21.6	2.70	0.90	0.05	1.82	3.83	3.88	5.65	68	2.0

BD (kg dm^{-3})	ECse (dS m^{-1})	Sand	Silt	Clay
		------------------------ (g kg^{-1}) ------------------------		
1.60	0.11	820	30	150

OM – Organic matter: Walkley-Black Wet Digestion; Ca^{2+} and Mg^{2+} extracted with 1 M KCl at pH 7.0; Na$^+$ and K$^+$ extracted with 1 M NH$_4$OAc at pH 7.0; Al^{3+} and (H$^+$ + Al^{3+}) extracted with 0.5 M CaOAc at pH 7.0; ECse – electrical conductivity of soil saturation extract; BD - bulk density; SB – sum of bases; t – effective cation exchange capacity; T – potential cation exchange capacity (pH = 7.0); V – base saturation; and ESP – exchangeable sodium percentage.

Table 2. Chemical characterization of the waters used in the experiment.

Public-supply water								
Period (Days)	K$^+$	Na$^+$	Mg^{2+}	Ca^{2+}	Cl$^-$	CO$_3^{2-}$	HCO$_3^-$	SAR
	------------------------mmol$_c$ L^{-1}------------------------							(mmol$_c$ L^{-1})$^{-0.5}$
1-45	0.28	4.56	0.80	0.70	2.40	0.40	2.90	5.20
46-90	0.31	6.54	0.30	1.10	3.00	0.50	3.00	7.80
91-135	0.18	6.05	0.40	0.90	2.80	0.20	2.80	7.50
136-180	0.20	7.62	0.30	0.70	2.60	0.30	2.6 0	6.37
Period (Days)	pH	EC	N	P	Cu	Fe	Mn	Zn
		dSm^{-1}	------------mg L^{-1}-----------		------------------------------mg L^{-1}-------------------------------			
1-45	7.82	0.50	0.10	0.10	0.02	0.05	0.03	0.08
46-90	8.29	0.55	0.10	0.10	0.03	0.06	0.05	0.05
91-135	8.00	0.60	0.15	0.10	0.03	0.04	0.03	0.07
136-180	7.93	0.65	0.10	0.10	0.02	0.07	0.03	0.04
Fish farming effluent								
Period (Days)	K$^+$	Na$^+$	Mg^{2+}	Ca^{2+}	Cl$^-$	CO$_3^{2-}$	HCO$_3^-$	SAR
	------------------------mmol$_c$ L^{-1}------------------------							(mmol$_c$ L^{-1})$^{-0.5}$
1-103	0.65	17.02	8.90	11.90	21.5	1.30	3.00	5.22
104-180	0.67	16.10	8.10	10.10	18.40	1.60	3.30	5.30
Period (Days)	pH	EC	N	P	Cu	Fe	Mn	Zn
		dSm^{-1}	-----------mg L^{-1}------------		--------------------------------mg L^{-1}-----------------------------			
1-103	8.15	3.65	2.30	0.79	0.03	0.65	0.08	0.10
104-180	8.45	3.00	2.35	0.72	0.04	0.50	0.05	0.15

pH – Hydrogen potential; EC – Electrical conductivity; K$^+$ – Potassium; Na$^+$ – Sodium; Mg^{2+} – Magnesium; Ca^{2+} – Calcium; Cl$^-$ – Chlorine; CO$_3^{2-}$ – Carbonate; HCO$_3^-$ – Bicarbonate; SAR – Sodium adsorption ratio, N – Nitrogen, P – Phosphorus, Cu – Copper, Fe – Iron, Mn – Manganese, Zn – Zinc.

At the end of the experiment, soil samples were collected in each experimental plot studied (IM1, IM2, IM3), for the three *Panicum maximum* cultivars, sent to the laboratory and characterized for soil fertility (Table 3) according to Teixeira et al. (2017). The three cultivars were analyzed in four cuttings, at 45, 90, 135 and 180 days after sowing. The plants were cut at 10 cm height above the soil surface, using scissors. The plant material was placed in paper bags, dried in an air circulation oven at temperature of 65 °C until reaching constant weight, and subsequently weighed to obtain dry biomass production.

Table 3. Chemical attributes of the soil at the end of the experiment.

Cultivar	OM	N	P	K^+	Na^+	Ca^{2+}	Mg^{2+}	(H+Al)
	-------------------g kg^{-1}----------------		-----------mg dm^{-3}------------		--------------------$cmol_c$ dm^{-3}--------------------			
IM1 - irrigation with public-supply water (control)								
Tanzania	8.9	0.4	10.9	16.5	31.1	1.0	0.6	0.0
Mombasa	9.9	0.5	10.9	17.1	39.8	1.2	0.4	0.0
Massai	8.4	0.4	11.5	18.4	35.3	1.0	0.6	0.0
IM2 - irrigation with public-supply water + fertilization with NPK								
Tanzania	9.8	0.5	25.0	33.6	35.6	1.2	0.4	0.0
Mombasa	10.5	0.5	15.0	34.8	37.5	1.2	0.4	0.0
Massai	9.1	0.5	18.0	33.1	37.8	1.0	0.7	0.0
IM3 - irrigation with fish farming effluent								
Tanzania	17.7	0.5	22.9	68.2	33..2	2.6	2.7	0.0
Mombasa	19.3	0.6	21.0	75.5	491.0	2.7	2.7	0.0
Massai	20.5	0.6	24.6	77.8	488.6	3.1	1.8	0.0

