PASTURE FERTIGATION WITH CATTLE WASTEWATER EFFLUENT

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ABSTRACT: The reuse of effluent from cattle wastewater (CWW) in the irrigation of degraded pasture of Tifton 85 was investigated in terms of its potential to supply the water and nutritional for the forage, and to maintain soil fertility. The experiment was in field, in factorial design with three water compositions (stream water, stream water and effluent 1:1, and effluent) and two doses of nitrogen fertilization (0 e 45 kg N ha^{-1}). Were evaluated forage productivity (fresh matter, dry matter, forage matter density, height, and water use efficiency) and the soil chemical attributes (0-20m depth) after a single regrowth period of the pasture from May to September-2020. The effluent increased forage productivity and water use efficiency, but it was not proportional to the ARB effluent loads. The nitrogen fertilization only influenced plant height for stream water treatments. There was increasing of sodification indicators and potassium level on soil, however none of them reached contamination levels. The effluent maintained organic soil matter and CEC with its highest dose and mineral fertilization. Despite the productivity increases, the reuse of CWW effluent is not sufficient to maintain or increase all the soil nutrients.

KEYWORDS: Water reuse, soil fertility, Tifton 85

FERTIRRIGAÇÃO DE PASTAGEM COM EFLUENTE DE ÁGUA RESIDUÁRIA DE BOVINOCULTURA

RESUMO: O reúso de efluente de água residuária de bovinocultura (ARB) leiteira na irrigação de Tifton 85 foi investigado quanto ao seu potencial suprimento da demanda hídrica e nutricional da forrageira e às alterações da fertilidade do solo. O experimento a campo foi delineado em fatorial com três composições de lâmina de irrigação (água de córrego, água de córrego e efluente de ARB 1:1, e efluente de ARB) e duas doses de adubação nitrogenada (0 e 45 kg N ha^{-1}). Foram avaliados a produtividade da forrageira (matéria fresca, matéria seca,

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densidade de forragem, altura, eficiência no uso da água) e os atributos químicos da camada superficial do solo (0-20 cm) após um período de rebrota da pastagem, entre maio e setembro de 2020. O efluente de ARB aumentou a produtividade e a eficiência no uso da água do capim, porém, a produção da forrageira não foi proporcional ao aumento das cargas de efluente aplicadas. A adubação nitrogenada influenciou as variáveis morfológicas do capim somente na pastagem irrigada com água de córrego. Houve aumento nos indicadores de sodificação do solo e do nível de potássio, porém, nenhum deles atingiu nível de contaminação. O efluente de ARB na dose máxima e associado à adubação mineral manteve o teor de matéria orgânica e a capacidade de troca de cátions. Apesar da elevação da produtividade, o uso de efluente de ARB para fertirrigação do Tifton 85 não é suficiente para reposição de todos os nutrientes do solo.
PALAVRAS-CHAVE: Reúso da água, fertilidade do solo, Tifton 85

INTRODUCTION

The dairy farming generates high volumes of wastewater, and its final disposal causes concern regarding the environment, mainly the security of the receiving body. The water is a vehicle who transports feces, urine and other residues out of the milking and handling facilities. Thus, the cattle wastewater (CWW) has high organic matter content and is generated continuously and uninterruptedly.

The wastewaters have several interesting nutrients for agriculture, such as the agricultural reuse of domestic sewage and industrial wastes (ERTHAL et al., 2010a; TEIXEIRA et al., 2017), but this practice needs attention due to environmental pollution risk. The nutrient mobility, soil physic and hydric characteristics, irrigation and soil management, precipitation and plant absorption march contribute to attenuate or aggravate those risks and phytotoxic effects. Several studies reinforce the importance of wastewater or effluent composition, especially regarding the limits of nitrogen and phosphorous recommended for the crop and the sodium load.

