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Panicum maximum cultivars irrigated with fish farming effluent[1]

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ABSTRACT - Effluent from fish farming with saline water is a source of water, also rich in organic matter and nutrients, that can be used in irrigation of cultivated plants and even fully or partially replace mineral fertilization. The objective was to evaluate the growth, biomass production and quality of P. maximum cultivars fertigated with fish farming effluent in a greenhouse experiment, using a randomized block design with eight replicates. Treatments were arranged in a split-split-plot scheme, with three irrigation managements in the plot (irrigation with public-supply water, irrigation with public-supply water + conventional fertilization, and irrigation with fish farming effluent), three cultivars of P. maximum (Tanzania, Mombasa, and Massai) in the sub-plot, and four cutting times in the sub-sub-plot (45, 90, 135, and 180 days after sowing). Plant height, number of tillers, production of fresh biomass, neutral detergent fiber, acid detergent fiber, ether extract, crude protein, dry matter, and mineral matter contents were analyzed. The highest growth, production, and quality of P. maximum grass occurs when irrigated with public-supply water and under conventional NPK fertilization. Fertigation with fish farming effluent reduces the growth and production of P. maximum grass, but allows obtaining better quality forage. It is possible to irrigate P. maximum grass using fish farming effluent with satisfactory yields. The growth of cv. Massai was more sensitive to irrigation with fish farming effluent than those of the cultivars Tanzania and Mombasa.

Key words: Tanzania. Mombasa. Massai. Water reuse. Salinity.

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INTRODUCTION

The major challenge of livestock farming has been to increase the yield per area with greater environmental sustainability. Cultivating pastures is a very important activity for the sustainability of livestock farming and is considered to have high production potential, low cost and great nutritional value; in addition, it can be carried out by small, medium and large producers, including in regions where family income depends on subsistence agriculture (NASSARY; BAIJUKYA; NDAKIDEMI, 2020).

For being considered an essential food for consumption by the herd, pasture has been constantly improved in relation to seed selection, increased production and resistance to pests, especially in the arid and semi-arid regions of the world (GUILLAUME *et al.*, 2021). Arid and semi-arid regions, due to the irregular distribution of rainfall, have concentrated pastures with lower yield and quality (PRAXEDES *et al.*, 2019), making the management of water resources available and essential to reduce the problems caused by water scarcity and the consequent limitation in the yield of forage species (ROCHA FILHO *et al.*, 2021).

Irrigation and/or fertigation with fish farming effluent is one of the alternatives to meet the water and nutritional needs of forages and, in addition, a way to properly dispose of the waste generated in fish farming, since reuse reduces or avoids the contamination of water bodies by untreated saline effluents (CASTRO; AZEVEDO; BEZERRA NETO, 2006).

In Brazil, the use of fish farming effluent has been reported by several authors as an efficient way of managing water resources in agriculture and, despite having high salinity, it is rich in nutrients from fish excrement and unconsumed feed (DIAS *et al.*, 2018). Using fish farming effluent in irrigation promotes several benefits, including the addition of nitrogen and phosphorus, improving soil conditioning and increasing water holding capacity (SILVA; LOSEKANN; HISANO, 2013). In this context, small farmers would stop using conventional fertilization due to economic unviability, with no changes in the yield and quality of pastures.

Thus, due to the variation in the physicochemical compositions of the effluents, it is important to conduct research on the technical feasibility of the potential for agricultural use of fish farming effluents to ensure productivity with lower cost in the livestock farming activity and greater environmental safety. In this context, the objective of this study was to evaluate the growth, biomass production and quality of *P. maximum* cultivars irrigated with fish farming effluent.

MATERIAL AND METHODS

The study was conducted in a greenhouse, located at the Department of Agronomic and Forestry Sciences, Federal Rural University of the Semi-Arid Region (UFERSA), East campus, in Mossoró, RN, between July 2019 and January 2020. The municipality is located in the semi-arid region of Northeast Brazil (5°11’31’’ S and 37°20’40’’ W, at an altitude of 18 m).