Cultivar	Fe	Mn	Cu	Zn	pH	EC	CEC	ESP
	-----------------------mg dm^{-3}--------------------------				H_2O	dS m^{-1}	$cmol_c$ dm^{-3}	%
IM1 - irrigation with public-supply water (control)								
Tanzania	8.4	10.1	0.2	2.0	7.6	0.2	1.8	7.6
Mombasa	7.0	9.2	0.3	1.8	7.4	0.2	1.8	9.5
Massai	8.1	8.6	0.3	1.7	7.4	0.2	1.8	8.5
IM2 - irrigation with public-supply water + fertilization with NPK								
Tanzania	10.9	9.3	0.2	1.8	7.6	0.3	1.8	8.4
Mombasa	9.5	9.8	0.3	1.6	7.5	0.2	1.9	8.8
Massai	9.7	9.1	0.3	1.9	6.8	0.4	1.9	8.4
IM3 - irrigation with fish farming effluent								
Tanzania	8.9	10.8	0.4	1.9	7.2	1.2	6.9	20.8
Mombasa	14.6	9.0	0.3	1.8	7.2	1.2	7.7	27.6
Massai	13.6	10.9	0.3	1.6	7.2	0.9	7.2	29.4

OM – Organic matter: Walkley-Black Wet Digestion; Ca^{2+} and Mg^{2+} extracted with 1 M KCl at pH 7.0; Na^+ and K^+ extracted with 1 M NH_4OAc at pH 7.0; EC – electrical conductivity of the 1:2.5 extract. N was determined by the Kjeldahl method.

Plant dry matter samples were crushed in a Wiley mill and analyzed for contents of nitrogen (N), phosphorus (P), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn). In the laboratory, the material was subjected to sulfuric acid wet digestion ($H_2SO_4 + H_2O_2$) in an open system, to determine the total leaf N contents by the Kjeldahl method (MIYAZAWA et al., 2009). Nitric digestion (HNO_3) was performed in a microwave oven to determine the contents of P, K, Na, Ca, Mg, Fe, Cu, Mn and Zn by means of inductively coupled plasma atomic emission spectrometry (MIYAZAWA et al., 2009).

The data obtained in the experiment were subjected to analysis of variance, F test ($p \leq 0.05$); in case of significance, the means were compared by Tukey test at 1% and 5% probability levels, using SISVAR 5.6 software (FERREIRA, 2019).

RESULTS AND DISCUSSION

The interaction between irrigation management and cultivars ($p<0.05$) and the interaction between irrigation management and cutting times ($p<0.01$) significantly influenced the biomass production of *P. maximum* grass.

In the interaction between irrigation management and cultivars for *P. maximum* grass, it was found that biomass production is independent of the studied variety of *P. maximum* grass, because higher biomass production is obtained under irrigation with public-supply water and fertilization with NPK (IM2) (Table 4). The biomass production of irrigated and fertilized grass is clearly higher than that found in the other treatments. Canto et al. (2013) and Galindo et al. (2018a) also observed increments in biomass productivity in fertilized pastures.

The results for grass irrigated with public-supply water (IM1) and grass irrigated with fish farming effluent (IM3) were similar among cultivars, except for the cv. Massai, which obtained lower biomass production when irrigated with fish farming effluent (41.63 g pot^{-1}) compared to the production obtained under irrigation with public-supply water (48.31 g pot^{-1}) (Table 4). The salinity of the effluent (3.0-3.65 dS m^{-1}) associated with the restriction of the container used in the experiment intensifies the soil salinization process, causing delay in the expected biomass production. The literature shows that waters with electrical conductivity greater than 2.0 dS m^{-1} significantly reduce *Panicum maximum* biomass production, mainly due to specific ions such as Na^{+} and Cl^{-} (DIAS et al., 2019; PRAXEDES et al., 2019; SILVA et al., 2020).

Table 4. Dry biomass production (g pot^{-1}) of *P. maximum* grass for a split-split-plot scheme as a function of irrigation management (IM), cultivars (C) and cutting times (CT), respectively.

Cultivar	Irrigation Management (IM)		
	IM1	IM2	IM3
Tanzania	41.79 b	85.54 a	43.70 b
Mombasa	47.84 b	82.89 a	43.04 b
Massai	48.31 b	84.32 a	41.63 c
Cutting Times (CT)	IM1	IM2	IM3
CT1	21.18 b	33.08 a	20.58 b
CT2	50.93 b	99.21 a	50.22 b
CT3	48.20 b	94.97 a	43.82 b
CT4	63.60 b	109.73 a	56.55 c

IM1 = irrigation with public-supply water; IM2 = irrigation with public-supply water + fertilization with NPK; IM3 = irrigation with fish farming effluent; CT1 = 45 days after sowing; CT2 = 90 days after sowing; CT3 = 135 days after sowing; CT4 = 180 days after sowing. Lowercase letters in the same row compare means by Tukey test at 5% probability level ($p<0.05$).