Tifton 85's Brazilian pastures are used to raise high-yielding livestock for its high-quality forage yield, desirable phytoremediation characteristics such as fast growth, high biomass production, competitiveness, vigor and pollution tolerance. Under irrigation and low competition for light and nutrients, the Tifton 85 can absorb up to 300 kg N $ha^{-1}yr^{-1}$ (OLIVEIRA et al., 2019), so it is interesting to stimulate the species potential of nutrient extraction by managing it with short intervals between cuts. The specie responds with biomass growth and nutrient accumulation on its biomass to reuse fertigation using CWW (ERTHAL et al., 2010b) and treated sewage (NOGUEIRA et al., 2011). Still, long-time reuse fertigation in Tifton 85 pastures assists in the maintenance of the soil microbial due to the supply of labile carbon, water and nitrogen, and to the forage biomass mineralization (NOGUEIRA et al., 2011).

The wastewater components dynamics on soil-plant systems knowledge is important manage its reuse, specially the CWW, then develop alternatives that improve the management of water resources in this production chain. With that, the objective with this paper was to evaluate: (i) the productivity of Tifton 85 fertigated with CWW effluent and nitrogen fertilization; and (ii) the chemical modifications in the 0-20 cm soil depth.

MATERIAL AND METHODS

This experiment was conducted on field in Gameleira de Goiás-GO, coordinates 16°24’41,9” S 48°47’53,9” W, in a dystrophic Red-Yellow Oxisol, 980 m altitude, and climate Aw according to Köppen-Geiger’s classification. The weather conditions in the period are showed in Fig.1 and soil initial chemical characteristics are showed in Table 1.

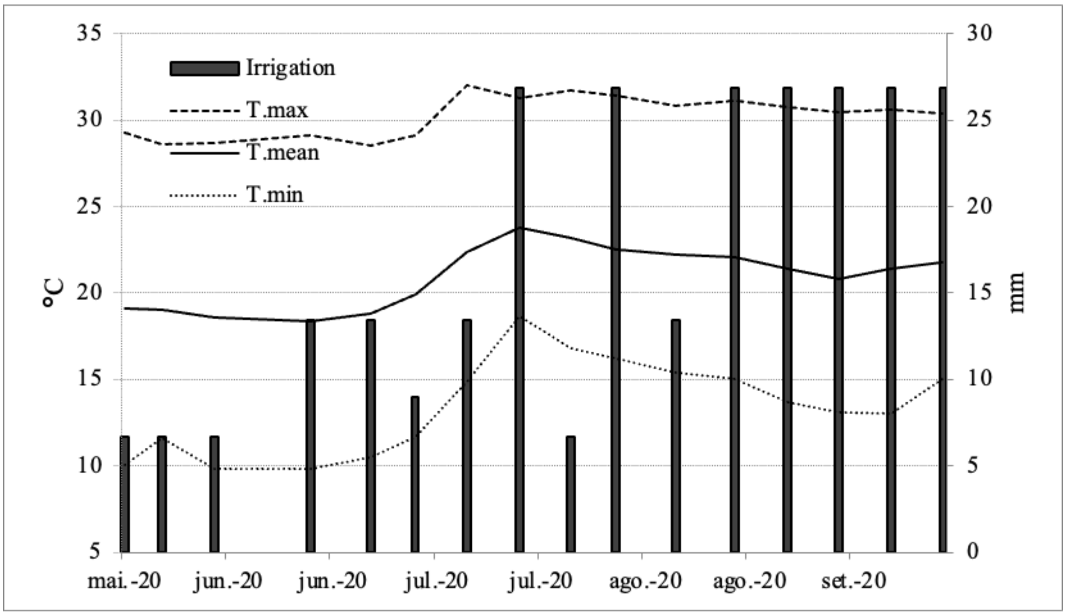

Figura1. Air temperature (min, mean and max) of the experimental site and irrigation, from may-29 to sep-12-2020.

Table 1. Soil initial chemical characteristics.