The climatic type is BSh (very dry, with the rainy season in summer extending to autumn), according to Köppen’s classification (ALVARES *et al.*, 2013). The average annual relative humidity is 68.9%, while the average annual temperature is 27.7 ºC (VANOMARK *et al.*, 2018). During the study, the maximum and minimum temperatures observed in the greenhouse were 44.1 and 20.6 ºC, and the maximum and minimum values of relative humidity were 85.0 and 22.0%, respectively.

The soil material used came from a *Latossolo Vermelho Amarelo distrófico argissólico* (Oxisol) collected at 0-30 cm, from the Rafael Fernandes Experimental Farm belonging to UFERSA, located in the district of Lagoinha, rural area of the municipality of Mossoró, RN. The soil was collected, dried, pounded to break up clods, sieved through a 2.0-mm mesh and sampled for physical and chemical analysis (PRAXEDES *et al.*, 2022), as shown in Table 1.

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	CEC	V	ESP
	(%)	----- (mg dm^{-3}) ------		----------------------- ($cmol_c$ dm^{-3}) ------------------------								------ % ------	
5.40	2.13	2.0	61.1	16.7	1.60	1.10	0.20	0.33	2.90	3.23	0.33	90	1.0

ECse dS m^{-1}	BD kg dm^{-3}	Sand	Silt	Clay
		--- (g kg^{-1}) ---		
0.11	1.60	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 NH4OAc at pH 7.0; Al^{3+} and (H^+ + Al^{3+}) extracted with 0.5 M CaOAc at pH 7.0; ECse = electrical conductivity of the soil saturation extract; BD = Bulk density

The experiment was arranged in a randomized block design with eight replicates. Treatments were arranged in a split-split-plot scheme, with three irrigation managements in the plot (irrigation with public-supply water, irrigation with public-supply water + conventional fertilization and irrigation with fish farming effluent), three cultivars of *P. maximum* (Tanzania, Mombasa and Massai) in the sub-plot, and four cutting times in the sub-sub-plot (45, 90, 135 and 180 days after sowing).

Each replicate consisted of a plastic pot filled with 20 dm^3 of soil, with a perforated base covered with a 3-cm-thick layer of crushed stone No. 1 and 2-mm-mesh nylon screen. Before planting the crop, liming was carried out by applying calcium hydroxide ($CaOH_2$), according to the base saturation obtained in the soil analysis, with 54% calcium.

After 15 days of acidity correction, the soil of the IM2 irrigation management was fertilized according to the fertilization recommendation of Holanda *et al.* (2017), applying 60 kg ha^{-1} of $P_2O_5^-$, 60 kg ha^{-1} of K_2O, and 60 kg ha^{-1} of N, corresponding to 600 mg of $P_2O_5^-$, 600 mg of K_2O, and 600 mg of N per pot. Nitrogen and potassium doses were split, applying 20 and 40 kg ha^{-1} of N and K_2O as basal and 40 and 20 kg ha^{-1} of N and K_2O as topdressing at 45 days after sowing, respectively. Fertilizers were applied via fertigation, using potassium chloride (60% K_2O), monoammonium phosphate (10% N and 50% $P_2O_5^-$) and urea (50% N).

P. maximum cultivars were sown in July 2019, by manually planting 20 seeds per pot at a 1.0 cm depth. The seeds showed germination power of 90% after 7 days and, when they reached 5.0 cm in height, thinning was carried out, leaving only one plant per pot. After the first cut, a fertilizer application was made in the IM2 treatment (public-supply water + fertilization), to replace the fertilization, and the volume of solution per fertigation application was 100 mL per pot.

During the experimental period, daily irrigation was carried out in the morning, using a drip irrigation system, with emitters spaced from lines with diameter of 16 mm and flow rate of 2.5 L. Two types of water were used for irrigation, one from the supply network (PSW) of the Central Campus of UFERSA, from the Water and Sewage Company of Rio Grande do Norte (CAERN), and the other was fish farming effluent (FFE), collected in the Aquaculture Sector of the East campus of UFERSA. Chemical characterization of the water used in the experiment is shown in Table 2.

