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Full Length Research Paper

Grass production Tifton 85 and nutrient extraction with swine wastewater doses

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Swine wastewater (SW) is considered as a source of nutrients for agriculture. The quantities and frequencies applied may vary according to the soil class, the nature and composition of the waste, the climatic conditions and the cultivated plant species. Therefore, this study aimed to evaluate the effects of application of five Swine wastewater doses (0, 500, 1000, 2000 and 2500 m³ ha^{-1}) in the production of components and grass nutrient extraction Tifton 85 and changes in soil chemical properties after the end of the last application of swine wastewater. To achieve these goals, we evaluated the quantities of extracted nutrients, density and height of the pre-grazing grass, forage accumulation rate and carrying capacity. The experimental design was a randomized block. The production of dry matter was 18159.80 kg ha^{-1}, and the average height of 85 Tifton was 34.83 cm. The higher carrying capacity, 10 AU ha^{-1} was obtained with the dosage of 2500 m³ ha^{-1}. While, the dose of 2000 m³ ha^{-1} supplied the nutritional needs of Tifton 85 in nitrogen, potassium, calcium, magnesium, copper, iron, zinc and boron. The quantities of extracted nutrients (kg ha^{-1}) at grass Tifton 85 grazed were: N = 405.14; P = 57.77; K^+ = 387.69; Ca^{2+} = 77.05; Mg^{2+} = 49.68; S-$SO4^{-2}$ = 31.48; B = 0.33; Cu^{2+} = 0.20; Fe = 2.88; Mn^{2+} = 4.61; Zn^{2+} = 2.86. The application of increasing doses of SW promoted a linear increase in grass production components Tifton 85, as well, promoted changes in soil chemical properties and quantities of extracted nutrients.

Key words: Pasture, liquid waste, nutrient extraction, plant growth.

INTRODUCTION

Brazilian swine production is increasing annually in order to meet both domestic and foreign market demand with regard to the quality of raw materials and environmental care (Pinto et al., 2014). Brazil is the fourth largest producer of pork in the world, this represents the equivalent of 3.7 million tonnes of pigs (EMPRAPA, 2017). The main problem of this activity, therefore, is the generation of enormous quantities of manure that can

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corroborate to the pollution of terrestrial and aquatic ecosystems (Segat et al., 2015).

The fertilization of crops with swine wastewater is a common practice and is attractive for the reduction of natural resources and environmental pollution control. The feasibility of such use is due to the large volume of waste generated and the amount of nutrients that are easily mineralized when applied in soil (Lucas et al., 2013).

In this sense, an alternative that has been highlighted in the pursuit of sustainability in the recovery of degraded cultivated soils and pastures is the use of organic fertilizers or cover crops because the mineral fertilizers in this context is rather low due to its high cost and due to the low purchase power of most producers. For instance, mineral fertilizers in Africa cost at the farm gate, two to six times as much as in Europe, North America, or Asia (Sanchez, 2002). Therefore, organic inputs are a viable alternative source of plant nutrients for resource-poor farmers. Application of organic input usually leads to increased crop yields and pasture (Ogundare et al., 2012; Matthews, 2017). The acceptance by local farmers of the benefits of compost to the soil and crops would be a significant incentive to reduce the expensive mineral fertilizers and optimize their use (Azim et al., 2017). Thus, the use of SW is available as an alternative to replace the mineral fertilizer, demonstrating its efficiency in dry matter production and nutrient availability (Zanine and Ferreira, 2015; Gomes et al., 2017; Lucas et al., 2013). However, there is little information regarding the use of this waste in areas with degraded pastures (Fogel et al., 2013).

The supply of nutrients in adequate amounts via SW can increase the nutritional quality of the forage, enhancing performance and/or animal productivity (Assmann et al., 2009). Therefore, the use of Swine wastewater (SW) as a source of nutrients in pasture areas is presented as an alternative to disposal of this waste (Assmann et al., 2009; Seidel et al., 2010). Camargo et al. (2011) observed the effects of different doses of swine manure on forage Tifton 85 and found that an increase in dry matter production and P content grew linearly with the doses, thus suggesting a dose of 100 m³ ha^{-1} to obtain about 3500 kg ha^{-1} dry weight in a period of 28 days. Serafim and Galbiatti (2012) discussed that an increase in the application of swine waste increased the supply of nitrogen and phosphorus to the soil, thus promoting plant growth and increasing the ratio of leaf/stem.

Thus, it is needed to find the proper management from a biophysical point of view to promote sustainable agriculture. However, it is also necessary that farmers accept new strategies that propose cultural and technical shifts (Cerdà et al., 2018a). The search for information and knowledge to clarify how to use the SW in pastures is growing. To have a correct land management in intensive systems, it is important to know the nutrient extraction capacity for forage to mitigate the negative environmental impacts on the ground and to define the best application rates.

In this way, there is a need to design proper policies to achieve sustainability, and for this, the scientific community should produce information in collaboration with land managers and other actors, which will guide policy makers to implement the most efficient managements and strategies (Cerdà et al., 2018b). This study aimed to evaluate the effects of application of five SW doses (0, 500, 1000, 2000 and 2500 m³ ha^{-1}) in the following production components: bearing capacity, dry matter yield, density, percentage of dry matter grass height, dry matter production per day and in grass nutrient extraction Tifton 85 grazed and changes in soil chemical properties.

MATERIALS AND METHODS

Study area

The study was conducted during the period from January to April, 2013, at the Bonsucesso farm, which is located in, Minas Gerais state, Brazil, at the geographical coordinates 19°05'17"S and 48°22'00"W, at an altitude of 820 m, at an dystrophic yellow Oxisol, according to Embrapa classification in 2006. According to the Köppen and Geiger (1928) system, the climate is characterized as Aw (typical tropical, with average rainfall around 1600 mm per year, with moderate water deficit in winter and excessive rain in summer). Before the experiment installation, it was determined that the chemical and physical soil characteristics of the area at different depths of 0.00-0.20 m and 0.20-0.40 m (Table 1). For this, 10 soil samples to form a composite sample were collected at random in the experimental area with a Dutch auger.