In the interaction between irrigation management and cutting times, the best biomass production was observed in grass irrigated with public-supply water and fertilized with NPK (IM2). The values of biomass production for grass irrigated with public-supply water (IM1) and grass irrigated with fish farming effluent (IM3) were similar in all cuttings, except for the fourth, when the biomass production of grass irrigated with public-supply water (63.60 g pot^{-1}) was higher than that obtained with irrigation with fish farming effluent (56.55 g pot^{-1}) (Table 4). However, the literature has reported reductions in biomass production since the first cut (DIAS et al., 2019; PRAXEDES et al., 2019; SILVA et al., 2020). In this context, it is understood that prolonged irrigation with IM3 reduces the biomass production of *P. maximum* cultivars. Table 3 shows that the soil irrigated with fish farming effluent obtained higher nutrient accumulation and higher percentage of exchangeable sodium (sodium that is bound to negative charges of the soil). The lower biomass production of *P. maximum* grass irrigated with fish farming effluent occurred due to the increase in soil salinity and sodicity.

The interaction between irrigation management (IM), cultivars (C) and cutting times (CT) was significant for nitrogen and calcium contents ($p\leq0.05$) and for phosphorus, potassium, magnesium and sodium contents ($p\leq0.01$) in *P. maximum* grass.

In the first cut, the N contents of Mombasa and Massai cultivars were lower when plants were irrigated with public-supply water and fertilized with NPK (IM2) (10.77 and 10.01 g kg^{-1}, respectively), compared to plants irrigated with fish farming effluent (IM3) (12.80 and 11.77 g kg^{-1}, respectively) (Table 5). In the second cut, there was no difference caused by irrigation management for these two cultivars. However, in the third cut the highest N contents for the three cultivars were obtained when plants were irrigated with public-supply water and fertilized with NPK (IM2). In the fourth cut, the N contents of the *P. maximum* cultivars were similar under all types of irrigation managements.

In the first cut, N contents ranged from 8.37 to 12.80 g kg^{-1}, but in the fourth cycle the values were on the order of 0.68 to 1.86 g kg^{-1} of N. From the third cut, there was a sharp decrease in N content. These results indicate that in the third cycle a supplementation with N would be required. However, nutrient contents may vary depending on plant age and stage of development because, with the maturity stage, forage species tend to decrease their N, P and Mg contents and increase their Ca content (MALAVOLTA et al., 1974). The decrease in N contents in this study did not mean decrease in biomass production (Table 4). However, the biomass production of fertilized grass (IM2) was up to two times higher than that of unfertilized grass (IM1 and IM3).

Table 5. Nitrogen (N), phosphorus (P) and potassium (K) contents in *P. maximum* grass plants in split-split-plot scheme as a function of irrigation management (IM), cultivars (C) and cutting times (CT), respectively.

Cultivar (C)	Irrigation Management (IM)	Cutting Times (CT)			
		CT1	CT2	CT3	CT4
		N (g kg^{-1})			
Tanzania	IM1	8.37 bB	5.25 cC	3.28 bC	0.77 aA
	IM2	11.43 aA	9.83 aA	6.07 aA	1.86 aA
	IM3	11.27 aB	8.06 bB	3.99 bA	0.82 aA
Mombasa	IM1	12.36 aA	8.64 aA	4.76 abA	0.68 aA
	IM2	10.77 bAB	9.52 aAB	5.09 aA	0.88 aA
	IM3	12.80 aA	9.95 aA	3.61 bA	1.48 aA
Massai	IM1	11.16 abA	7.10 aB	4.27 bAB	0.82 aA
	IM2	10.01 bB	8.26 aB	6.02 aA	1.09 aA
	IM3	11.77 aAB	7.26 aB	3.66 bA	0.88 aA
		P (g kg^{-1})			
Tanzania	IM1	2.12 bA	2.03 bA	2.17 bA	1.74 bA
	IM2	2.99 aB	3.55 aA	4.10 aA	1.52 bA
	IM3	2.76 abA	2.53 bA	2.46 bA	2.56 aA
Mombasa	IM1	2.17 bA	1.80 bA	1.53 bA	1.26 aAB
	IM2	3.09 aB	3.70 aA	4.10 aA	1.83 aA
	IM3	1.83 bB	2.41 bA	2.12 bA	1.77 aB
Massai	IM1	2.58 bA	1.70 aA	1.86 bA	0.76 bB
	IM2	4.09 aA	2.00 aB	3.58 aA	1.45 aA
	IM3	1.76 cB	2.19 aA	2.47 bA	1.60 aB
		K (g kg^{-1})			
Tanzania	IM1	7.42 cA	5.80 bB	8.06 aA	6.91 bA
	IM2	9.06 bA	7.45 aA	8.32 aA	6.27 bB
	IM3	10.40 aA	8.35 aA	8.44 aA	9.31 aB
Mombasa	IM1	7.50 bA	5.91 bB	6.75 bB	6.29 cA
	IM2	8.57 aA	7.02 aA	8.12 aA	7.37 bA
	IM3	7.50 bB	7.70 aA	8.73 aA	9.18 aB
Massai	IM1	7.94 cA	7.32 abA	8.08 aA	6.95 bA
	IM2	9.46 bA	7.08 bA	8.21 aA	7.32 bA
	IM3	10.81 aA	8.27 aA	8.95 aA	10.42 aA

IM1 = irrigation with public-supply water; IM2 = irrigation with public-supply water + fertilization with NPK; IM3 = irrigation with fish farming effluent; CT1 = 45 days after sowing; CT2 = 90 days after sowing; CT3 = 135 days after sowing; CT4 = 180 days after sowing. Lowercase letters in the column compare IM within the C x CT interaction by Tukey test at 5% probability level ($p<0.05$). Uppercase letters in the column compare C within the IM x CT interaction by Tukey test at 5% probability level ($p<0.05$).