The three cultivars were analyzed in four cuts, at 45, 90, 135 and 180 days after sowing (DAS). Initially, plant height was measured from the soil to the apex, using a tape measure, and the number of tillers was manually counted. Subsequently, the plants were cut at a height of 10 cm above the soil surface, using scissors. The plant material was placed in paper bags and taken to the laboratory to measure fresh biomass production, and then dried in an air circulation oven at a temperature of 65 °C until reaching constant weight and weighed again to obtain dry biomass production.

In each cut, samples of plant material were collected to determine the quality of the forage. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) contents were determined according to the method proposed by Van Soest (1994). Crude protein (CP) and ether extract (EE) were determined by the Kjeldahl and Soxhlet methods, respectively. All analyses were performed according to the methodology described by Silva and Queiroz (2002). The gravimetric technique was used to determine the dry matter (DM), with two phases: pre-drying, followed by final drying in an oven at 105 °C for 4 hours, with weighing every 1 hour until reaching constant weight. Mineral matter was also determined by the gravimetric method, using a muffle furnace at 550 °C for 5 hours to calcinate the samples, followed by weighing (SILVA; QUEIROZ, 2002).

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

Waters	K^+	Na^+	Mg^{2+}	Ca^{2+}	Cl^-	CO_3^{2-}	HCO_{3^-}	SAR
	------------------------------------- mmol$_c$ L^{-1} -------------------------------------							$(mmol_c\ L^{-1})^{-0.5}$
PSW	0.28	4.56	0.80	0.70	2.40	0.40	2.90	5.20
FFE	0.67	16.10	10.10	8.10	18.40	1.60	3.30	5.30
Waters	pH	EC	N	P	Cu	Fe	Mn	Zn
		dSm^{-1}	---------- mg L^{-1} ----------		------------------------- mg L^{-1} -------------------------			
PSW	7.83	0.50	0.10	0.10	0.02	0.05	0.03	0.08
FFE	8.45	3.00	2.35	0.72	0.04	0.50	0.05	0.15

PSW = Public-supply water; FFE = Fish farming effluent; 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

The data obtained in the experiment were subjected to analysis of variance, at 5% significance level by the F Test ($p < 0.05$); 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 x cultivar x cutting time was significant ($p < 0.01$) for plant height and number of tillers. For biomass production, the interaction between irrigation management and cutting time was significant ($p < 0.01$).

The highest values of height for *P. maximum* grass were obtained when the plants were irrigated with public-supply water and fertilized with NPK (IM2), regardless of cultivars and cutting times. Under the condition of IM2, cv. Massai obtained the lowest heights at all cutting times; this behavior was observed under irrigation with public-supply water without fertilization (IM1), at the second, third and fourth cuts, and also under irrigation with fish farming effluent (IM3), at the third and fourth cutting times (Table 3). Usually, cv. Massai is shorter than other cultivars of *P. maximum* (EMBRAPA, 2001).

When comparing IM1 and IM3 in the combinations of cultivars and cutting times, it was observed that irrigation with fish farming effluent reduced the growth of all *P. maximum* grass cultivars from the first cutting time (Table 3). Such reduction can influence both forage yields and leaf mass, in addition to requiring a longer grazing time, which can ensure satisfactory yields forage and leaf mass associated with a shorter grazing time and higher forage consumption. Therefore, the reduction in forage height due to irrigation with fish farming effluent can compromise forage yield. Researchers attribute the reduced growth of plants irrigated with fish farming effluent to the negative effects of the high salinity of the effluents, since high salinity causes osmotic stress. As it reduces growth, it decreases the photosynthesis of plants due to the diffusion of CO_2 and changes in photosynthetic metabolism, such as oxidative stress, directly influencing growth (PRAXEDES *et al*., 2019).

In the cultivars Mombasa and Massai, there was similarity in the heights obtained with IM1 and IM3 from the third cut. This fact did not occur for cv. Tanzania, indicating that the height of this grass is a variable sensitive to the high salinity of the fish farming effluent compared to the other cultivars (Table 3). Thus, it can be inferred that the cultivars Mombasa and Massai acclimatized to the high salinity of fish farming effluent applied by irrigation, so the success of the use of effluent in agriculture can be attributed to the tolerance to salinity of the species and to the cultivar of the same species, among other management strategies.