The study was conducted on grazing Tifton 85 and was installed five years ago. The experimental design was a randomized complete block design with five treatments and three replications. Plots were 3 x 3 m, amounting 9 m², 1 m boundary among plot. The treatments consisted of the following wastewater doses of swine (SW): control (without application of SW), 500, 1000, 2000 and 2500 m³ ha^{-1}. The waste used in the experiment comes from a swine production system in the finishing phase, handled with biodigester PVC blanket and stabilization pond, being stored for about 20 days. After this period, the SW is applied in the grazing areas. There was the uniform grass height of Tifton 85, 0.10 m tall, with hydraulic brush cutter before the start of the experiment. After the treatments (Table 2) and data collection (21 day cycle), the remaining forage of each cycle was quantified and grazed up to a height of 0.10 m.

The application doses of SW were performed manually with a 1-inch diameter hose and distributed evenly over each plot. The doses were calculated due to the application of time on each plot. Thus, the flow rate was set at 45 L min^{-1} and application times were 0 (no application), 2, 4, 8 and 10 min, respectively providing from the lower treatment dose to the higher dose. Each dose of SW was split into five applications, always at the beginning of each 21-day grazing cycle (Table 2). This installment was not to exceed the field capacity in a single application. In each application date, they were collected a sample of 600 mL of SW and stored in refrigerator. The five SW samples were homogenized, then pulled out a sample that was sent to Araxá Environmental laboratory for chemical characterization. The average levels of nutrients are SW: N = 823.60 mg L^{-1}; P = 20.46 mg L^{-1}; = K^+ 509.40 mg L^{-1}; Ca^{2+} = 51.54 mg L^{-1}; Mg = 33.53 mg L^{-1}; organic matter = 331.80 mg L^{-1}, B = 0.55

Table 1. Chemical characteristics and grain size of the soil, in the depths studied the experimental area with the Tifton 85 grass before application of treatments.

Depth	pH	P resin	K^+	$S\text{-}SO_4^{2-}$	Ca^{2+}	Mg^{2+}	Al^{3+}	H+Al
(m)	(water)	...........mg dm^{-3}..............			......................$cmol_c\ dm^{-3}$		....	
0.00-0.20	5.50	39.90	94.0	1.77	1.00	0.30	0.15	2.60
0.20-0.40	5.50	18.20	56.0	2.02	0.70	0.10	0.20	2.10

	B	Cu^{2+}	Fe	Mn^{2+}	Zn^{2+}	SB	t	T
	....		mg dm^{-3}.................................			............$cmol_c\ dm^{-3}$..........		
0.00-0.20	0.11	4.00	91.00	6.30	8.10	1.54	1.69	4.14
0.20-0.40	0.28	1.60	28.00	2.40	2.00	0.94	1.14	3.04

	MO	V	m	Clay	Silt	Sand
	%	%	%	....	g kg^{-1}................................	
0.00-0.20	2.3	37	09	153	25	822
0.20-0.40	1.6	30	17	165	17	818

Potassium (K) = (HCl 0.05 mol L^{-1} + H_2SO_4 0.0125 mol L^{-1}); available P (resin); Ca, Mg, Al, (KCl 1 mol L^{-1}); H + Al = (Buffer Solution - SMP pH 7.5); SB = Basic Sum; T = CEC at pH 7.0; V = Base saturation; m = saturation by aluminum; Organic matter (M.O.) = Colorimetric Method. Boron (B) = (0.0125% $BaCl_2.2H_2O$); Cu, Fe, Mn, Zn = (DTPA 0.005 mol L^{-1} + TEA 0.1 mol^{-1} $CaCl_2$ 0.01 mol L^{-1} a pH 7.3). Clay: pipette method. Chemical analysis carried out according to methodologies described by Embrapa (2009).

Table 2. Total dose of SW, portions of value applied to each treatment and dates of split applications in grass Tifton 85.

Dose total	05/01/13	26/01/13	16/02/13	09/03/13	30/03/13
	....	$m^3\ ha^{-1}$	....		
500	100	100	100	100	100
1000	200	200	200	200	200
2000	400	400	400	400	400
2500	500	500	500	500	500

mg L^{-1}; Cu^{2+} = 4.33 mg L^{-1}; Fe = 6.34 mg L^{-1}; Mn^{2+} = 0.91 mg L^{-1} and Zn^{2+} = 5.71 mg L^{-1} and pH $CaCl_2$ = 8.16. The methodologies used in determining the SW nutrients were based on Standard Methods for the Examination of Water and Wastewater (APHA, 2012). During the experiment, the rainfall and average temperature were measured daily and are displayed by means of each ten-day period (Figure 1). For evaluation of forage growth, five successive cuts were performed (over 0.10 m high) in 21-day intervals (cycles). To collect the sample mass of dry (DM) forage, the sampling method square template, proposed by Aguiar (2009), was used.

The forage harvested in the area sampled per plot were determined a fresh pasture mass. Subsequently, the identified sub-samples were dried in an oven with forced air circulation at 65°C for 72 h to determine the mass of dry matter over 0.10 m high (Gardner, 1986). The percentage of dry matter was then calculated and expressed in kg ha^{-1} DM. Then, soil samples were crushed (Willey mill) to determine the total content of nutrients. To determine the height of grass from the ground level to the highest part a top were used a scale and an x-ray paper were used to standardize the height of the plants, in 10 replications. The bulk density of forage was obtained by dividing the dry mass weight/height plants that was expressed in kg ha^{-1} cm^{-1}. The forage accumulation was calculated by subtracting the herbage mass in pre-grazing forage by the post-grazing mass. Forage accumulation rate (over 0.10 m) was expressed in kg ha^{-1} day^{-1} DM. It was calculated by dividing the accumulation of forage for 21 days grazing cycle by 21, the number of days in the cycle.

