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Application of swine wastewater for irrigation of Tifton 85 grass: Part I-productivity and nutritional quality

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Abstract

The use of swine wastewater (SW) for irrigation can be an excellent alternative to increase productivity and quality of pastures. This work was carried out from October 2013 to September 2014 in Dourados – MS. The objectives were evaluation of the productivity and nutritional quality of Tifton 85 grass (*Cynodon spp.*) under different doses of SW in the presence and absence of normal water irrigation. The experiment was set in a randomized block with split plots design, including water irrigated and non-irrigated in the main plots and four doses of SW in the subplots (75, 150, 225 and 300 m^3 ha^{-1} cut^{-1}), with four replicates. The total forage yield and the bromatological value (crude protein, neutral and fibre detergent acid and dry matter digestibility) were evaluated. There was a significant effect of irrigation and SW doses on total dry matter yield, reaching 41.4 Mg ha^{-1} $year^{-1}$ using the highest dose of SW (300 m^3 ha^{-1}) and irrigation use. Irrigation also provided higher crude protein levels, increasing with linear adjustment to SW doses, reaching 17.9% in the annual average. The neutral detergent fibre and the acid detergent fibre presented lower results under irrigation, reaching 65.4 and 32.6% in the annual average, respectively, and linearly decreased using SW doses. Inverse behavior was observed in the *in vitro* digestibility of dry matter, which was higher under irrigation, reaching 69.5% in the annual average and presenting linear growth according to doses of SW.

Keywords: organic fertilization, botanical composition, Cynodon spp., dry matter yield, forage quality, crude protein.
Abbreviations: SW_Swine wastewater.

Introduction

In countries such as Brazil, which the climate favours the growth of pastures, the diet derived from forages is the key to ruminant production. It is basically depends to pasture grazing or cultivation of forage crops (Morris and Kenyon, 2014; Chobtang et al., 2017a; 2017b). With the increasing water scarcity and seasonal climatic conditions that reduce production, the reutilization of wastewater is now considered essential in integrated water management (Abdoulkader et al., 2015). Although 96% of Brazilian ruminants are managed with pastures, the productivity is low, with a capacity of 1.2 animal unit per hectare (ABIEC 2015). There is, therefore, a need for more efficient livestock farming, with greater competitiveness compared to other land uses (Silva et al., 2013).

The climate change have been causing direct effects on grasses in the last decades (Raz-yaseef et al., 2015; Barbosa, 2016; Kalaugher et al., 2017), including changes in rainfall patterns that may lead to a considerable decline in agricultural production (Mall, Gupta and Sonkar, 2017), causing the seasonality of the production of tropical plants (Dantas et al., 2016), common in various regions of Brazil (Gomes et al., 2015a).

Irrigation has been used to reduce seasonality in the Center-South regions of Brazil (Gomes et al., 2015b). However, this supplemental irrigation could no eliminate the seasonality (Sanches et al., 2015). In this sense, we highlight the Cynodons, which has presented excellent productive results with irrigation, attenuating the seasonality with good nutritional results, especially the Tifton 85 grass (Gomes et al., 2015b; Sanches et al., 2015, 2016, 2017).

For the Central-South regions of Brazil, recent surveys with irrigated and non-irrigated cases indicate the average accumulation increments between 25 and 55 kg ha^{-1} day^{-1} of DM with irrigation for production of Tifton 85 grass (Queiroz et al., 2012; Nogueira et al., 2013; Teixeira et al., 2013; Gomes et al., 2015a, 2015b, Sanches et al., 2015, 2016, 2017).

Nitrogen fertilization has been a subsequent strategy to promote pasture intensification, with increasing linear responses in Tifton 85 (Quaresma et al., 2011; Gomes et al., 2015b; Taffarel et al., 2016; Sanches et al., 2017). Taffarel et al. (2016) reported an increase of up to 13.8 kg day^{-1} of DM for each kg of applied N, in an experiment with nitrogen doses. Gomes et al. (2015b) and Sanches et al. (2017) observed increase of 31.4 and 62.1 Kg day^{-1} of DM in irrigated Tifton 85 with nitrogen use at doses of 60 and 75 Kg of N, respectively, compared to the non-irrigated.

Due to the high costs of mineral fertilization, producers have been looking for lower-cost sources such as the use of biofertilizers (Orrico Junior et al., 2013). Swine wastewater is among the most used because it is produced in large quantities, need an appropriate environmental fate and are rich in several important elements for the growth of grasses, such as nitrogen, phosphorus and potassium (Zhao et al. 2009; Silva et al., 2013).

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).

The application of SW in the pastures occurs with fertilancer (tanks with applicator hoses) without adequate fertirrigation, since it requires investments in infrastructure (Andrade et al., 2014), prioritizing the fate of the effluent, with an increase in production below potential. The objectives of this research were to evaluate the productivity, composition and nutritional quality of Tifton 85 grass under several SW doses in the absence and presence of irrigation.

Results and discussion

Yield parameters of forage dry matter

Total forage productivity (TFP) and leaf and stem yield (PFC) were higher when irrigated water applied ($p < 0.05$) and responded in an increasing linear manner to doses of SW ($p < 0.05$) in the annual accumulation (Figures 4A and 4B) throughout the experimental period (Fig 5A, 5B, 5C and 5D).

The maximum yield that obtained in non-irrigated area was 25171 kg DM ha^{-1} $year^{-1}$ (69 kg DM ha^{-1} day^{-1}), and in irrigated area 40686 kg DM ha^{-1} day^{-1} (111.5 kg DM ha^{-1} day^{-1}). These are corroborated with literature, which mentioned accumulations between 55 and 90 kg DM ha^{-1} day^{-1} for irrigated Tifton 85 grass (Ribeiro and Pereira, 2011; Gomes et al., 2015a, Sanches et al., 2016). Meanwhile, in the irrigated area the accumulated dry matter has been between 105 and 125 kg DM ha^{-1} day^{-1} (Queiroz et al., 2012, Nogueira et al., 2013, Teixeira et al., 2013, Gomes et al., 2015b, Sanches et al., 2016).