In the cultivars, the N contents of Tanzania grass plants irrigated with fish farming effluent (IM3) were higher than those of plants irrigated with public-supply water without fertilization (IM1). And higher N contents were observed for the cv. Tanzania, with IM2, in the first, second and third cuts (Table 5). The cv. Tanzania was more responsive to N fertilization in the first two cuts than the cultivars Mombasa and Massai. When it did not receive N (IM1), the cv. Tanzania obtained the lowest leaf N contents, indicating that this cultivar is more sensitive to N availability in the soil. The cv. Mombasa obtained the highest N contents in the first and second cut, when compared to the other cultivars, being the most efficient in extracting N from the soil. Thus, the cv. Mombasa has high response to N fertilization, showing rapid growth of the aerial part (GALINDO et al., 2018b). The available N in the fourth cut was not enough for a good performance of this cultivar. In the cv. Massai in IM2, N contents were lower than those in the cultivars Mombasa and Tanzania in the first and second cuts. Silva et al. (2018b) found that Massai grass has low utilization of N from N fertilization due to volatilization.

The highest P contents of *P. maximum* cultivars from the first to the third cut occurred in IM2, except for cv. Massai in the second cut, which did not differ for irrigation management. In the fourth cut, the cv. Tanzania obtained higher P content when irrigated with fish farming effluent. However, there was no difference in P contents as a function of irrigation management for the cv. Mombasa. However, the cv. Massai in the fourth cut obtained higher P contents under IM2 and IM3. The cv. Tanzania, when irrigated with fish farming effluent, obtained the highest P contents in the first and fourth cuts compared to the cultivars Mombasa and Massai. Over the cutting times, the P content in the IM1 treatment decreased, but the P values remained stable in IM2 and IM3 until the third cut. In the fourth cut, there was a considerable decrease in the P contents of the cultivars, mainly in IM1 and IM2, and in the cultivars Mombasa and Massai under IM3. It is worth pointing out that the cv. Tanzania, when irrigated with IM3, obtained stable P contents throughout the cycles, which ranged from 2.76 to 2.46 g kg^{-1} (Table 5).

Regarding the behavior of the cultivars throughout the cycles, the cv. Tanzania in the fourth cut also obtained the highest P content when irrigated with IM3, indicating that this cultivar is more efficient in extracting P from the soil than the others, even under conditions of higher soil salinity (Table 5). However, under conditions of high soil salinity and sodicity, as observed in IM3 (Table 3), even with higher soil P levels than in IM2, the cultivars Mombasa and Massai had difficulty absorbing P in the saline soil. Conversely, the cv. Massai, compared to the others, showed lower P content when irrigated with IM3, which indicates that this variety is more sensitive to low P availability in the soil than the others, especially under conditions of high salinity (Tables 3 and 5). Low P contents may compromise the structural development of *Panicum* grass, so the addition of this nutrient is fundamental for the development of this crop (FLORENTINO et al., 2022). In this context, the ability of *P. maximum* grass to absorb P under conditions of high salinity, as observed in the cv. Tanzania, may be an indication of salinity tolerance, since the cv. Massai, which had lower P contents in the fourth cut, obtained the lowest biomass production when irrigated with fish farming effluent (Table 4).

In the analysis of IM within the C x CT interaction, the cultivars Tanzania and Massai in the first cut had the highest K contents with IM3. For the cv. Mombasa, the highest K content occurred in IM2 (Table 5). In the second cut, the K contents obtained under IM2 and IM3 were similar in the cultivars Tanzania and Mombasa, being higher than those found under IM1. For the cv. Massai, the highest K content, in the second cut, occurred in IM3. In the third cut, there was no difference between the types of irrigation management for the cultivars Tanzania and Massai. In turn, in the cv. Mombasa the K contents found under IM2 and IM3 were higher than those found under IM1 (control). In the fourth cut, the K contents of the three cultivars of *P. maximum* irrigated with fish farming effluent (IM3) were higher than those found with IM1 and IM2.

In the analysis of C within the IM x CT interaction, the cultivars Tanzania and Massai showed higher K contents under IM3, whereas the cv. Mombasa, in general, showed similar results, with the highest K contents under IM2 and IM3 (Table 5). Irrigation with fish farming effluent increased the K content in the shoots of the *P. maximum* cultivars, mainly Massai. Fish farming effluent, in addition to sodium, contains high concentration of potassium, which favored the absorption of this nutrient when compared to grass irrigated with public-supply water without and with fertilization with NPK.

According to the calcium (Ca) contents (Table 6), it was found that, in the first cut, the contents of this nutrient were not influenced by IM. In the second cut, it was observed that the cv. Massai had the lowest Ca content in the tillers when irrigated with IM1. For the third and fourth cuts, the highest Ca contents occurred when the cultivars were subjected to IM3 and the lowest Ca contents were obtained under IM1 for Mombasa and Tanzania, respectively.