In *Brachiaria brizantha*, Souza and Silva Neto (2018) found that cv. BRS Piatã obtains higher growth

Table 3 - Test of means for plant height of *P. maximum* grass in a split-split-plot scheme as a function of irrigation management (IM), cultivars (C) and cutting times (CT), respectively

Plant height (cm)					
		Cutting times (CT)			
Cultivar (C)	Irrigation management (IM)	1	2	3	4
Tanzania	1	52.38 bA	64.13 bA	61.13 bA	54.13 bA
	2	76.00 aA	74.50 aA	86.00 aB	75.75 aB
	3	47.88 cA	52.00 cA	54.50 cB	47.50 cB
Mombasa	1	52.38 bA	57.75 bB	59.25 cA	49.75 cB
	2	74.38 aA	71.25 aA	111.50 aA	87.00 aA
	3	46.88 cA	53.00 cA	70.75 bA	59.50 bA
Massai	1	53.75 bA	56.25 bB	50.38 bB	39.38 bC
	2	58.25 aB	64.13 aB	60.88 aC	50.63 aC
	3	47.25 cA	49.75 cA	48.88 bC	38.75 bC

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 ($p < 0.05$)

when irrigated with undiluted fish farming effluent. Despite the salinity of the fish farming effluent, continuous irrigation with effluent provides a nutrient supply to the crop that can attenuate the deleterious effects of high salinity, which does not occur when conventional quality water is used.

It is important to emphasize that the nutrient supply of the fish farming effluent used in the study did not exceed NPK fertilization, so it is necessary to correct soil acidity and fertility to ensure yields in the cultivation of *P. maximum* (FLORENTINO *et al.*, 2019).

P. maximum irrigated with public-supply water and fertilized with NPK (IM2) obtained higher tillering for all cultivars at all cutting times (Table 4), because the nutrient contained in fertilization stimulates elongation and appearance of leaves (GOMES; BITTAR; SÉRVULO, 2020). Corroborating these results, Martuscello *et al*. (2019) observed that nitrogen fertilization stimulates shoot growth.

Irrigation with fish farming effluent (IM3) caused lower tillering than IM2 for all cultivars at all cutting times (Table 4). However, in most combinations of cultivars and cutting time, the tillering of IM3 was similar to that of IM1. Thus, it is possible to obtain a well-structured forage of *P. maximum*, even when it is irrigated with fish farming effluent. A similar behavior was observed by Santos *et al.* (2017), when they formulated that tillering is an important characteristic in forage structure and proved that fish farming effluent did not interfere with fresh biomass.

Tillering in IM3 was higher than in IM1, for cv. Tanzania in the second cut, for cv. Massai in the first and third cuts and for cv. Mombasa in the fourth cut. There was a decrease in tillering in IM3 compared to IM1, in cv. Mombasa and cv. Tanzania in the third and fourth cuts, respectively (Table 4). Thus, the tillering of the *P. maximum* cultivars was more sensitive to the salinity of fish farming effluent in the first regrowth and, probably, there was acclimatization of the cultivars in the other cuts.

The best differentiation for the number of tillers among cultivars occurs in the last cut, when cv. Tanzania has higher tillering when irrigated with public-supply water and under no fertilization, whereas cv. Mombasa has higher tillering when irrigated with fish farming effluent (Table 4).

Thus, as observed for height and tillering, the highest biomass production of *P. maximum* occurred in IM2, for all cutting times (Table 5). This increase in biomass implies an increase in productivity, since the speed with which biomass grows becomes an indicator of improved productivity and, therefore, of economic life. Higher biomass under IM2 was due to the practice of fertilization, which plays a fundamental role in the establishment and maintenance of pastures. Increase in biomass is clear with the addition of NPK fertilization, which is essential for the establishment of *P. maximum* pastures. Increase in biomass productivity in correctly fertilized pastures was also verified by Galindo *et al.* (2018).