Sanches et al., 2016 reported yield of 37603.1 and 25457.6 kg ha^{-1} $year^{-1}$ in irrigated and non-irrigated areas in a study on Tifton 85, which is consistent with the results of present study. Thus, it is observed that the irrigation contributes to increasing yield in cycles possibly through favouring the assimilation of available soil and climate resources.

During the experimental period, the absence of irrigation promoted higher soil water tensions (Fig 2) with annual irrigated and non-irrigated averages of 18.1 and 44.1 kPa, respectively, resulting in 400 mm of irrigation and reflecting lower productivity in all cuts in non-irrigated plots (Fig 5A). Sanches et al. (2015) observed average increase of 1325.8 kg ha^{-1} $cycle^{-1}$ in Tifton 85 production as a function of irrigation with lower water tension in the soil.

Under irrigation, the average yield was 22404 kg MS ha^{-1} in TFP_{crop} (cuts from 1 to 6) and 14338 kg MS ha^{-1} in $PTF_{off\text{-}season}$ (cuts from 7 to 12), by which the average is getting closed to the ratio of 64% *off-season/crop*. In the non-irrigated area, the mean TFP_{crop} was 13973 kg MS ha^{-1} and the mean $TFP_{off\text{-}season}$ was 8874 kg MS ha^{-1}, and the *off-season/crop* ratio reached 63.5%. Therefore, the use of irrigation could reduce the seasonality, as already observed by other authors (Nogueira et al., 2013; Teixeira et al., 2013; Gomes et al., 2015a; Sanches et al., 2015; Sanches et al., 2016).

The presence of nitrogen positively influenced the TFP and LSP in the cycles (Fig 5.c, and 5.d), with respective linear regressions. The effect of nitrogen on fertilization of Tifton 85 has shown linear increases resulting 1348 and 3007 kg $ha^{-1}cycle^{-1}$ yield from the lowest to the highest dose, respectively (Quaresma et al., 2011; Gomes et al., 2015b; Taffarel et al., 2016; Sanches et al., 2017). Sanches et al. (2017) and Quaresma et al. (2011), observed increases of 1348.9 and 1360.2 kg ha^{-1} $cycle^{-1}$ with higher doses of 100 and 240 kg of N ha^{-1}, values higher than the increases of 545 kg ha^{-1} $cycle^{-1}$ at dose 300 m^3 of SW in this work. However, the authors worked with chemical fertilizers.

In relation to the SW doses applied in Tifton 85 grass (Fig 4A), other authors have also observed the occurrence of increasing linear behaviour in dry matter yield. However, it is not easy to conclude a direct comparison between these studies, since besides the distinct edaphoclimatic condition; there are several other factors such as presence or absence of irrigation, the chemical composition of the SW, the analyzed period, the doses used and the frequency of the applications that can affect yield.

Vielmo et al., (2011) used SW in non-irrigated area with mean N, P and K concentrations of 1800, 1280 and 1100 mg L^{-1} respectively, 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,. In the corresponding period (October 2005-March 2006), this work obtained higher productivity, equal to 189 kg ha^{-1} day^{-1} of dry matter using dose of 300 m^3 ha^{-1} without irrigation and the SW with lower concentrations of N, P and K (579, 236 and 680 mg L^{-1}, respectively). This may have occurred due to the better distribution of SW in the period with six applications, while Vielmo et al. (2011) made two applications of SW. In different experiments on Tifton 85 and wastewater in the absence of irrigation, Camargo et al. (2011) and Andrade et al. (2014), used mean concentrations of N, P, K of 4520, 390 and 750 mg L^{-1} and 8240, 9310 and 3870 mg L^{-1}, respectively, and SW doses from 0 to 100 and from 0 to 94 m^3 ha^{-1}. They verified that at the highest dose, productivity of 163 and 130 kg DM ha^{-1} day^{-1} can be achieved, respectively. In the corresponding period and in the absence of irrigation, this work verified productivity of 91 kg DM ha^{-1} day^{-1} at the dose of 300 m^3 ha^{-1}.

Table 1. Means (µ) and standard errors (SE) of the chemical composition of swine wastewater (SW) applied on Tifton 85 grass pasture. Dourados - MS. 2013 - 2014.

	N total	P	K	Na	Ca	Mg	Cu	Fe	Mn	Zn	SDT	DBO	DQO	CE	pH
	mg L^{-1}													dS m^{-1}	----
µ	578,9	236,4	679,8	379,2	75,7	76,2	7	38,6	7,5	7,9	1897,7	1238,6	2616,6	2,9	7,4
se	±5,23	±5,15	±2,62	±9,38	±3,71	±3,95	±0,58	±2	±0,37	±0,31	±73,63	±57,72	±125,29	±0,78	±0,03