The pasture's carrying capacity was calculated considering an herbage allowance of 5 kg DM per 100 kg live weight. After the measurements of pasture, the cattle were put to graze, aimed at standardizing the grass height to 0.10 m. After 21 days of application of the last installment of SW, soil samples were taken at different soil depths such as 0.00-0.20 m and 0.20-0.40, originating six samples, randomly collected in the plot with a Dutch auger. The pH in water, exchangeable acidity (Al^{3+}), potential acidity (H + Al) and soil organic matter (OM), phosphorus (P), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) copper (Cu^{2+}), zinc (Zn^{2+}), manganese (Mn^{2+}) and iron (Fe) was analyzed, according to the methodology described by EMBRAPA (2009).

The aerial parts of the plants were subjected to analysis of the N, P, K, Ca, Mg, S, Fe, Cu, Mn, Zn, B according to methodologies EMBRAPA (2009) after each 21-day cycle. With the nutrient content of aerial parts of each cycle, the accumulation of these nutrients and recovery efficiency of each of the plant were evaluated. The accumulation of nutrients in the aerial part of each cycle was then used to define the nutrient uptake of the grazed pasture (kg ha^{-1}) to 105 days of experiment. All results were analyzed using the Barttlet and Jarque-Bera test (Jarque and Bera, 1980) to check the homogeneity of variances conditions and normality, respectively. Analysis of variance and regression

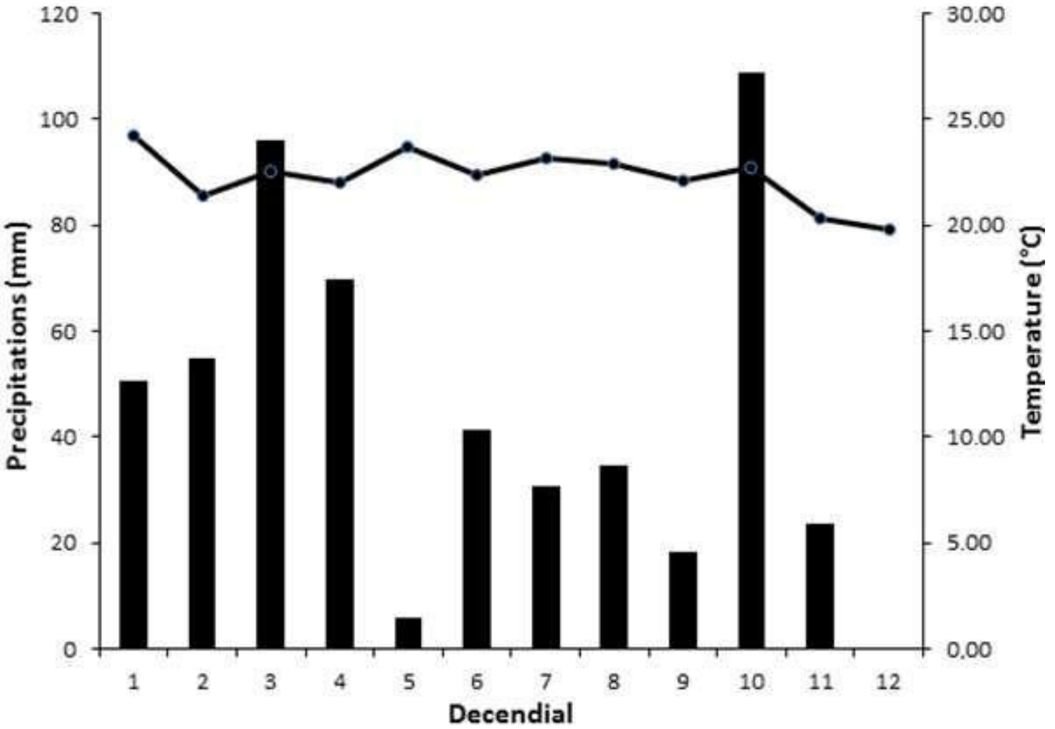

Figure 1. Storm Precipitation and Average Temperature during the period experiment.

analysis for the SW doses were carried out, to determine levels of significance, using the SAEG 9.1 program, 2007.

RESULTS AND DISCUSSION

The results of analysis of variance for the production of components are shown in Table 3. The application of different doses of SW provided a linear increase in all grass production components Tifton 85 studied (Figure 2). The average heights of Tifton 85 ranged between 31 and 39 cm with a 21-day cycle (Figure 2d). Results similar to the Aguiar (2009), an experiment in Uberaba, with intensive management, which found an average height in the spring/summer of 36.4 cm and an annual average of 29.7 cm.

The higher carrying capacity, 10 AU ha^{-1} was obtained with the dosage of 2500 m³ ha^{-1}, whereas grazing efficiency of 50% (Figure 2b). Lupatinie Hernandez (2006) showed, among various types of forage, the Tifton 85 grass with high fertilization responded better to irrigation, with a carrying capacity of up to 10 AU ha^{-1}. Which, showed the great forage production potential of grass associating intensive management, adequate fertilization and irrigation. The accumulation rate of dry matter per day obtained averages 138-219 kg ha^{-1} day^{-1} (Figure 2e). Aguiar et al. (2005) showed an average annual accumulation rate of forage of 172 kg ha^{-1} day^{-1}. Drummond et al. (2006) reached herbage accumulation rate of 148.2 kg ha^{-1} day^{-1} of dry matter in grazing Tifton 85 fertilized with swine waste in the region of Uberaba - MG. Research works on pastures have presented linear increases of forage dry matter using doses of wastewater (Orrico junior et al., 2013; Andrade et al., 2014; Homem et al., 2016), with average accumulation doses of up to 170 kg ha^{-1} day^{-1} of DM in Tifton 85 grass using swine wastewater (Andrade et al., 2014).