The nutritional load of the fish farming effluent did not fully meet the nutrient demand of the *P. maximum* cultivars,

Table 4 - Means comparison test for number of tillers of *P. maximum* grass in a split-split-plot scheme as a function of irrigation management (IM), cultivars (C) and cutting times (CT), respectively

Number of Tillers					
Cultivar (C)	Irrigation management (IM)	Cutting time (CT)			
		1	2	3	4
Tanzania	1	12 bA	17 cA	17 bA	20 bA
	2	17 aA	27 aA	25 aA	30 aA
	3	12 bA	20 bA	18 bAB	16 cB
Mombasa	1	14 bA	18 bA	19 bA	17 cB
	2	17 aA	28 aA	23 aA	32 aA
	3	12 bA	17 bB	16 cB	20 bA
Massai	1	11 cA	17 bA	16 cA	17 bB
	2	18 aA	27 aA	24 aA	23 aB
	3	14 bA	19 bAB	19 bA	18 bAB

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 ($p < 0.05$)

requiring the addition of nutrients to meet the nutritional demand. However, the biomass production of this grass under IM3 was similar to that under IM1 for all cuts, except for the fourth cut, when IM1 was superior to IM3 (Table 3). The reduction in *P. maximum* biomass production due to prolonged irrigation with fish farming effluent corroborates the results reported by Praxedes *et al.* (2019) and Sá *et al.* (2021), who also found a decrease in biomass production in cultivation irrigated with saline water and formulated that continued irrigation with saline water increases soil salinity, causing restrictions in biomass accumulation.

The interactions irrigation management (IM) x cultivar (C) ($p < 0.01$) and irrigation management (IM) x cutting time (CT) ($p < 0.05$) were significant for crude protein (CP). For mineral matter, the interactions IM x CT and C x CT were significant ($p < 0.01$). There was a significant individual effect of IM for acid detergent fiber (ADF) ($p < 0.01$) and ether extract (EE) ($p < 0.05$). For ADF, neutral detergent fiber (NDF), EE and dry matter (DM), there was a significant individual effect of CT ($p < 0.01$).

NDF increased from 71.14% in the first cut to 75.26% in the fourth cut (Table 6). In general, the fiber content increased as a function of the number of forage regrowths. An important fact is that the salinity of the fish farming effluent did not influence the NDF content in the *P. maximum* cultivars, which corroborates the results reported by Silva *et al.* (2020), who studied *P. maximum* cv. BRS Zuri and found no difference in NDF with the increase in salinity; however, this variable decreased with the cutting times.

It is worth pointing out that the NDF contents obtained for the cultivars Tanzania, Mombasa and Massai are higher than those found in cv. BRS Zuri by Silva *et al*. (2020). Despite being saline, fish farming effluent provides nitrogen and other nutrients for the grass, which helped to maintain the fiber content, as N stimulates the formation of new tissues, boosting the increase in NDF contents (MAGALHÃES *et al.*, 2015).

P. maximum irrigated with public-supply water (IM1) obtained the highest ADF contents. The ADF contents of grass irrigated with public-supply water + fertilization with NPK (IM2) and irrigated with fish farming effluent (IM3) were similar (Table 6). Regarding NDF, it was observed that the salinity of the fish farming effluent did not affect its contents in the *P. maximum* cultivars, as statistical similarity was observed between the studied IMs.

In this context, the forages produced possibly have good quality of dietary fiber, since the NDF values exceed ADF values, which indicates both the quality and the quantity of dietary fiber present in the forages, influencing the intake of DM by the animals (SIMONETTI; MARQUES, 2016). Thus, irrigation with fish farming effluent improved the fiber quality of *P. maximum* cultivars compared to IM1, since osmotic stress causes decrease in the stem and reduction in lignification levels, which affects the ADF content and improves the digestibility of the forage (MAGALHÃES *et al.*, 2015). ADF content increased as a function of the cutting time from 33.56% in the first cut to 41.49% in the fourth cut. This indicates that, with the establishment of *P. maximum* cultivars, there was an increase in the levels of fiber that is difficult to digest, such as cellulose and lignin (SIMONETTI; MARQUES, 2016; SILVA *et al.*, 2020).