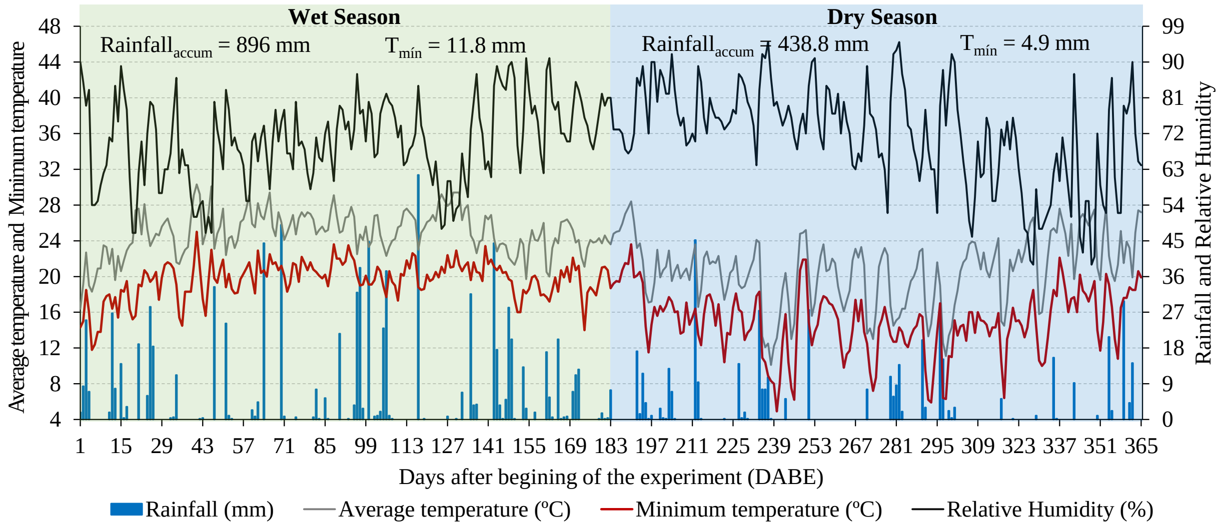

Fig 1. Precipitation values (mm), mean temperature (ºC), minimum temperature (ºC) and relative humidity (%) from October 1st, 2013 to September 30th, 2014. Dourados - MS. $Rainfall_{accum}$ = accumulated rainfall in the period, , T_{min} = lowest temperature presented in the period.

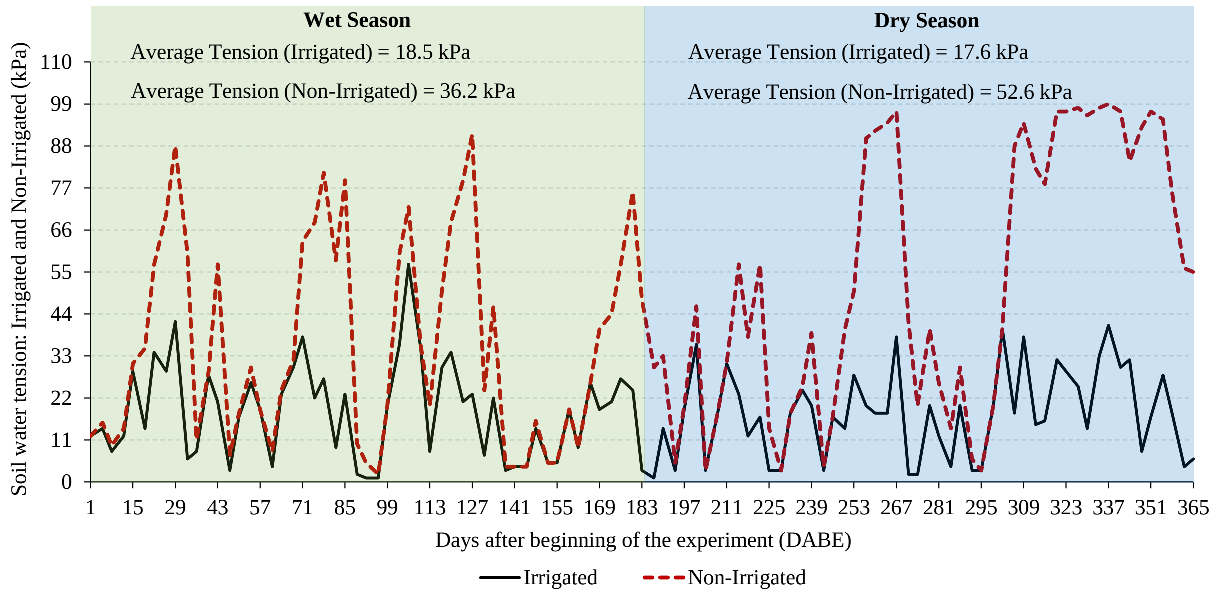

Fig 2. Soil water tension values in the soil during the experimental cycle, in Tifton 85 grass in irrigated and non-irrigated areas. Dourados – MS, 2013 - 2014.

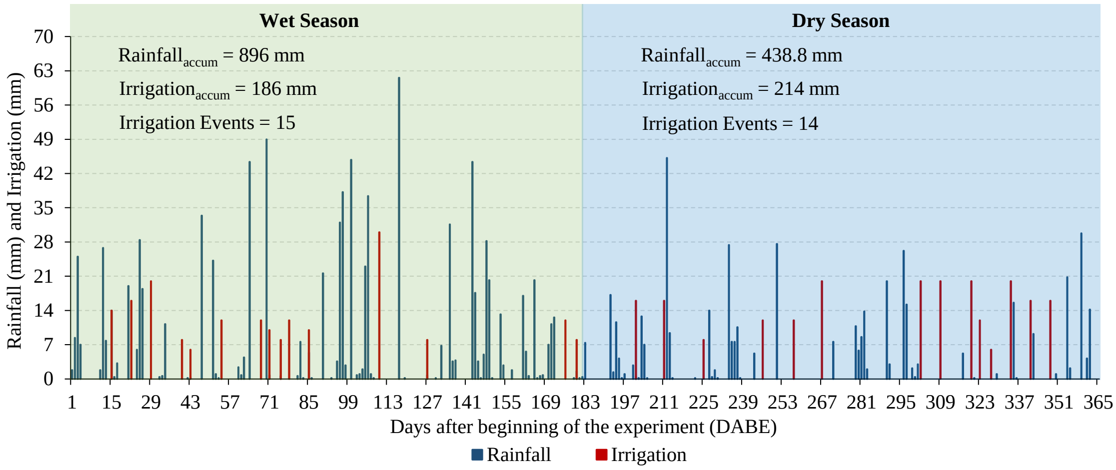

Fig 3. Irrigation and precipitation values in the Tifton 85 grass area. Dourados - MS, 2013-2014.