Ca was better absorbed by the Panicum cultivars analyzed when they were subjected to fish farming effluent (IM3), with contents ranging from 3.63 to 6.60 g kg-1, followed by NPK fertilization (IM2), with contents ranging from 3.31 to 4.80 g kg-1 and then by IM1, with contents ranging from 3.83 to 4.48 g kg-1 (Table 6). These results can be attributed to the residual effect of nutrients present in fish farming effluent (IM3), which promoted improvement in plant nutritional status. According to Malavolta, Liem and Primavesi (1986), the adequate Ca contents for Panicum grass range between 1.5 and 6.0 g kg-1. The values observed in the present study are within or very close to the range described Malavolta, Liem and Primavesi (1986).

In the analysis of IM within the C x CT interaction, in the first cut for Mg content (Table 6), it was observed that the cv. Tanzania had the highest Mg contents under IM1 and IM2. For the cultivars Mombasa and Massai, the highest Mg contents were observed when they were irrigated with IM3. In the second, third and fourth cuts, the highest Mg contents for all cultivars analyzed were observed in IM3. The cultivars of P. maximum accumulated Mg in their tissues when irrigated with fish farming effluent (IM3).

Table 6. Calcium (Ca), magnesium (Mg) and sodium (Na) contents of *P. maximum* grass in a split-split-plot scheme as a function of irrigation management (IM), cultivars (C), and cutting times (CT), respectively.

Cultivar (C)	Irrigation Management (IM)	Cutting Times (CT)			
		CT1	CT2	CT3	CT4
Ca (g kg^{-1})					
Tanzania	IM1	3.60 aA	3.80 aAB	4.27 bA	3.71 cB
	IM2	3.77 aA	4.11 aA	4.49 bA	4.80 cA
	IM3	3.70 aA	4.54 aA	6.04 aA	6.53 aA
Mombasa	IM1	3.83 aA	4.10 aA	3.43 cB	4.02 bAB
	IM2	3.31 aA	4.16 aA	4.61 bA	4.41 bA
	IM3	3.79 aA	4.68 aA	5.95 aA	6.66 aA
Massai	IM1	3.65 aA	3.17 bB	4.05 bAB	4.48 bA
	IM2	3.77 aA	4.48 aA	4.57 bA	4.24 bA
	IM3	3.63 aA	4.40 aA	5.86 aA	6.60 aA
Mg (g kg^{-1})					
Tanzania	IM1	5.74 aA	4.09 bAB	4.55 bAB	2.79 cA
	IM2	6.08 aA	4.31 bA	4.44 bA	4.49 bA
	IM3	4.34 bC	6.26 aB	8.09 aB	9.87 aA
Mombasa	IM1	4.53 bB	4.29 bA	4.19 bB	3.21 bA
	IM2	4.94 bB	4.52 bA	4.51 bA	3.94 bA
	IM3	5.92 aB	7.70 aA	9.35 aA	10.62 aA
Massai	IM1	5.16 bAB	3.28 bB	5.18 bA	3.28 cA
	IM2	5.28 bAB	3.88 bA	4.27 bA	4.79 bA
	IM3	6.97 aA	7.58 aA	8.92 aAB	9.74 aA
Na (g kg^{-1})					
Tanzania	IM1	2.08 bA	2.62 bA	4.00 cA	5.71 cB
	IM2	2.14 bA	2.66 bB	7.77 bC	9.73 bB
	IM3	3.11 aAB	5.74 aB	13.11 aA	16.51 aB
Mombasa	IM1	1.92 bA	2.95 bA	4.43 cA	6.31 cAB
	IM2	2.01 bA	2.91 bB	9.44 bB	12.93 bA
	IM3	3.75 aA	5.28 aB	13.65 aA	18.80 aA
Massai	IM1	2.05 aA	2.76 cA	4.72 cA	6.88 cA
	IM2	2.37 aA	4.57 bA	10.66 bA	12.86 bA
	IM3	2.66 aB	12.86 aA	13.16 aA	15.41 aC

IM1 = irrigation with public-supply water; IM2 = irrigation with public-supply water + fertilization with NPK; IM3 = irrigation with fish farming effluent; CT1 = 45 days after sowing; CT2 = 90 days after sowing; CT3 = 135 days after sowing; CT4 = 180 days after sowing. Lowercase letters in the column compare IM within the C x CT interaction by Tukey test at 5% probability level ($p<0.05$). Uppercase letters in the column compare C within the IM x CT interaction by Tukey test at 5% probability level ($p<0.05$).

In the analysis of C within the IM x CT interaction, in the first cut for Mg content (Table 6), it was observed that the cv. Mombasa under the three types of irrigation management obtained the lowest Mg contents compared to the others. In the second and third cuts, the cv. Mombasa obtained the highest Mg contents for all types of irrigation water, except for the third cut of the cv. Mombasa irrigated with IM1, when Mg contents were higher than those found in the other cultivars under this management condition. It is worth pointing out that the cultivar Tanzania absorbs the lowest Mg contents when irrigated with fish farming effluent in the first, second and third cuts, compared to the others, with contents of 4.34, 6.26 and 8.09 g Mg kg^{-1} of dry matter, respectively. However, the values obtained for Tanzania grass are higher than those found in the literature, which range from 1.8 to 2.5 g (Mg) kg^{-1} of dry matter (SILVEIRA; MONTEIRO, 2010). The high Mg contents observed in *P. maximum* cultivars can be explained by the high concentrations of Mg in irrigation water, especially in the fish farming effluent (Table 2).