			Chemical characteristics[1]					
Depth	P	K	Ca	Mg	S	Al	H+Al	pH
m	mg dm^{-3}		cmolc dm^{-3}		mg dm^{-3}	cmolc dm^{-3}		H_2O
0,00-0,20	9.2	39.0	6.3	2.4	0.1	0.1	5.4	5.6
Depth	Na	Zn	Cu	Fe	Mn	M.O	CTC	V
m			mg dm^{-3}			g dm^{-3}		%
0,00-0,20	0.0	6.4	0.54	152.0	115.0	66.0	8.8	58.5

[1]Profundidade (Prof); P and K extractor, Mehlich^{-1}; Organic matter (SOM); cationic exchange capacity (CEC); Base saturation (V).

The experiment occurred during dry season (05/29-09/12/2020) in a single regrowth cycle. The Tifton 85 pasture was conducted for 4 years with conventional soil fertility management following the recommendations for intensive grazing, without irrigation. The soil management was interrupted over a year, then the experiment was installed.

The CWW was generated in the milking facilities, conducted to coarse removal in sand trap followed by stabilization ponds system composed of two anaerobic ponds and one facultative pond. The organic matter removal efficiency of this system was 86%. The CWW effluent used in irrigation was stored in an independent pond from where it was collected for irrigation. A second pond was used to storage natural water derived from a near stream, also for irrigation. Both effluent and stream water was analyzed for chemical and physical characteristic in 20 days intervals (Table 2).

Table 2. Total load (kg ha^{-1}) applied with different composition of irrigation water*.

Irrigation water	NO_3^-	NO_2^-	$P_{org.}$	K^+	Ca^{2+}	Mg^{2+}	Na^+	Fe^{3+}	ST
Stream	0.88	0.03	0.07	0.48	0.00	2.58	0. 00	0.35	281.0
Effluent+Stream	112.61	2.81	87.75	398.29	94.93	160.78	39.04	24.39	4.271.4
Effluent	225.22	5.61	175.50	796.58	189.86	321.56	78.07	48.78	8.542.9

*It was considered 90% application efficiency of the irrigation equipment. Did not consider losses due to leaf interception.

The irrigation was by sprinkler in weekly frequency, providing the total of 280 mm during the experiment. The irrigation management opted was in deficit, supplying 34% of the crop potential evapotranspiration (PET) estimated for the pasture. The water soil tension was monitored always before irrigation using 4 pairs of tensiometers installed in 0-20 cm and 20-40 cm depth.

The pasture was initially uniformized with a mower at 5 cm height. The evaluation occurred when at least 70% of the plots reached reproductive stage (panicle pre-emission). For that, three representative areas in each plot were delimited by a square frame with 0.25 m^2, from where was measured forage height and harvested at 20 cm in order to simulate the cattle grazing pattern. The forage was weighed immediately after harvest to determine fresh matter production, and the dry matter production was determined after drying (55ºC for 48 hours).

The factorial scheme and block design was chosen, with three composition of irrigation water and two nitrogen fertilization levels. The treatments consisted of stream water without fertilization (S-0), stream water with fertilization (S-45), CWW effluent and stream water (1:1) without nitrogen fertilization (ES-0), CWW effluent and stream water (1:1) with fertilization (ES-45), CWW effluent without fertilization (E-0) and CWW effluent with fertilization (N). The fertilized treatments received 45 kg N ha^{-1} (urea) by spreading after the uniformization mowing. Each plot consisted of a 4,5 x 4,5 m area (already excluding the borders).

Parameters evaluated in the forage: fresh matter (FM) and dry matter (DM) yields, height (H), water use efficiency (WUE = DM/total irrigation), forage matter density (FMD = DM/H), forage dry matter per kg of nitrogen applied (DM-N), forage dry matter per kg of phosphorous applied (DM-P) and forage dry matter per kg of potassium applied (DM-K). And soil chemical attributes on topsoil (0-20 cm): Ca, Mg, K, P available, Cu, Fe, Mn, Zn, Na, organic matter (SOM), cationic exchange capacity (CEC) effective and total ($CEC_{pH7.0}$), sodium adsorption ratio (SAR) (EMBRAPA, 2017).

Statistical analysis was performed using SigmaPlot 14 (trial version) software. Analysis of variance (ANOVA) and Tukey-test was used to compare the averages of treatments at $p<0.05$ level.