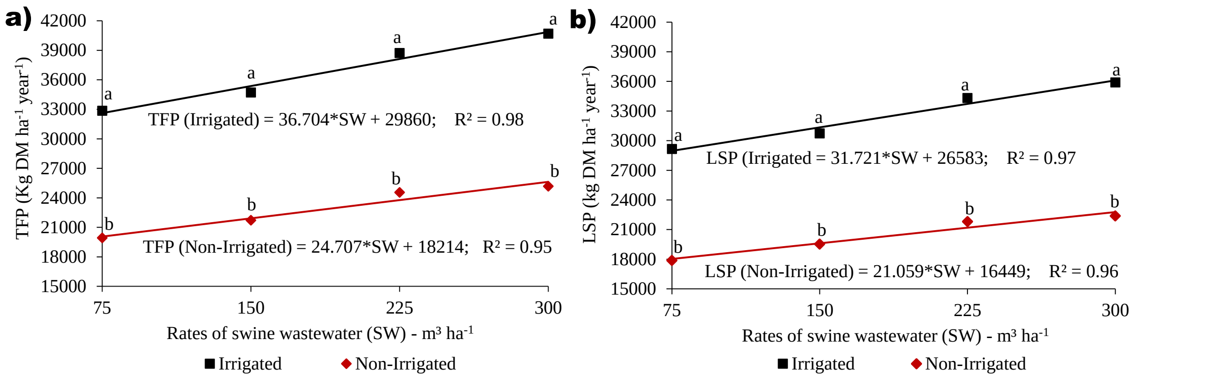

Fig 4. Total forage productivity (A) and leaves and stems productivity (B) of the dry matter of Tifton 85 grass as a function of irrigation and doses of Swine Wastewater -SW. Dourados - MS, 2013-2014.

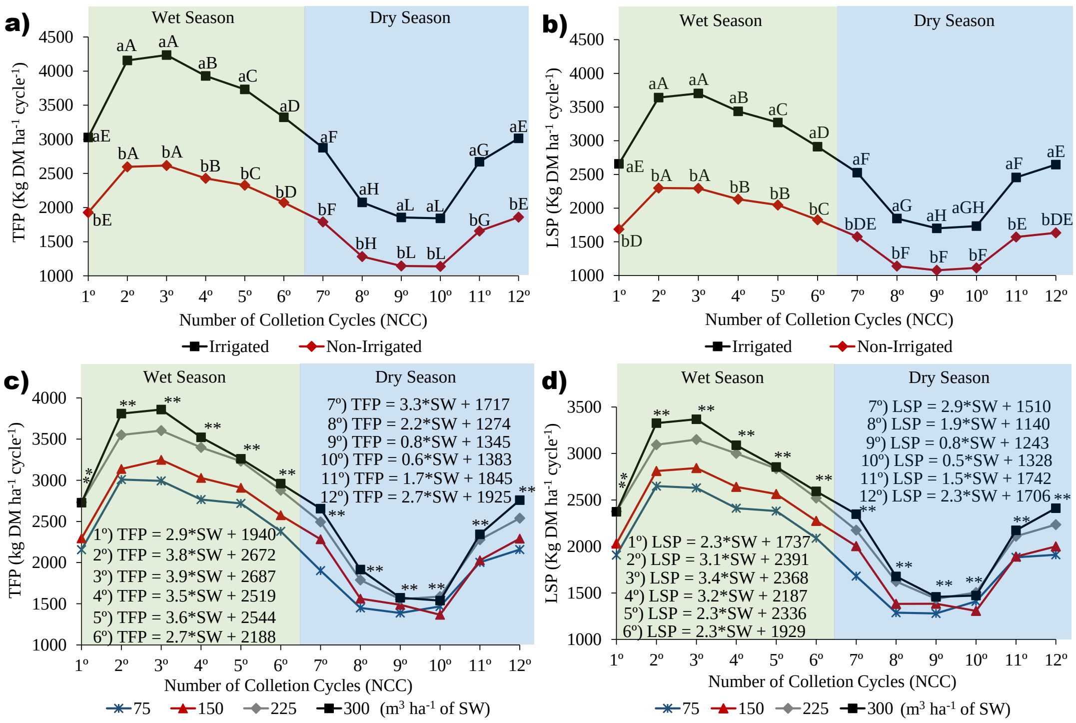

Fig 5. Total forage productivity (TFP), leaves and stems productivity (LSP) of Tifton 85 grass, by cutting, as a function of irrigation and SW doses. * (p <0.05); ** (p <0.01); Ns (not significant). Dourados - MS, 2013-2014.

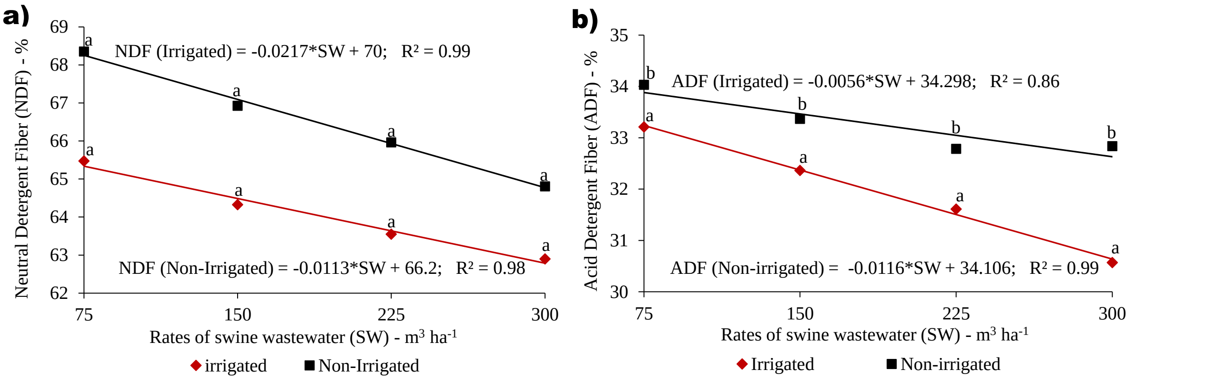

Fig 6. Neutral detergent fiber and acid detergent fiber of dry matter of Tifton 85 grass as a function of irrigation and swine wastewater doses. Dourados - MS, 2013-2014.