Vielmo et al. (2011) used SW at doses of 0 to 320 m^{3} ha^{-1}, cycle of 28 days on Tifton 85, and verified a production of 151 kg ha^{-1} day^{-1} of dry matter at the highest dose. Gomes et al. (2018) obtained higher productivity, equal to 189 kg ha^{-1} day^{-1} of dry matter using dose of 300 m^{3} ha^{1}. Andrade et al. (2012) in an experimental area on the campus of Rio Paranaiba UFV evaluated the forage accumulation and managed in the intensive irrigated system. The ideal point of grazing and the chemical composition of forage produced in summer and autumn in pasture managed in intensive system with Tifton 85 grass found herbage accumulation rates of 140.0 kg ha^{-1} day^{-1} of DM in the summer and 122.2 kg ha^{-1} day^{-1} of DM in the fall. The height of the ideal grass for grazing was 25.4 cm.

The highest production of dry matter was obtained with an average dose of 2500 m³ ha^{-1} (Figure 2a), which was 66.5% higher than the average control, in the period of 105 days. The linear increase of production and grass

Table 3. Averages of the components related to production Tifton 85 subjected to increasing doses of SW.

Components of production	Averages	p-valor	CV%
Carrying capacity (UA ha^{-1})	7.69	0.000	5.90
Production of dry matter (kg ha^{-1})	18159.80	0.000	5.90
Density (kg ha^{-1} cm^{-1} of DM)	109.40	0.008	7.08
Dry matter (%)	23.39	0.058	3.15
Grass height (cm)	34.83	0.000	2.05
Accumulation rate of dry matter per day (kg ha^{-1})	172.95	0.000	5.90

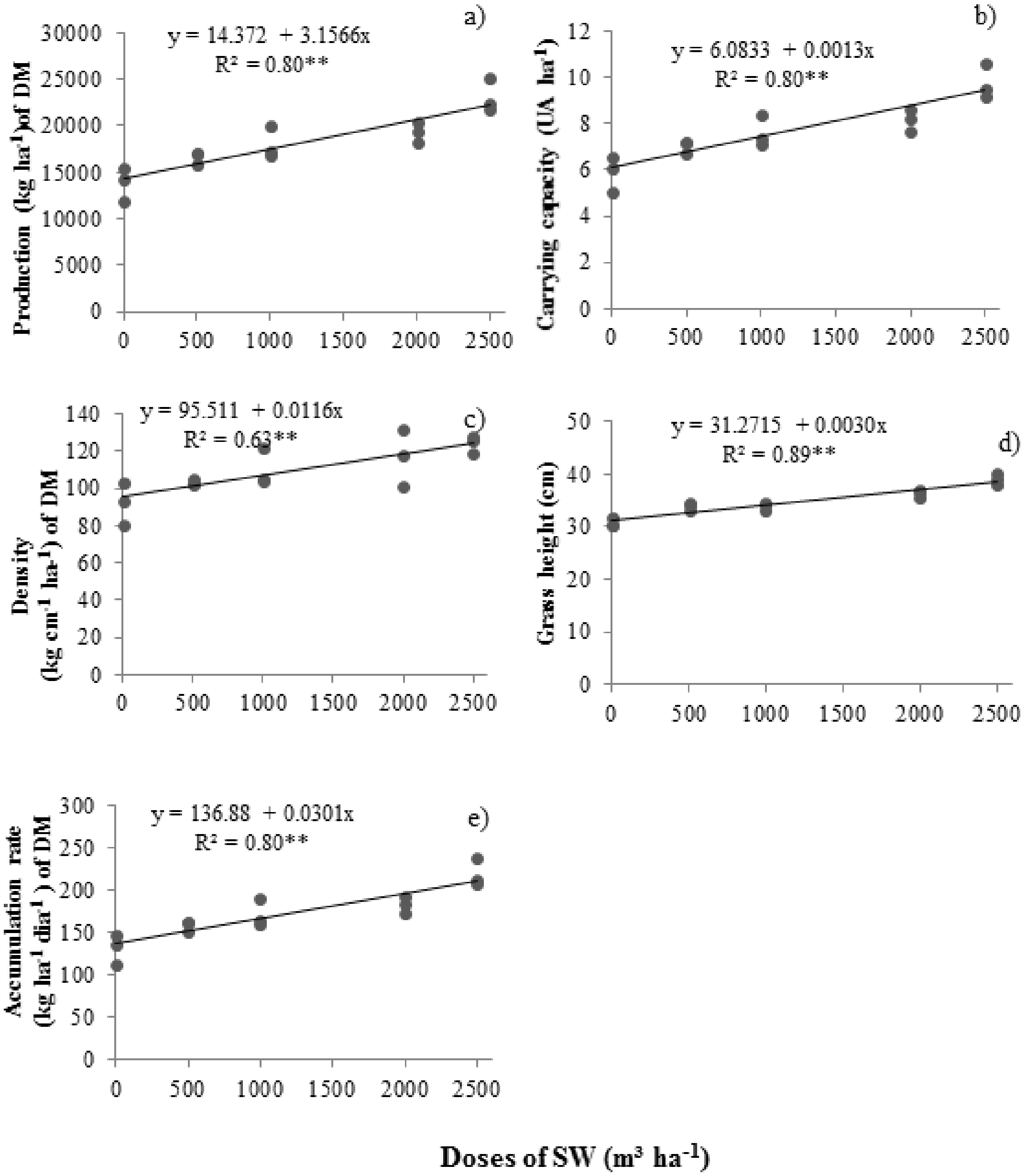

Figure 2. Components of production: production (kg ha^{-1}) **(a)** carrying capacity **(b),** density **(c)** of the grass height **(d)** and accumulation rate of dry matter per day **(e)** the trial period with the Tifton 85 grass, when subjected to increasing doses of SW. **: Significant at 1% probability.