RESULTS AND DISCUSSION

The CCW effluent influenced forage height only with nitrogen fertilization (Table 3), partially agreeing with Silva et al. (2018) for Vaquero grass (*Cynodon dactylon*) fertigated with agroindustrial wastewater (AWW), where forage height only differed from conventional irrigation on the third cycle of harvesting and fertigation. The nitrogen fertilization was important on height gains when the Tifton 85 received only stream water, and the forage reached lowest height in the absence of nitrogen and CWW effluent.

Table 3. Yield indicators of Tifton 85 pasture irrigated with different composition of irrigation water and nitrogen fertilization.

	S	ES	E	S	ES	E
N dose	Height (cm)	CV = 13.5%		Fresh matter (t ha^{-1})	CV = 30.8%	
0	26.9 Aa	33.3 Aa	32.7 Aa	7.2 Ba	14.4 Aa	14.8 Aa
45	17.5 Bb	32.3 Aa	34.4 Aa	3.8 Ba	15.8 Aa	15.2 Aa
	Dry matter (t ha^{-1})	CV = 29.7%		FMD (kg MS cm^{-1})	CV = 26.5%	
0	2.5 Ba	5.4 Aa	5.3 Aa	125.8 Aa	164.4 Aa	162.6 Aa
45	1.3 Ba	5.0 Aa	5.3 Aa	123.2 Aa	154.6 Aa	157.4 Aa
	WUE (kg DM mm^{-1})	CV = 21.8%		DM-N (kgDM kgN^{-1})	CV = 17.2%	
0	0.85 Ba	1.81 Aa	1.92 Aa	-	48.1 Aa	23.6 Ba
45	1.21 Ba	1.95 Aa	1.91 ABa	56.9Aa	31.9 Bb	19.8 Ba
	DM-P (kgDM kgP^{-1})	CV = 23.3%		DM-K (kgDM kgK^{-1})	CV = 18.0%	
0	-	164.0 Aa	84.0 Ba	-	13.6 Aa	6.7 Ba
45	-	180.0 Aa	86.3 Ba	-	12.6 Aa	6.7 Ba

0: without nitrogen fertilization; 45: with 45 kg N ha^{-1} fertilization; CV: coefficient of variation.

Means followed by the same capital letter on the row and lowercase on the column are equals by Tukey test (5% probability).

The ARB effluent irrigation increased forage yield (fresh and dry) regardless nitrogen fertilization, but not proportionally to the ARB effluent quantities applied. The same was observed for Vaquero grass fertigated with AWW, in a lower yield scale (SILVA et al., 2018).

Dry matter per nitrogen applied (DM-N) decreased with increasing of ARB effluent proportions on irrigation water. According to Sanches et al. (2017), a reduction in nitrogen conversion in forage matter occurs with fertilizations up to 78,6 kg N ha^{-1} cut^{-1}. In contrast, Marcelino et al. (2003) noted linear increments on Tifton 85 yield until 90 kg N ha^{-1} cut^{-1}.

The forage matter density did not vary between treatments, showing morphologic proportionality. In turn, Silva et al. (2018) observed highest FMD differences for Vaquero grass already in the first cut, in summer, indicating that probably the water deficit used in the present study and the weather conditions may have limited the grass full expression.

The ES-0 and ES-45 treatments reached highest DM-K (1.95 times greater than E-0 and E-45 treatments) and DM-P (2.0 times greater), both nutrients supplied only via ARB effluent (Table 2). Those treatments also were 1.84 greater in forage production per unit of nitrogen supplied by both ARB effluent and nitrogen fertilization sources. Even providing water and nitrogen, the weather conditions during the experiment was not favorable to forage yield, considering that Tifton 85 the metabolism C4, which is known to respond better fertilizers in seasons where occurs highest air temperatures and longer photoperiod (MARCELINO et al., 2003).