The *P. maximum* forages showed NDF contents higher than 70%. According to Van Soest (1994), NDF values between 55 and 60% limit the ingestion capacity of animals. For Oliveira *et al*. (2015), tropical forages have high NDF contents, which are adequate when above 55%, reaching up to 80% at more than 36 days of age. On the other hand, for the ADF content, the values are adequate when below 40% (GALINDO *et al.*, 2018). Thus, the results obtained in this study are in agreement with those reported by these authors, indicating that the forage has a good composition in terms of NDF and ADF, with NDF higher than 55% in all cuts, while ADF is less than 40% until the third cut and close to it in the fourth cut.

Table 5 - Means comparison test for biomass production of *P. maximum* grass in the decomposition of irrigation management (IM) considering each cutting time (CT)

	Biomass production (g pot^{-1})		
	IM1	IM2	IM3
CT1	114.49 b	149.01 a	98.78 b
CT2	176.75 b	325.83 a	166.31 b
CT3	158.21 b	365.69 a	139.27 b
CT4	252.58 b	438.67 a	208.93 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 row compare IM considering each CT by Tukey test at 5% probability level ($p < 0.05$)

In the decomposition of IM considering each cultivar, lower crude protein (CP) contents were recorded under IM1 in the cultivars Tanzania and Mombasa, with no difference between IM2 and IM3. For cv. Massai, there was no difference between irrigation managements for CP content (Table 7). In the decomposition of IM considering each cutting time, the highest CP contents were found in the grass under IM3 in the first cut, and in the second, third and fourth cuts the highest CP contents occurred in the grasses under IM2 and IM3 (Table 7). Grass irrigated with fish farming effluent (IM3) obtained CP values similar to those found in the grass irrigated with public-supply water and fertilized with NPK (IM2) (Table 5). The supply of nitrogen via effluent and conventional fertilization improves the vigor and productivity of the regrowth, increasing CP content (DELEVATTI *et al*., 2019). Only the cv. Massai was able to maintain CP contents under IM1, an indication that this cultivar is less demanding in terms of nutrients than the others.

The highest contents of ether extract (EE) were found in grass irrigated with public-supply water and fertilized with NPK (IM2) and the lowest contents were found in grass irrigated with fish farming effluent (IM3) (Table 8). EE contents decreased with grass age, ranging from 2.69 m in the first cut to 1.86 m in the fourth cut (Table 8). Santos *et al.* (2011), when evaluating structural and bromatological characteristics of Tanzania grass under isolated, simultaneous and alternating grazing of sheep and cattle, found EE levels ranging from 2 to 3%. In the present study, these EE levels in the grass were obtained under all irrigation managements. However, in the second and fourth cuts, the EE contents were lower than 2% (Table 8).

Table 6 - Means comparison test for neutral detergent fiber (NDF) and acid detergent fiber (ADF) of *P. maximum* grass as a function of irrigation management (IM) and cutting times (CT)

Irrigation Management	NDF (%)	ADF (%)
IM1	73.69 a	38.72 a
IM2	73.20 a	36.99 b
IM3	72.15 a	36.34 b
Cutting Time	NDF (%)	ADF (%)
CT1	71.14 c	33.56 d
CT2	72.60 b	35.53 c
CT3	73.05 b	38.82 b
CT4	75.26 a	41.49 a

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 means by Tukey test at 5% probability level ($p < 0.05$)

Table 7 - Means comparison test for crude protein (CP) of *P. maximum* grass in the decomposition of irrigation management (IM) considering each cutting time (CT) and IM considering each cultivar (C)

CP (%)			
	Irrigation Management		
Cultivars	IM1	IM2	IM3
Tanzania	3.40 b	3.50 ab	3.79 a
Mombasa	2.89 b	3.62 a	3.83 a
Massai	3.50 a	3.48 a	3.58 a
Cutting Times	IM1	IM2	IM3
CT1	2.63 b	2.51 b	2.96 a
CT2	3.05 b	3.58 a	3.61 a
CT3	3.52 b	3.92 a	4.08 a
CT4	3.85 b	4.12 ab	4.28 a

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 row compare means by Tukey test at 5% probability level ($p < 0.05$)

The dry matter (DM) contents were influenced by crop maturity; the highest DM content occurs in the second cut (first regrowth) and tends to decrease until the fourth cut (Table 8). This pattern was also observed by Fluck *et al*. (2018), who analyzed the chemical composition of forage and found that maturity influences DM contents.