Table 4. Average macro content, micronutrients and chemical characteristics of the soil subjected to increasing doses of SW.

Depth	Variable	P resin	K^+	$S\text{-}SO_4^{2-}$	Ca^{2+}	Mg^{2+}	SB	H+Al	T
		....	mg dm^{-3}	....		.... cmol$_c$ dm^{-3}		....	
0.00-0.20 m	Averages	31.27	101.00	3.67	0.64	0.44	1.34	2.29	3.63
	p-valor	0.385	0.468	0.011	0.230	0.034	0.092	0.594	0.344
	C.V. %	58.97	22.62	39.83	24.71	22.92	17.82	14.07	10.67
0.20-0.40 m	Averages	7.16	102.00	4.87	0.43	0.26	0.95	1.75	2.7
	p-valor	0.241	0.742	0.003	0.004	0.001	0.008	0.028	0.633
	C.V. %	57.79	27.81	26.66	16.85	13.14	14.94	10.95	8.12

		pH	M.O.	V	B	Cu^{2+}	Fe	Mn^{2+}	Zn^{2+}
		(water)	%	%		....	mg dm^{-3}	....	
0.00-0.20 m	Averages	5.49	1.69	36.82	0.10	3.10	54.40	7.22	5.27
	p-valor	0.089	0.328	0.168	0.096	0.464	0.679	0.029	0.652
	C.V. %	3.44	15.64	14.91	15.18	26.26	42.83	23.21	42.75
0.20-0.40 m	Averages	5.61	1.05	35.09	0.9	1.89	18.87	4.52	1.5
	p-valor	0.003	0.906	0.003	0.977	0.725	0.313	0.015	0.463
	C.V. %	4.17	12.76	13.22	22.32	64.97	26.21	24.81	31.38

height influenced the dry matter density, which increased from 92.4 kg ha^{-1} cm^{-1} DM in witness to 125.2 kg ha^{-1} cm^{-1} DM at the highest dose (2500 m^3 ha^{-1}), an increase of 34.5% in the grass density (Figure 2c). With increasing doses of the SW, the pH did not show any variation in the two depths (Tables 1 and 4), due to the alkaline characteristics of SW. According to the results this study, Silva et al. (2014) observed that soil attributes related to the acidity did not suffer influence of successive applications of SW. These differed from Queiroz et al. (2004) who observed a lowering of the pH with the application of SW. According to Bouwer (2000), in soils receiving wastewater, there may be a decrease in pH due to the mineralization of organic compounds of the SW, which facilitates the production of CO_2 and organic acids. Already, Lucas et al. (2013) observed the pH increased from 5.47 to 6.77 in the soil (0 to 0.60 m) at 1015 days of SW application. Increased pH values of soil were consistent with the high pH values of SW used, ranging from 7.08 to 7.70.

The available potassium content (K^+) in the soil was similar at both depths with 101.0 and 102.0 mg dm^{-3} levels (Table 4) and fall within the adequate availability class, according to CFSEMG Ribeiro et al. (1999). A significant increase in K^+ content at a depth of 0.20-0.40 m, indicated a percolation of K^+ for the deeper layers, because the soil characterization analysis before applying the SW doses (Table 1) the levels were 94.0 and 56.0 mg dm^{-3} in these depths. By being a monovalent, K^+ has low retention on soil colloids, being susceptible to being leached from the surface layers for the subsoil layers. Which with the application of SW doses, the amount of added K^+ was high than extracted by Tifton 85 (Figure 3c), favoring an increase in the levels of K^+ in the soil (Table 4).

The potassium content of the soil increased in this experiment because when compost is used, according to Scherer (2001), the potassium K^+ from the mineral and organic fertilizer are similar. Thus, there is no requirement to undergo any mineralization through the action of microorganisms.

According to Penha et al. (2015) long-term applications of pig slurry in a Brazilian Cerrado soil have shown to affect chemical characteristics of the soil. High pig slurry rates increased P contents only in the soil surface, while the contents of K increased throughout the soil profile. This fact shows the marked difference in terms of P and K behaviors in tropical soils, indicating that K is more prone to be leached in a Cerrado soil following successive applications of pig slurry. The phosphorus (P) showed a higher concentration in the surface layer (Table 4). This is because the positive organic radicals in SW adsorb P, favoring surface accumulation. Also the clay in these soils are sesquioxidic which feature high phosphorus adsorption. The P in Cerrado soils have low mobility focusing mainly in layers of 0.00 to 0.10 m. In a study on the use of swine wastewater in natural pasture, Ceretta et al. (2003) showed no changes in phosphorus concentration, with high concentration of P in the surface layer, with increases of 580% to 8.3 months and 6.710% at 48 months of application liquid effluent from pig farms. These studies indicate the importance of monitoring when performing constant application of SW in the same area.