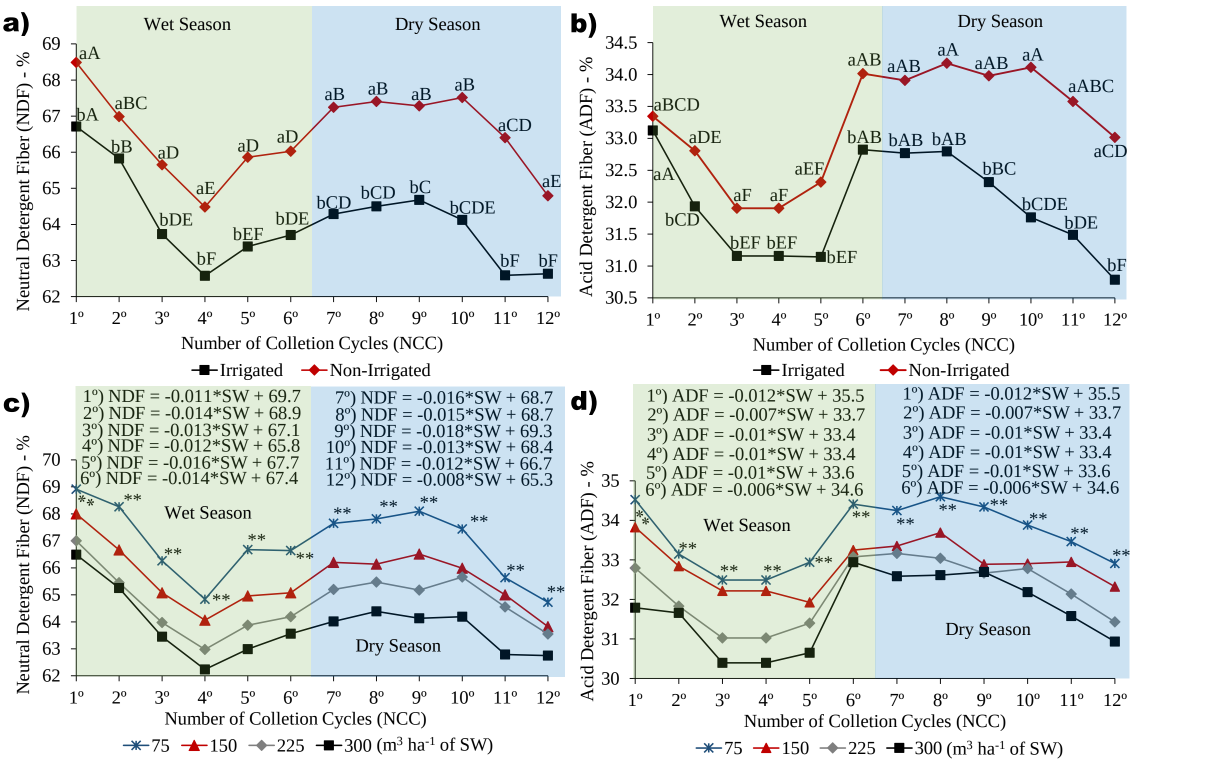

Fig 7. Neutral detergent fiber and acid detergent fiber of the dry matter of Tifton 85 grass, by cutting, as a function of irrigation and swine wastewater doses. *(p <0.05); **(p <0.01); Ns (not significant). Dourados - MS, 2013-2014.

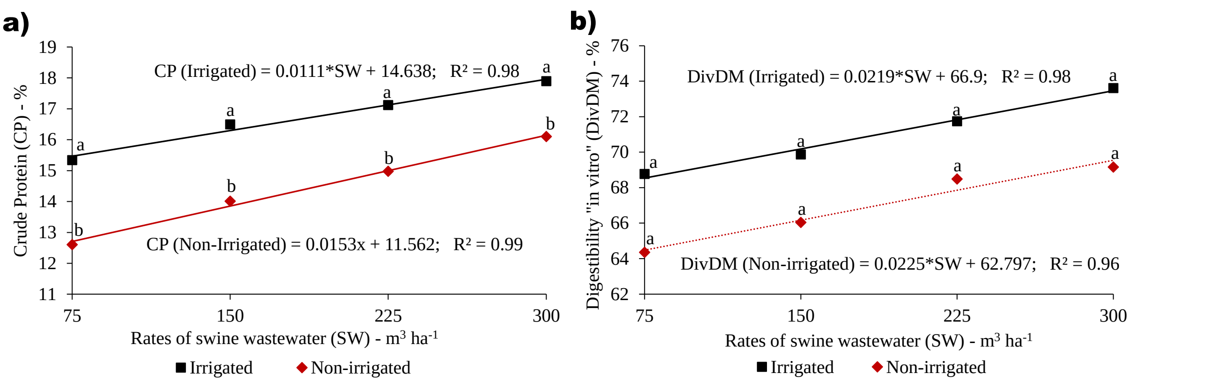

Fig 8. Crude protein levels and dry matter *in vitro* digestibility of Tifton 85 grass as a function of irrigation and swine wastewater (SW) doses. Dourados - MS, 2013-2014.