Probably this single cycle of evaluation was not long enough to occur total nutrient and organic matter mineralization from the ARB effluent, and there were less nutrients in fact available to supply pasture nutritional demands. Nonetheless, as shown by Oliveira et al. (2019) with fertigation using dairy wastewater (DWW), the nitrogen utilization on the second regrowth cycle for Tifton 85 is 1.4 greater than the nitrogen provided by mineral sources.

The soil water tension varied from 33 to 77 kPa, in the range where the crop response to nitrogen fertilization is still positive, according to Marcelino *et al*., 2003. The WUE was lower in when Tifton 85 was irrigated only by stream water than irrigated partially or totally with ARB effluent, in addition, there was no differences on WUE when the pasture was irrigated with ARB effluent.

The irrigation management in deficit (34% of PET) and the low air temperatures registered may be responsible for the daily dry matter yield with fertigation (58.6 kg MS $ha^{-1}d^{-1}$) and stream water (34.2 kg MS $ha^{-1}d^{-1}$) below expectations. These values are much lower for

Tifton 85 irrigated than those described by Sanches et al. (2017) with mineral fertilization (141 kg MS $ha^{-1}d^{-1}$ for 75 kg N $ha^{-1}cut^{-1}$) and by Oliveira et al. (2019) with DWW fertigation (183,4 kg MS $ha^{-1}d^{-1}$ for 100 kg N $ha^{-1}cut^{-1}$), both studies conducted in summer and with attending 100% of PET. However, it must consider that, in addition to environmental factors, those studies proceed lower sampling cuts (5 and 10 cm, respectively).

About soil chemistry, after 106 days of pasture regrowth there was no modifications in the soil contents of Fe, Zn and Cu. The magnesium also maintained (2.22 cmolc dm^{-3}) despite the applied loads via ARB effluent was up to 321 kg Mg ha^{-1}. Further investigation is needed to identify the causes of this stabilization.

The ARB effluent irrigation reduced soil pH mostly associated with nitrogen fertilization (Table 4) and may be due to pH of the irrigation water (which varied from 6.4 to 7.8), exchangeable ions also from irrigation water (ERTHAL et al., 2010a), organic matter oxidation processes (TEIXEIRA et al., 2017), plant absorption and leaching that leads to decreasing CEC (MIOTO et al., 2019).

Table 4. Chemical attributes of pasture topsoil irrigated with different composition of irrigation water and nitrogen fertilization.

	Initial	S	ES	E	Initial	S	ES	E
	pH H_2O		CV = 2.6%		CEC (cmolc.dm^{-3})		CV = 5.5%	
0	5.6 Aa	5.6 Aa	5.4 Aa	5.4 Aa	8.8 Aa	7.3 Ba	7.3 Ba	7.4 Bb
45	5.6 Aa	5.5 Aa	5.4 ABa	5.2 Bb	8.8 Aa	7.6 BCa	7.1 Ca	8.3 ABa
	SOM (g.kg^{-1})		CV = 9.9%		P (mg.dm^{-3})		CV = 17.5%	
0	66.0 Aa	76.8 Aa	71.2 Aa	77.2 Aa	9.2 Aa	2.2 Ba	3.2 Ba	3.3 Ba
45	66.0 Ba	69.5 Ba	75.5 ABa	87.0 Aa	9.2 Aa	1.8 Ca	3.3 BCa	3.7 Ba
	Ca^{2+} (cmolc.dm^{-3})		CV = 10.9%		Mn^{2+} (mg.dm^{-3})		CV = 36.4%	
0	6.3 Aa	5.0 Ba	4.9 Ba	5.2 Bb	115.0 Aa	55.5 Ba	47.4 Ba	50.7 Ba
45	6.3 Aa	5.4 BCa	4.9 Ca	5.8 ABa	115.0 Aa	54.1 Ba	52.8 Ba	51.4 Ba
	K^{+} (mg.dm^{-3})		CV = 18.6%		Na^{+} (mg.dm^{-3})		CV = 36.9%	
0	39.0 Ca	40.9 Ca	66.4 Ba	97.3 Aa	0.0 Ca	1.63 Ba	2.35 ABa	2.87 Aa
45	39.0 Ba	33.1 Ba	73.8 Aa	94.6 Aa	0.0 Ba	0.80 Ba	2.29 Aa	3.50 Aa
	RAS (mmolc $^{-0,5}$)		CV = 37.8%					
0	0.0 Ca	0.06 Ba	0.09 ABa	0.11 Aa				
45	0.0 Ba	0.04 Ba	0.09 Aa	0.13 Aa				