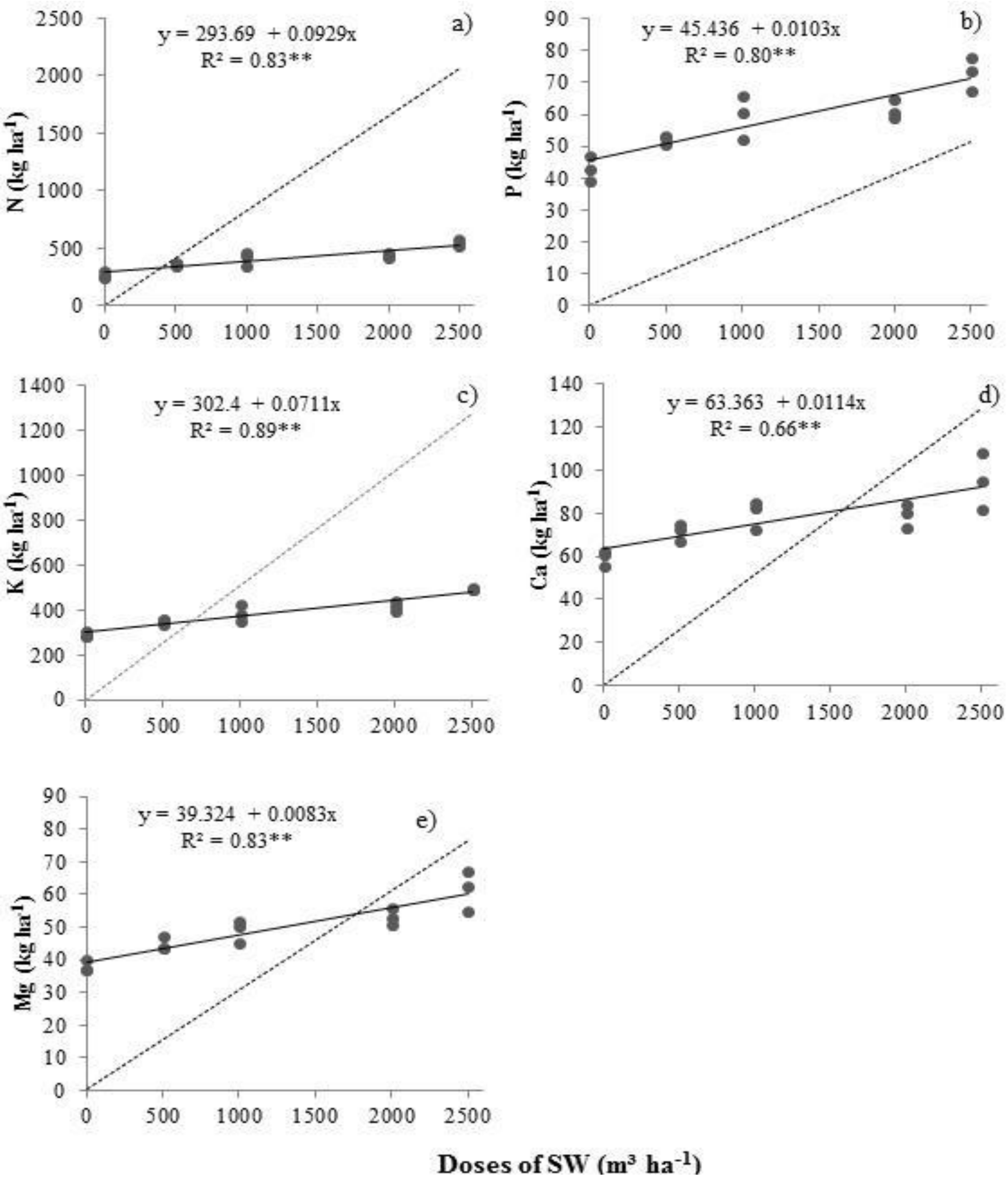

Figure 3. Extraction of the nutrients N (a), P (b), K (c), Ca (d) and Mg (e) by dry weight.
** and *: significant at 1 and 5% probability, respectively. The dotted line refers to the addition of nutrients to the soil by increasing doses of SW and the continuous line for extracting the forage.

However, Seganfredo et al. (2017), reports that the application of SW increases the ease of desorption of P and this makes it necessary to control its movement in the profile and transport through runoff. There was a significant effect of the SW application on the content of (Mg^{2+}) available in soil (Table 4). According to Ribeiro et al. (1999), the levels observed in two depths remained low (0.44 and 0.26 $cmol_c$ dm^{-3}). However, there was a significant increase in Mg^{2+}, in both evaluated depths, as in soil characterization analysis before applying the SW

Table 5. Medium of the leaf content of macro and micronutrients of Tifton 85 subjected to increasing doses of SW.

Element	N	P	K	S	Ca	Mg	B	Cu	Fe	Mn	Zn
			g kg^{-1}						mg kg^{-1}		
Averages	22.62	3.12	21.28	1.69	4.18	2.66	18.11	11.19	151	242	144
p-valor	0.008	0.064	0.021	0.020	0.565	0.238	0.308	0.984	0.619	0.301	0.004
C.V. %	2.39	4.28	3.56	6.27	4.43	4.98	12.29	13.25	11.31	21.96	0.11

doses (Table 1), the determined values were 0.30 and 0.10 cmol$_c$dm^{-3} at a depth of 0.00 to 0.20 and 0.20-0.40 m, respectively. With the application doses of the SW the added amount of Mg^{2+} was higher than that extracted by Tifton 85 (Figure 3e), thus favoring the increase in Mg^{2+} content in soil (Table 4). The content of calcium (Ca^{2+}) at a depth of 0.00 to 0.20 m is 0.64 cmol$_c$dm^{-3}, while the depth is 0.43 m 0.20-0.40 cmol$_c$dm^{-3} (Table 4), and these levels considered low by Ribeiro et al. (1999). However, replacement of Ca^{2+} is less than the amount extracted at doses of 500 and 1.000 m³ ha^{-1} SW, however, higher in doses of 2000 and 2500 m³ ha^{-1} SW (Figure 3d), not favoring the accumulation of calcium in two depths assessed (Table 4). Queiroz et al. (2004) observed no changes in Ca^{2+} levels in soil with wastewater.

The base saturation (V) showed a significant increase in the depth of 0.20-0.40 m (35.09%) with the application of SW doses (Table 4) in relation to the initial content (30%) (Table 1). This result is related to the increase in potassium and magnesium content at this depth. With the application of SW, the levels of organic matter that were 2.3% at a depth of 0.00 to 0.20 and 1.6% in the depth 0.20-0.40 m (Table 1), did not show any increase due to the application of the treatments (Table 4), with no significant differences. Mattias (2006) did not observe an increase of organic matter in the application of liquid effluent from swine farms.