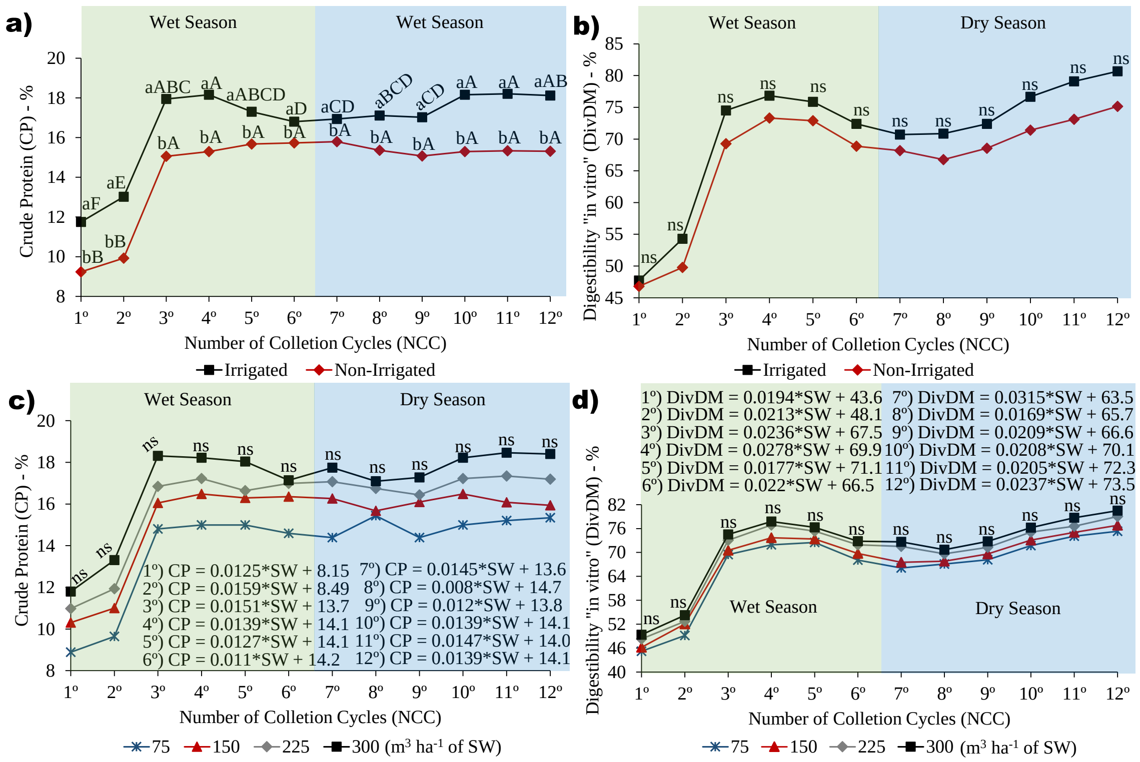

Fig 9. Crude protein of the dry matter, dry matter *in vitro* digestibility of Tifton 85 grass, by cutting, as a function of irrigation and SW doses. * (p <0.05); ** (p <0.01); Ns (Not significant). Dourados - MS, 2013-2014.

In this work, the higher productivity, even using smaller doses, may have occurred due to the higher concentration of N in SW and because the experiment was developed in an area established 36 months ago with SW applications Andrade et al. (2014).

Zenatti et al. (2012), used SW on Tifton85 with average concentrations of N, P and K of 1260, 1626 and 2400 mg L^{-1}, respectively, with doses of 0 to 600 m^3 ha^{-1}, divided in eight applications every 7 days in Marechal Candido Rondon - PR, The experiment was carried out in greenhouse and irrigation management was done from May to August 2010. They recorded the productivity of 205 kg DM ha^{-1} day^{-1} at the highest dose, while in 300 m^3 ha^{-1} of SW dose, they produced 94 kg DM ha^{-1} day^{-1}. In the corresponding period with irrigation and using SW at the highest dose (300 m^3 ha^{-1}), the present study verified productivity of 113 kg DM ha^{-1} day^{-1}. The highest productivity at the corresponding dose may be associated to the protected environment and SW more concentrated in nutrients due to weekly application.

Leaves and stems productivity (Figs 4B, 5C and 5D) presented similar behaviour to TFP (Fig 4A, 5A and 5B). At the SW dose of 300 m^3 ha^{-1} cut^{-1}, the TFP reached 22379 and 35901 kg DM ha^{-1}, irrigated and non-irrigated, respectively. These values represented 86 and 88% of the TFP, by which the annual percentage of dead material was 14 and 12% without and with irrigation, respectively.

Gomes et al. (2015a) conducted a Tifton 85 experiment in the Northwest region of Paraná, in a full cycle period (one year). They also verified a higher percentage of dead material in the absence of irrigation equal to 17%, whereas they recorded 13% of dead plants with irrigation management. In both cases the values found were higher. However, in the actual grazing condition Sanches et al. (2015), conducting experiment with Tifton 85 in continuous grazing up to 10 cm, from April to November and observed averages of 5.9 and 17.8 under irrigated and non-irrigated conditions, respectively.

Bromatological parameters: Nutritive value of forage

The levels of neutral detergent fiber (NDF) and acid detergent fiber (ADF) responded in a linearly decreasing manner to the applied SW doses (p <0.05) in the annual accumulation (Figs 6A and 6B) as well as practically in all the experimental period (Figs 7A, 7B, 7C and 7D). The ADF responded to irrigation (Fig 6B). In another study, Tifton 85 did not respond to different nitrogen doses (25, 50, 75 and 100 kg of N ha^{-1}); however, it responded to irrigation (Sanches et al., 2017). In fact, a little increase was occurred with the use of doses, resulting in no significant effect.

In the rainy season (November to February) (cuts from 1 to 4), there was a decrease from 66.7% to 62.6% in irrigated area and from 68.5% to 64.5% in non-irrigated area in NDF percentages (Fig 7A and 7B). This fact may be related to the higher temperatures of this period (Fig 1) and the initial fertilizations with SW that may have increased soil fertility. In the dry season, lower temperatures must have influenced negatively, reducing the quality of the forage, producing higher levels of NDF and ADF. However, Sanches et al. (2016) working with Tifton 85 at different seasons (autumn, winter, spring and summer) did not observe significant results for NDF and ADF. However, irrigation had a negative effect of 4% of NDF.

The mean annual values of NDF and ADF found in the irrigated area were 64.1 and 31.9%, respectively, and the mean annual values of NDF and ADF found in the non-irrigated area were 66.5 and 33.3%, respectively. Sanches et al. (2015) conducted experiment on Tifton 85 in irrigated and non-irrigated conditions in the Northwest of Paraná from April to November, and verified higher values of NDF and ADF in the absence of irrigation. The authors verified mean values of NDF and ADF with irrigation of 70.2 and 32.5% and 72.0 and 32.7% without irrigation, respectively.