For the Na content in the analysis of IM within the C x CT interaction, it was observed that, for all cultivars at all cutting times, the highest Na content was obtained when plants were irrigated with fish farming effluent, except in the first cut of the cv. Massai, when there was no difference between the types of irrigation management (Table 6). The high Na contents in *P. maximum* cultivars irrigated with fish farming effluent are due to the high Na concentrations present in the effluent, ranging from 16.1 to 17.02 mmol$_c$ L^{-1} (Table 2), thus influencing the biomass of the cultivars, especially Massai (Table 4). Thus, a careful management of drip irrigation is needed for using fish farming effluent in the cultivation of *P. maximum* cultivars, mainly with the use of a drainage system, since it poses risk of toxicity to plants, due to the high concentrations of Na and Cl ions, which may reduce biomass accumulation, as verified by other authors (DIAS et al., 2019; PRAXEDES et al., 2019; SILVA et al., 2020).

For the Na contents of the *P. maximum* cultivars within the IM x CT interaction, it was found that the cultivar Mombasa under IM2 and IM3 had the highest Na contents in the fourth cut, followed by the cultivars Tanzania and Massai, respectively (Table 6). The biomass production of the cv. Massai was reduced when it was irrigated with IM3 compared to IM1 (Table 4), but the cv. Massai had the lowest Na content in the tissues, in the fourth cut when compared to the others, indicating that this cultivar is more sensitive to Na accumulation in tissues and expends more energy in the process of Na exclusion in the roots than the other cultivars studied, which compromises its biomass accumulation. Conversely, the cultivars Mombasa and Tanzania can better cope with high Na contents in tissues, since they had similar biomass production between IM1 and IM3 (Table 4). The highest Na contents were verified in the fourth cut, coinciding with the period in which there was a difference in biomass production between IM1 and IM3 (Table 4). Therefore, it can be inferred that Na contents above 13.11, 13.65 and 13.16 g hg^{-1} of dry matter (verified in the third cut), in the leaves of the cultivars Tanzania, Mombasa and Massai, respectively, can cause toxicity and biomass loss (Tables 4 and 6).

The IM x CT x C interaction was significant for the iron content ($p<0.05$) and for the zinc and copper contents ($p<0.01$) of *P. maximum* grass. The manganese (Mn) content of *P. maximum* grass was significantly affected ($p<0.01$) only by cutting time.

For Fe content in each cut (Table 7), it was found that, in the first, second and third cuts, IM3 promoted higher Fe contents in all cultivars. In the fourth cut, only the cultivars Tanzania and Massai showed higher contents of the micronutrient when irrigated with IM3, while Mombasa showed higher Fe contents when subjected to IM1 and IM2. It was observed that Fe contents increased with shoot maturity. However, in the fourth cycle, the values decreased. This was probably a consequence of the competitive inhibition between Fe and Mn, resulting in the negative effect of Fe absorption. The range of the micronutrient Fe found in the study was 37.94-223.58 mg kg^{-1}. For Werner et al. (1997), the range considered suitable for iron is 50-200 mg kg^{-1} contained in the shoot dry matter. Therefore, only in the first cut the plants were Fe deficient, although they showed no visual symptoms, and this nutrient was supplied by irrigation.

Regarding the Zn content of the *P. maximum* cultivars (Table 7), it was observed in the first cut that the cultivars differed as a function of IM, with higher Zn contents in the cv. Tanzania when subjected to IM2, and in the cultivars Mombasa and Massai when subjected to IM3. For the second, third and fourth cuts, it was observed that the highest Zn contents were found when the cultivars were subjected to IM3.

The IM1 treatment promoted lower Zn supply, and IM3 promoted greater Zn supply. There was a decrease in Zn contents from the fourth cut, when plants were irrigated with IM1 and IM2. With IM3, there was a decrease, but not so significant. In the four cuts evaluated, the Zn contents were within the range indicated by Werner et al. (1997), who reported adequate values between 20 and 300 mg kg^{-1} for forage species in ruminant feeding, and those obtained in this study are between 23.69 and 85.90 mg kg^{-1}.

In relation to the Cu contents of the *P. maximum* cultivars for the first cut, the cultivars Mombasa and Massai were similar under all irrigation managements (Table 7). The cv. Tanzania, during this period, had higher Cu contents in IM1. In the second and third cut, IM3 favored Cu absorption by plants, which was possibly due to the presence of Cu in the effluent. In the fourth cut, there was no influence of IM on Cu absorption by plants, and this decrease is explained by the low availability of Cu in the soil. In general, when comparing the Cu contents obtained in this study (Table 7) with the levels suggested by Guimarães, Ferreira and Carvalho (1980), it can be affirmed that the contents of this element in the plants can be considered adequate in the first and second cuts and low in the third and fourth cuts, since the authors classified them as low up to 4 mg kg^{-1} and as adequate between 5 and 15 mg kg^{-1}.

Regarding the Mn content of the *P. maximum* cultivars (Table 8), it was observed that there was no difference with the use of IM, that is, the cultivars were similar in the absorption of this micronutrient. However, maturity influenced the availability of Mn in the cultivars, with a decrease along the cuts.