The lack of response to the increase of organic matter can be explained by Assmann et al. (2006) who observed no increase in organic matter content by applying liquid swine waste. For, according to the authors, they must be considered inherent characteristics of manure used, where the quality of the organic compounds may determine a greater or lesser accumulation in the soil. The organic compounds present in the liquid manure of pigs have been easily digested by oxidizing in a few days or weeks and are favored for higher microbial activity. The microbial biomass is considered a vital part of the organic matter, composed of micro-organisms (bacteria, fungi and actinomycetes), comprising 2 to 5% carbon and up to 5% of total nitrogen (Moreira and Siqueira, 2003). There were no significant differences among treatments in nutrient contents Fe, Cu^{2+} and Zn $^{2+}$ (Table 4). However, for Lucas et al. (2013) and Rosa et al. (2017a, b), the applications of swine wastewater favored the accumulation of copper and zinc.

According to Girotto (2007), successive applications of SW to the soil cause accumulation of Zn^{2+} in the surface layers that were found significant for the accumulation of Zn^{2+} layer to the depth of 0.10 m. The Cu^{2} + and Zn^{2+} elements are used in animal feed as a supplement, without being fully absorbed and therefore excreted in high amounts, remaining in SW (Rosa et al., 2017b). The high capacity of Oxisol adsorbs Cu and Zn and low mobility of these elements could be verified by (Lopes et al., 2014). Gomes Filho et al. (2001) reported poor copper mobility in soil, stating that this element among the heavy metals is the most strongly adsorbed or complexed by the soil. Furthermore, according to Lopes et al. (2014) high adsorption of Cu^{2+} and Zn^{2+} may be the result of an increase in soluble organic compounds, which have the ability to complex these nutrients. The average leaf content of nutrients N, P, K, S and Zn differed due to the application of increasing doses of SW (Table 5). Thus, the application of different doses of SW influenced the foliar contents of these nutrients.

Knowledge of the leaf content of an intensive system of production, mainly in a very demanding nutritionally species, such as Tifton 85 grass, is very important for determining the amount of nutrient to be restored, reaching thus the mass production desired dry matter. Silva (1999) described the range of suitable concentrations for Tifton as follows, relative to macronutrients: C = 20.0-26.0; P = 1.5-3.0; K = 15.0-30.0; Ca = 3.0-8.0; Mg = 1.5-4.0; S = 1.5-3.0 g kg^{-1}. For optimal range micronutrient is: B = 5.0-30.0; Cu = 4.0-20.0; Fe = 50.0-200.0; Mn = Zn = 20.0-300.0 and 15.0-70.0 mg kg^{-1}.

In this experiment the nutrient contents fall within the proper range suggested by Silva (1999), except Zn, wherein the average of treatments was 144 mg kg^{-1}. The extraction of nutrients by dry weight of the shoot (above 10 cm) was high, demonstrating that the Tifton 85 grass has high nutrient extraction capacity (Table 6). The extraction of macro and micronutrients of shoots of grass Tifton 85 follows the following order: N> K> Ca> P> Mg> S> Mn> Fe> Zn> B> Cu (Table 6). As the DM output followed a linear growth projection (Figure 2a), all nutrients obtained the same trend (Figures 3 and 4).

The dose of 500 m³ SW ha^{-1} provided the soil 411.08 kg ha^{-1} of N and extraction was 358.01 kg ha^{-1} of N, which corresponds to 87.09% of the applied level. These results show that the synchronism between the availability of N from SW culture and demand generated

Table 6. Extraction of nutrients from the Tifton 85 grass (dry matter), subjected to increasing doses of SW.

Element	N	P	K	S	Ca	Mg	B	Cu	Fe	Mn	Zn
					kg ha^{-1}						
Averages	405.14	57.77	387.69	31.48	77.05	49.68	0.33	0.2	2.88	4.61	2.86
p-valor	0.001	0.001	0.000	0.005	0.017	0.008	0.057	0.025	0.007	0.078	0.050
C.V. %	7.73	6.25	5.34	11.23	9.65	8.98	10.50	13.30	8.49	27.09	15.36