Initial: before treatments start; 0: without nitrogen fertilization; 45: with 45 kg N ha^{-1} fertilization; CEC: cationic exchange capatity; SOM: soil organic matter; SAR: sodium adsorption ratio; CV: coefficient of variation.

Means followed by the same capital letter on the row and lowercase on the column are equals by Tukey test (5% probability).

This initial decreasing in soil pH when fertigated with wastewater is common, but this decreasing is expected until the soil-plant system adjusts to the inputs from the reuse water. In the study with CWW irrigation the soil pH was recovered after 4 regrowth cycles (ERTHAL et al., 2010a), and after 3 years of fertigation for treated sewage (NOGUEIRA et al., 2011). The decreasing in CEC and calcium content shows that it is still necessary to do soil pH correction with calcareous in order to raise soil pH and cations replacement, mainly calcium. The manganese decreasing also requires attention, even though it is not much required much by pastures (EMBRAPA, 2004).

The addition of organic matter may have contributed to stabilization of CEC in E-45 treatment. However, we must look carefully to soil organic matter in areas recently submitted to reuse fertigation due to the occurrence of the priming effect (NOGUEIRA et al., 2011).

The soil sodium content and SAR increased with ARB effluent doses, but without risks of soil sodification due to low exchangeable sodium percentage (< 1%). Usually, effluents with high sodium contents, as treated sewage, adds sodium to the colloid exchange surface and releases calcium and magnesium to the soil solution, supporting plant absorption and increasing soil sodicity (MIOTO et al., 2019). Fortunately, the ARB effluent did not provide such sodium loads. The increases in sodium content in the soil may also be due to progressive increasing in PET by perennial crops (TZANAKAKIS et al., 2017).

The ES-0 and ES-45 treatments raised the levels of potassium on soil from medium to adequate classification (entre 51 e 80 mg K kg^{-1}) while the E-0 and E-45 treatments raised from medium to high level (> 80 mg K kg^{-1}). The E-0 treatment provided more potassium in soil solution than ES-0 treatment.

The Cerrado soils with CEC up to 4.0 cmolc dm-3 are less likely to leach potassium as long the fertilization is up to 100 kg K $ha^{-1}application^{-1}$ (EMBRAPA, 2004). However, there is leaching risk with ARB effluent reuse because the doses applied (up to 796 kg K ha^{-1}) are above the recommended for intensive pastures in soils with low potassium level (100 to 200 kg K ha^{-1}) (PEREIRA et al., 2018). The Tifton 85 can remove 16 kg K há-1 per regrowth cycle under similar weather conditions to the ones in this study (OLIVEIRA et al., 2019). Therefore, it is important to proceed chemical analyses periodically of the wastewater or effluent and of the soil profile.

The phosphorous loads were sufficient to establishment of high demanding pastures in Cerrado, as Tifton 85 (EMBRAPA, 2004). The soil phosphorous content decreased equally for all treatments, regardless the mineral fertilization. With only stream water irrigation, the phosphorous dropped 19.6% compared to the initial concentration, indicating the Tifton 85 demand for this nutrient and the need to provide it for the pasture from another source besides ARB effluent.

CONCLUSION

The ARB effluent used in irrigation promoted increasing in forage yield, height and water use efficiency.

After one cycle of regrowth of the Tifton 85 pasture there was increasing on soil contents for potassium and sodium without showing risks of soil contamination. There was also decreasing in soil pH, cationic exchange capacity and contents of calcium, manganese and phosphorous.

Thus, it is recommended to associate ARB effluent irrigation with others soil fertility practices in order to maintain the soil quality and provide additional nutrients.

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