The *Panicum* cultivars evaluated had low tolerance to Mn, which was possibly due to competition with Fe, because these elements are antagonistic, so a high content of Fe (Table 7) inhibited the absorption of Mn in the cultivars (GONÇALVES JR et al., 2015). When comparing the Mn contents of the *Panicum* cultivars with the levels suggested by Werner et al. (1997), it can be affirmed that the contents of this element in the first and third cuts can be considered adequate and low in the second and fourth cuts, since the range considered adequate for forage grasses according to these authors is 40-250 mg kg^{-1}.

Table 7. Iron (Fe), zinc (Zn) and copper (Cu) contents of *P. maximum* grass in a split-split-plot scheme as a function of irrigation management (IM), cultivars (C) and cutting times (CT), respectively.

Cultivar (C)	Irrigation Management (IM)	Cutting Times (CT)			
		CT1	CT2	CT3	CT4
		Fe (mg kg^{-1})			
Tanzania	IM1	39.13 bA	94.31 bA	71.56 bA	66.88 aAB
	IM2	38.19 bA	88.16 bA	76.56 bA	56.69 aB
	IM3	54.67 aA	199.57 aB	212.80 aAB	69.31 aAB
Mombasa	IM1	37.94 bA	90.00 bA	70.44 bA	72.25 aA
	IM2	41.13 bA	88.94 bA	66.71 bA	73.63 aA
	IM3	60.38 aA	194.63 aB	201.50 aB	60.25 aB
Massai	IM1	48.38 bA	89.86 bA	76.56 bA	56.14 bB
	IM2	43.56 bA	88.67 bA	70.75 bA	69.67 abAB
	IM3	67.50 aA	223.58 aA	218.38 aA	77.30 aA
		Zn (mg kg^{-1})			
Tanzania	IM1	42.63 aA	35.31 bA	35.44 bB	25.19 bA
	IM2	53.19 aA	42.50 bA	42.13 bA	24181 bA
	IM3	43.88 aA	57.00 aB	58.56 aA	43.75 aA
Mombasa	IM1	41.44 bA	34.31 bA	42.38 bA	23.69 bA
	IM2	43.44 abA	35.69 bA	50.29 bA	26.06 bA
	IM3	55.13 aA	63.03 aB	65.13 aA	45.75 aA
Massai	IM1	41.56 bA	34.13 bA	49.94 aA	26.00 bA
	IM2	50.44 abA	40.75 bA	52.38 aA	26.38 bA
	IM3	54.64 aA	85.90 aA	61.13 aA	42.63 aA
		Cu (mg kg^{-1})			
Tanzania	IM1	5.50 aA	6.44 aA	3.75 bA	3.69 aA
	IM2	4.19 bA	6.75 aA	3.69 bA	2.00 bA
	IM3	3.44 bB	6.81 aB	5.44 aA	3.56 aA
Mombasa	IM1	5.19 aA	6.94 abA	3.44 bA	3.00 aA
	IM2	4.57 aA	5.94 bA	3.56 bA	2.50 aA
	IM3	4.57 aA	7.29 aB	5.88 aA	3.44 aA
Massai	IM1	5.88 aA	6.31 bA	3.69 bA	3.69 aA
	IM2	5.06 aA	2.19 cB	3.56 bA	2.19 bA
	IM3	5.07 aA	8.57 aA	5.81 aA	3.50 aA

IM1 = irrigation with public-supply water; IM2 = irrigation with public-supply water + fertilization with NPK; IM3 = irrigation with fish farming effluent; CT1 = 45 days after sowing; CT2 = 90 days after sowing; CT3 = 135 days after sowing; CT4 = 180 days after sowing. Lowercase letters in the column compare IM within the C x CT interaction by Tukey test at 5% probability level ($p<0.05$). Uppercase letters in the column compare C within the IM x CT interaction by Tukey test at 5% probability level ($p<0.05$).

Table 8. Manganese (Mn) content of *P. maximum* grass as a function of cutting times (CT).

Cutting Time	Mn (mg kg^{-1})
CT1	69.42 a
CT2	37.06 c
CT3	40.82 b
CT4	34.97 c

CT1 = 45 days after sowing; CT2 = 90 days after sowing; CT3 = 135 days after sowing; CT4 = 180 days after sowing. Lowercase letters in the column compare means by Tukey test at 5% probability level ($p<0.05$).

CONCLUSIONS

The highest biomass production and the best nutritional status are obtained in irrigated and fertilized grass, but fish farming effluent can be used in the irrigation of *P. maximum*, assuming production losses.

Irrigation with fish farming effluent increases sodium content in *P. maximum* plants, which led to a reduction in the biomass of all cultivars, requiring monitoring of salinity in the *P. maximum* cultivars.

The salinity of fish farming effluent increased Ca, Mg, Fe, Mn and Zn contents in the tissues, resulting in nutritionally acceptable values for the *P. maximum* cultivars.

REFERENCES

CANTO, M. W. et al. Características do pasto e eficiência agronômica de nitrogênio em capim-tanzânia sob pastejo contínuo, adubado com doses de nitrogênio. **Ciência Rural**, 43: 682-688, 2013.

DIAS, N. S. et al. Biomass, protein content and cell damage in Tanzânia grass irrigated with saline water. **Journal of Agricultural Science**, 11: 59-66, 2019.

FERREIRA, D. F. Sisvar: a computer analysis system to fixed effects split plot type designs. **Revista Brasileira de Biometria**, 37: 529-535, 2019.