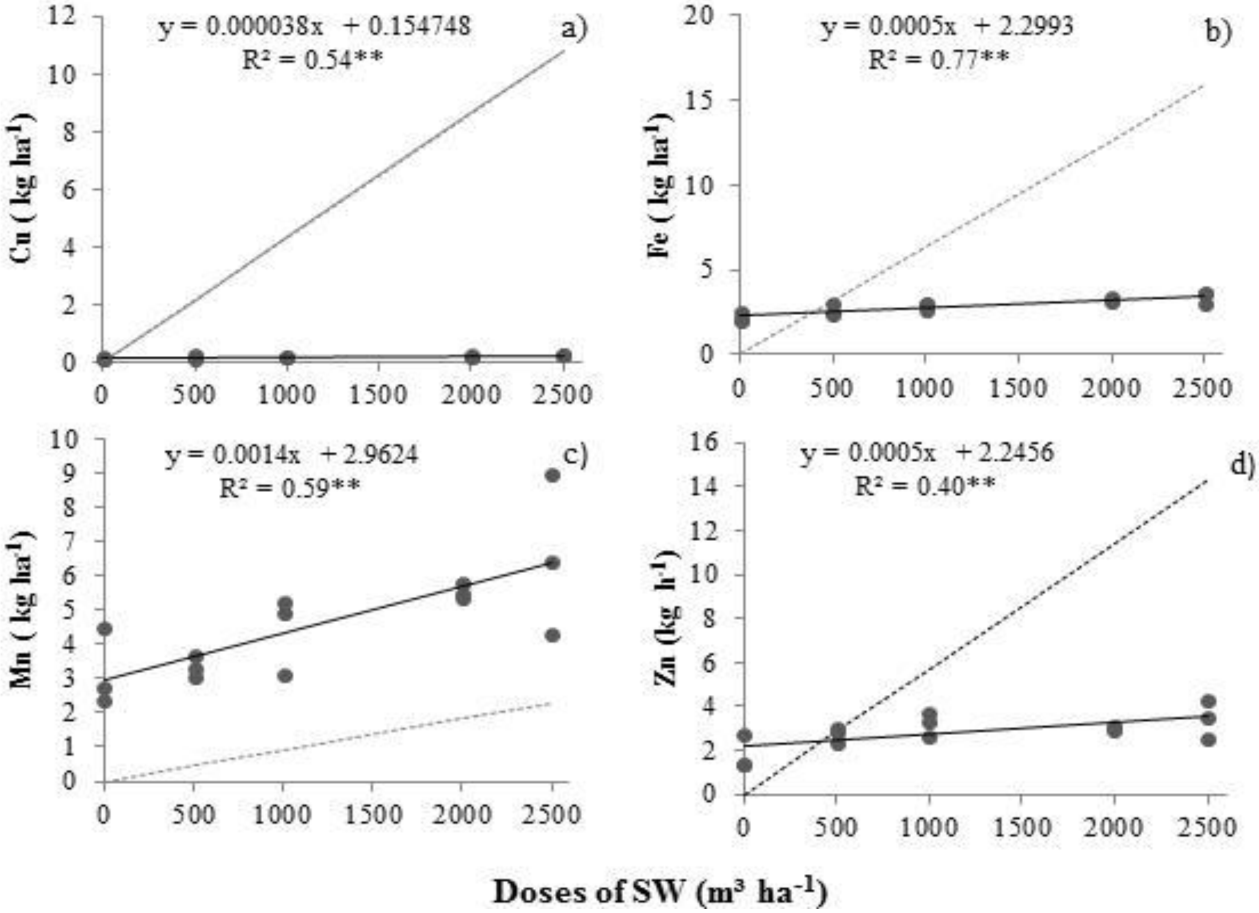

Figure 4. Extraction of micronutrients Cu **(a),** Fe **(b),** Mn **(c)** and Zn **(d)** by dry weight.
** Significant 10% probability. The dotted line refers to the addition of nutrients to the soil by increasing doses of SW and the continuous line for extracting the forage.

a beneficial effect on the nutrient recycling process. This balance can reduce the mineral N concentration in the soil solution, promoting the sustainability of the production system. Surely, this dose is the most appropriate in the environmental point of view with respect to N (Figure 3a). Sharpe and Harper (2002) further justify about 35% of N SW is lost in the form of NH_3 during application. The phosphorus provided by increasing doses of SW was lower than that extracted by the plant in all treatments (Figure 3b), since the nutrient content in this SW is low (20.46 mg L^{-1}). Silva et al. (2012) conducted an experiment on the Bonsucesso farm and found that the phosphorus content in SW was reduced by approximately 80% to pass the Biodigester and the lagoon decantation, thus justifying the low content in SW. According to Mattias (2006), the accumulation of P in soils treated with SW correlates with a lower N/P ratio of waste, since it meet the required amounts of N by plants it is necessary to simultaneously apply greater amounts of P resulting in accumulation and organic P moving in the environment. At a dose of 500 m³ ha^{-1} potassium applied via wastewater (254.69 kg ha^{-1})

was lower than that extracted by the plant (Figure 3c). Higher doses left nutrient residues in the soil (Figure 3c and Table 4).

The calcium extractions (Figure 3d) and magnesium (Figure 3e) by Tifton 85 grass were lower than the amount provided by the SW dose 2.000 m³ ha^{-1}. In this dose, the SW has provided the soil 103.8 kg ha^{-1} of calcium and magnesium 67.06 kg ha^{-1} and extracting the Tifton 85 was 86.16 kg ha^{-1} of calcium and 55.92 kg ha^{-1} magnesium, this being the SW dose sufficient to provide the amount extracted at 85 Tifton. There is a tendency to accumulate copper (Cu) in soil with SW (Figure 4a). Cu average extraction obtained in the dry matter of grass Tifton 85 was 0.2 kg ha^{-1}. The lowest dose of SW added tem times more than the Cu extracted by forage, while the highest dose added 40 more times. Figure 4 illustrates the low extraction by Cu Tifton 85 grass.

Lima and Miyada (2003) conducted an experiment with Cu in the form of cupric citrate, a more soluble source with greater utilization by the animal and less waste left in the excretions. Thus, they concluded that cupric citrate may replace the Cu sulfate, contributing to reducing this nutrient in the SW. SW in any of the doses could supply the manganese (Mn) needed for the production of Tifton 85 grass (Figure 4c). It is necessary to monitor this nutrient in the soil and the plant, as part of nutrients extracted by grass after being consumed by cattle and returned to the soil through animal waste. Zn supplied by the dose of 500 m³ ha^{-1} was 2.86 kg ha^{-1} approaches the extracted amount of and 2.72 kg ha^{-1} at Tifton 85 (Figure 4d). The view on organic waste recycling needs to be diversified, being recovery and recycling of nutrients from organic wastes are a possible solution. When organic waste recycling is complemented by nutrient extraction, some nutrient loops within society can be closes, enabling more sustainable agricultural production in future (Kirchmann et al., 2017).

Conclusions

The application of increasing doses of SW promoted a linear increase in carrying capacity, mass production of dry matter, density, height, and mass accumulation rate of dry matter per day of Tifton 85 grass. The wastewater doses promoted changes in soil chemical properties. The dose of 2.000 m³ ha^{-1} supplied the nutritional needs of the grass Tifton 85 in nitrogen, potassium, calcium, magnesium, copper, iron and zinc.

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CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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