Using 0 to 320 m^3 ha^{-1} doses of SW in Tifton 85, Vielmo et al. (2011) also verified that NDF responded linearly decreasing to the applied SW doses, being 68.3 and 65.3% in the lowest and the highest dose, respectively. In this study, the values were 66.9 and 63.9% in the lowest and the highest dose of SW, respectively, corroborating with previously verified.

Scheffer-Basso et al. (2008) observed decreasing linear behaviour in the percentages of ADF in relation to the applied SW doses, from 0 to 45 m^3 ha^{-1} cut^{-1}, being 46.0 and 42.9% in the lowest and the highest dose, respectively. Higher values observed in this work (33.6 and 31.7% in the lowest and the highest dose respectively), is possibly due to higher dose of SW adopted in this experiment.

Taffarel et al. (2016) and Sanches et al. (2017), studied different nitrogen doses (0, 25, 50, 75 and 100 kg ha^{-1} and 25, 50, 75 and 100 kg ha^{-1}, respectively) but did not observe any effect with respect to relation to the cycle. It is understood that the nutritional responses are smaller and less evident than those of dry matter accumulation. Therefore, some studies have shown responses that improve nutritional quality and others do not.

The crude protein (CP) content of pasture along with irrigation was higher ($p < 0.05$) than those without irrigation both in the annual accumulation (Fig 8A) and also in practically the entire experimental period (Fig 9A), corroborating with several works on Tifton 85 (Gomes et al., 2015a, 2015b; Sanches et al., 2015, 2016, 2017).

At 75 to 300 m^3 ha^{-1} cut^{-1} doses of SW, annual mean CP values ranged from 15.3 to 17.9% and 12.6 to 16.1% with and without irrigation, respectively. The highest CP values under irrigation should be related to the lower soil water tension for most of the experimental period (Fig 2).

Similarly, as occurred with productivity, there was an increase of CP in the second quarter of the rainy season (December to February) (Fig 9A), possibly due to the initial applications of SW that improved the initial condition of the soil (Fig. 2). Figure 2 shows the dry season, which is probably due to the lower temperature during experiment period, decreasing production and increasing nutritional quality. Andrade et al. (2014), stated that with the low temperature during the cycle and pasture growth, the experiment behaved a slow growth due to dry and cold period (autumn / winter). With this decreased the senescence contributed to the nutritional increase in the leaves, consequently increasing the crude protein concentrations.

The SW doses were always linearly increasing (Figs 8A and 9B), corroborating with the linear responses reported by Taffarel et al. (2016) that applied different doses of nitrogen (0, 25, 50, 75 and 100 kg ha^{-1}) in Tifton 85. In general, mean CPs in irrigated and non-irrigated areas were 16.6 and 14.3%, respectively, always behaving superiorly for irrigation during cycles. Sanches et al. (2017) observed similar behaviour with averages of 16.1 and 14.1 to irrigated and non-irrigated crops, respectively, being always greater in the irrigated during 7 cycles of experimental culture.

Sanches et al. (2015) also verified that the use of irrigation increased the PB level from 15.2 to 16.7% in the period from April to November. Scheffer-Basso et al. (2008) also verified an increasing linear behaviour of the CP mean percentages in relation to the applied SW doses, from 0 to 45 m^3 ha^{-1} cut^{-1}, 10.7% at the highest dose applied in São Sepé, RS, from October 2003 to April 2004. Lower values verified by this work were obtained in the same period with mean value of 17.1% in the highest dose (300 m^3 ha^{-1}). Possibly this difference, among several factors linked to the conduction of the experiment, is due to the higher SW doses applied in this experiment.

Similarly, Vielmo et al. (2011) used SW doses from 0 to 320 m^3 ha^{-1} cut^{-1} in Tifton 85, also observed a linear increase in the percentages of CP in relation to the applied doses of SW, obtaining 18.9% in the highest dose. In this work, CP was obtained in a similar dose (300 m^3 ha^{-1}), equal to 16.15%, but it was emphasized that the experiment was in the initial phase of implantation.

The dry matter *in vitro* digestibility (DivDM) of Tifton 85 grass was higher under irrigation treatments ($p<0.05$) and responded in an increasing linear manner of SW doses ($p<0.05$), both in the annual accumulation (Fig 8B) as well as throughout the experimental period (Figs 9C and 9D). Sanches et al. (2015, 2016, 2017) have shown an average increase of 2% in DivDM in Tifton 85 under irrigation treatment, demonstrating that the improvement in the edaphoclimatic conditions which can bring improvements to the grass (Raz-yaseef et al., 2015, Barbosa, 2016, Kalaugher et al. , 2017), such as digestibility, which is very important for ruminant use.

In the rainy season (from November 12^{th}, 2013 to January 21^{th}, 2014), there was an increase of 47.7 to 74.5% in percentage of DivDM under irrigation and from 46.8 to 69.3% in non-irrigated area (Figs 9C and 9D). This may be related to high temperatures which favour the growth of leaves (Fig 1) and the initial SW applications where probably improved soil fertility.

Between the 6^{th} and 9^{th} cutting (from April to July), lower temperatures (Fig 1) may have negatively influenced the increase in stalk concentrations, reducing the quality of the forage, producing lower levels of DivDM. In contrast, Sanches et al. (2016), observed that the lowest leaf /stem ratio of 1.0 was occurred in the summer. However, the authors worked with variable cycles defined the cut by the height of the forage. Andrade et al. (2014) evaluated the leaf elongation rate (LER) as a function of the days to regrowth, observing that the duration of the cycle directly influences leaf growth. Thus, possibly a fixed cycle of 30 days, may have favoured the rainy season in detriment of the dry season.

No studies were found in the literature verifing DivDM in Tifton 85 with the use of SW. However, Taffarel et al. (2014) used doses 0 to 67 kg ha^{-1} of N in the western region of Paraná, in a period from October to January, and verified an increase in DivDM from 48.5 to 55.8%, respectively. These values are lower compared to the present work, where the values of 66.6 and 71.4% of the lowest (75 m^3 of SW) and the highest (300 m^3 of SW) doses, respectively, were found in the same period.