FLORENTINO, L. S. et al. Avaliação da produção de biomassa de forragem do capim *Panicum maximum* cv. mombaça submetido a adubação mineral e orgânica. **Brazilian Journal of Development**, 8: 1131-1144, 2022.

GALINDO, F. S. et al. Acúmulo de matéria seca e nutrientes no capim-mombaça em função do manejo da adubação nitrogenada. **Revista de Agricultura Neotropical**, 5: 1-9, 2018a.

GALINDO, F. S. et al. Manejo da adubação nitrogenada no capim-mombaça em função de fontes e doses de nitrogênio. **Revista de Ciências Agrárias**, 41: 900-913, 2018b.

GONÇALVES JR, A. C. et al. Teores de nutrientes e metais pesados em plantas de estragão submetidas a diferentes fertilizações. **Revista Ciência Agronômica**, 46: 233-240, 2015.

GUIMARÃES, P. T. G.; FERREIRA, J. G.; CARVALHO, J. G. Adubação de pastagens. **Informe Agropecuário**, 6: 34-52, 1980.

HOLANDA, J. S. et al. **Indicações para adubação de culturas em solos do Rio Grande do Norte**. Parnamirim, RN: EMPARN, 2017. 63 p.

MALAVOLTA, E. et al. **Nutrição mineral e adubação de plantas cultivadas**. 2. ed. São Paulo, SP: Pioneira, 1974. 727 p.

MALAVOLTA, E.; LIEM, T H.; PRIMAVESI, A. C. P. A. Exigências nutricionais das plantas forrageiras. In: MATTOS et al., (Eds.). **Calagem e Adubação de Pastagens**. Piracicaba, SP: Associação Brasileira da Potassa e do Fosfato. 1986. v. 1, cap. 2. p. 31-76.

MOURA, R. S. T.; LOPES, Y. V. A.; HENRY-SILVA, G. G. Sedimentação de nutrientes e material particulado em reservatório sob influência de atividades de piscicultura no semiárido do Rio Grande do Norte. **Química Nova**, 37: 1283-1288, 2014.

MIYAZAWA, M. et al. Análise química de tecidos vegetais. In: Silva, F. C. (Ed.) **Manual de análise química de solos, plantas e fertilizantes**. 2. ed. Brasília, DF: Embrapa Informação Tecnológica, 2009. v. 1, cap. 2. p. 191-233.

PEDRO-MONZONÍS, M. et al. A review of water scarcity and drought indexes in water resources planning and management. **Journal of Hydrology**, 527: 482-493, 2015.

PRAXEDES, S. S. C. et al. Desempenho do capim Tanzânia irrigado com água salobra aplicada via aspersão e gotejamento. **Irriga**, 24: 236-253, 2019.

PRAXEDES, S. S. C. et al. Photosynthetic responses, growth, production, and tolerance of traditional varieties of cowpea under salt stress. **Plants**, 11: 1-18, 2022.

SALGADO, V. C. et al. Watermelon cultivation in the semi-arid irrigated with different heights of treated domestic sewage. **Engenharia Sanitária e Ambiental**, 23: 727-738, 2018.

SÁNCHEZ, A. S.; NOGUEIRA, A. B. R.; KALID, R. A. Uses of the reject brine from inland desalination for fish farming, *Spirulina* cultivation, and irrigation of forage shrub and crops. **Desalination**, 364: 96-107, 2015.

SANTOS, H. G. et al. **Sistema Brasileiro de Classificação de Solos**. 5 ed., rev. e ampl. - Brasília, DF: Embrapa, 2018. 356 p.

SILVA, A. B. et al. Agricultural answers and chemical composition of Massai grass under different nitrogen doses and urea sources. **Semina. Ciências Agrárias**, 39: 1225-1238, 2018b.

SILVA, E. F. L. et al. Fish farming effluent application in the development and growth of maize and bean plants. **Journal of Agrarian Sciences**, 46: 74-81, 2018a.

SILVA, E. B. et al. Chemical composition of *Panicum maximum* 'BRS Zuri' subjected to levels of salinity and irrigation depths. **Revista Ciência Agronômica**, 51:

e20175997, 2020.

SILVA, J. L. A. et al. Uso de águas salinas como alternativa na irrigação e produção de forragem no semiárido nordestino. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 18: 66-72, 2014.

SIMÕES, W. L. et al. Beet cultivation with saline effluent from fish farming. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 20: 62-66, 2016.

SILVEIRA, C. P.; MONTEIRO, F. A. Macronutrientes em folhas diagnósticas do capim-tanzânia adubado com nitrogênio e cálcio. **Revista Brasileira de Zootecnia**, 39: 736 -745, 2010.

SOUZA, A. C. M. et al. Economic analysis and development of the Nile Tilapia cultivated in the nursery using reject brine as water support. **Water Air Soil Pollut**, 233: 1-9, 2022.

TEIXEIRA, P. C. et al. **Manual de métodos de análises de solo**. 3. ed. Brasília, DF: **EMBRAPA**, 2017. 573 p.

VÖRÖSMARTY, C. J. et al. What scale for water governance. **Science**, 349: 478-479, 2015.

WERNER, J. C. et al. Forrageiras. In: RAIJ, B. Van et al. (Eds.). **Recomendações de adubação e calagem para o Estado de São Paulo**.2. ed. Campinas, SP: Instituto Agronômico, 1997. v. 2, cap. 24. p. 263-274.