For mineral matter (MM), the decomposition of IM considering each CT, in general, showed that the IM2 treatment obtained the lowest MM values at all cutting times. The highest MM contents were found in the grass under IM3 from the second cut (Table 9). In the case of IM2, this treatment obtained the highest biomass production compared to the others (Table 5), and the decrease in MM may have occurred due to the dilution of minerals in the biomass. The opposite occurs in the IM3 treatment, which with less biomass ended up concentrating the MM, especially from the second cut, since the salts and nutrients present in the fish farming effluent tend to accumulate in the soil under conditions of continuous irrigation (DIAS *et al*., 2018).

Table 8 - Means comparison test for ether extract (EE) and dry matter (DM) of *P. maximum* grass as a function of irrigation management (IM) and cutting times (CT)

Irrigation Management	EE (%)	DM (%)
IM1	2.11 ab	93.16 a
IM2	2.34 a	92.69 a
IM3	2.01 b	92.82 a
Cutting Time	EE (%)	DM (%)
CT1	2.69 a	91.72 d
CT2	1.89 bc	93.99 a
CT3	2.18 b	93.45 b
CT4	1.86 c	92.40 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 column compare means by Tukey test at 5% probability level ($p < 0.05$)

Table 9 - Means comparison test for mineral matter (MM) of *P. maximum* grass in the decomposition of irrigation management (IM) considering each cutting time (CT) and cultivars (C) considering each CT

MM (%)			
Cutting Times	Irrigation Management		
	IM1	IM2	IM3
CT1	8.94 a	7.99 b	8.13 b
CT2	7.08 b	5.68 c	7.97 a
CT3	7.29 b	7.47 b	8.68 a
CT4	8.04 b	8.59 ab	8.98 a
Cutting Times	Cultivar		
	Tanzania	Mombasa	Massai
CT1	8.13 a	8.63 a	8.30 a
CT2	7.17 a	6.98 a	6.58 a
CT3	7.73 a	7.82 a	7.90 a
CT4	8.00 b	8.61 a	8.99 a

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 row compare means by Tukey test at 5% probability level ($p < 0.05$)

In the decomposition of C considering each CT, there was difference only in the last cut, when the MM contents of the cultivars Mombasa and Massai were higher than that of Tanzania (Table 9). MM contents depend on many factors, including the concentration of nutrients in the soil (SIMILI *et al.*, 2008). Increase in MM is indicative of the absorption and accumulation of salts and nutrients in the plant tissue, so the cultivars Mombasa and Massai accumulated more salts in their tissue in the long term (180 days).

The best growth, biomass production and bromatological characteristics of *P. maximum* cultivars were obtained in irrigated and fertilized pasture. Irrigation with fish farming effluent reduced growth and biomass production compared to irrigated and fertilized grass, but it was similar to grass irrigated with public-supply water without fertilization for biomass production, especially in the Mombasa and Massai cultivars.

With the bromatological analysis, it was observed that despite the reduction in biomass production, the grass irrigated with fish farming effluent obtained bromatological characteristics similar to those found in the irrigated and fertilized grass and better than those found in the grass only irrigated with public-supply water. Thus, it is possible to irrigate *P. maximum* grass with fish farming effluent and obtain quality forage, but with significant losses in biomass production.

In the present study, irrigation with fish farming effluent associated with organic or conventional fertilization was not studied, which could improve production and even resemble the result obtained with grass irrigated with public-supply water and under conventional fertilization. Further research can be carried out associating irrigation with fish farming effluent and fertilization for the production of *P. maximum*.

CONCLUSIONS

1. Fish farming effluent can be used to irrigate *P. maximum* grass with good forage quality and without significant losses in growth and production;
2. Irrigation with fish farming effluent improved forage quality compared to grass irrigated and without additional fertilization;
3. The growth of cv. Massai was more sensitive to the high salinity of fish farming effluent applied by irrigation, and the cultivars Tanzania and Mombasa were tolerant.

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