Materials and methods

Location, soil classification and climatic characteristics

This work was conducted at the Experimental Farm of the Federal University of Grande Dourados, in Dourados-MS (latitude 22º 14 'south and longitude 54º 59' west, with altitude of 434 m) from October 2013 to September 2014, an one year of experiment. The climate is humid mesothermic type (Cwa), with rainy summer and dry winter. The soil of the experimental area is classified as a Red Latosol Distroferric (Santos et al., 2013). The chemical analysis of the soil from 0 to 0.20 m layer presented 4.72 of pH (H2O); 13.41 mg dm-3 of P; 9.4 mmolc dm-3; 4.82 cmolc dm-3 of Ca; 2.86 cmolc dm-3 of Mg; 2.93 cmolc dm-3 of H + Al; 1.2 cmolc dm-3 of Al and 74.6% of base saturation (V). In the experimental period, the cumulative value of precipitation was 896 and 438.8 mm, in the wet (October to March) and dry (April to September) seasons, respectively. The mean relative of humidity was 70.3 and 71.6%, in the wet and dry season, and minimum temperature was 11.8 ºC and 4.9 ºC, respectively (Fig 1).

Experimental design

The experiment was carried out under a statistical design of random blocks as split-plot with four replications. The treatments in the plots referred to two levels of irrigation (with and without). In the subplots, the treatments were four SW doses applied at each cutting cycle (75, 150, 225 and 300 m^3 ha^{-1}). So, with four replications, there were 32 experimental unities (subplots), each one with 3 m^2 (2 m x 1.5 m).

Characteristics of swine wastewater (SW)

The SW was collected from the third and last decantation pond of a pig farm located near the experimental area and transported using a sealed polyethylene reservoir. The SW applications in the pasture were carried out immediately after its arrival in the experiment area and always after the collection of the Tifton 85 grass. The chemical characterization of SW was performed in 10 samples collected at the time of application. They remained frozen at -10 °C until laboratory tests were started using the Standard Methods for the Examination of Water and Wastewater (APHA, 2012). The pH, electrical conductivity (EC) and total dissolved solids (TDS) were measured on site with a Multi-parameter measuring device. The Biochemical Oxygen Demand (BOD) was determined by dilution and incubation at 20°C for 5 days. Chemical Oxygen Demand (COD) was determined by the dichromate digestion method in acid medium and titration with ammoniacal ferrous sulfate. The other parameters were obtained with an Atomic Absorption Spectrophotometer (Table 1).

Irrigation systems and management

The installed irrigation system was the conventional sprinkler type, with Agropolo® NY 30 sprinklers. They were spaced 12 m by 12 m. The application intensity (AI) was determined at the site, obtaining a value of 23 mm h^{-1} at 196 kPa of pressure. Irrigation management was performed using tensiometers installed at 0.20 m depth, comprising 4 tensiometers in the irrigated area and 4 in the non-irrigated area. In the non-irrigated area, the tensiometers was used for purpose of comparison. Soil water tension readings were performed on Tuesdays and Fridays, with subsequent irrigation, when soil water tension was equal to or greater than 20 kPa.

In the dry season, the average tensions of 17.6 and 52.6 kPa for irrigated and non-irrigated areas, respectively, were verified, and in the wet season, mean tensions of 18.5 and 36.2 kPa, irrigated and non-irrigated, respectively (Fig 2).

The moisture at field capacity (Θ_{cc}) was considered as the humidity corresponding to the value of Ψm = 10 kPa. In this way, the irrigation depth (ID) was determined by the difference between volumetric moisture in the field capacity (Θ_{cc}) and the current volumetric moisture (Θ_c), multiplied by the effective root depth (Z), equal to 400 mm. The irrigation time (IT), in each event, was obtained by the ratio of ID by application intensity (AI). The values of Θ_c were estimated through the soil water retention curve, obtained with the aid of a Richards's extractor in the Laboratory of Relations, Water, Soil, Plant and Atmosphere of the Federal University of Grande Dourados (UFGD) and adjusted by the VAN GENUCHTEN (1980) equation:

$$\vartheta c = 0.192 + \left[\frac{(0.391-0.192)}{\left[1+(0.0003\Psi_a)^{0.3240}\right]^{5.6392}}\right]; \quad (R^2=0.99 \text{ e } p<0.01)$$

Where:

Θ_c = Current volumetric humidity (cm^3 cm^{-3})

Ψa = Current matric potential of water in the soil (kPa)

The accumulated irrigation depth during the experimental period was 400 mm, distributed through 29 events, with 15 events (186 mm) and 14 events (214 mm), occurring in the wet and dry season, respectively. In the respective periods, rainfall was 896 and 438.8 mm (Fig 3).

Plant materials and development

The cuts were performed at intervals of 30 days, with post-cut height of 10 cm (residue), by means of costal brushcutter. Before cutting, a frame of 0.25 m^2 was placed in the center of each plot to collect the fodder produced up to the height of the residue. The collected samples were botanically separated in dead material, Stem + sheath + leaves and forced to the circulation oven at 65ºC for 72 hours to determine the dry matter of: Total Forage Productivity (TFP) and leaf and stem productivity (LSP).

Subsequently, sub samples were taken to determine the bromatological components of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), and dry matter in vitro digestibility, according to Silva and Queiroz (2002).

The experimental data were subjected to analysis of variance at 5% of probability and regression analysis when significant differences were observed between the doses of SW. The software used was Assistat 7.7 (Francisco and Carlos, 2016).

Conclusion

The Tifton 85 grass presented linear behaviour in relation to the applied doses of swine wastewater, increasing yield, crude protein and dry matter *in vitro* digestibility and decreasing the neutral detergent fibre and acid detergent fibre. Using the sprinkler system to apply the swine wastewater and to irrigate, increase in dry matter yield improved the nutritional quality of Tifton 85 grass.

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