Australian Journal of Crop Science
AJCS

AJCS 15(03):377-386 (2021) ISSN:1835-2707
doi: 10.21475/ajcs.21.15.03.p2751

Cultivation of ruziziensis grass (*Urochloa ruziziensis*) using swine liquid manure fertilization

Marinho Rocho da Silva[1], Joadil Gonçalves Abreu[1], Oscarlina Lucia dos Santos Weber[1], Livia Vieira de Barros[1], Edna Maria Bonfim-Silva[2], Ana Paula Alves Barreto Damasceno[2], Wlly Cristiny Mendes de Oliveira[1]

[1]Federal University of Mato Grosso - UFMT, Faculty of Agronomy and Zootechny, 2367 Fernando Corrêa da Costa Avenue, Cuiabá, 78060-900, Brazil
[2]Federal University of Rondonópolis - UFR, Institute of Agricultural and Technological Sciences, 5055 Students Avenue Rondonópolis, 78.735-901, Brazil

Abstract

The objective of this study was to evaluate the use of liquid swine manure (LSM) as fertilization in the implantation of *Urochloa ruziziensis*. The experimental design was randomized blocks with five treatments and four replications, with the treatments being four doses of LSM (0; 100; 200 and 300 m^3 ha^{-1}) and one dose of mineral fertilization. Seven cuts were carried out uniformly, after which plant height (PH), total dry mass yield (TDMY), crude protein content (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF), macromineral extraction (N, P, K, Ca, Mg and S) and microminerals (Fe, Zn, Mn and Cu) of plants were evaluated every 30 days. Mineral fertilization provided higher PH, CP content and extraction of N and S, but lower NDF content. For ADF variable, there was no difference between treatments. The results of dry mass yield (DMY) and extractions of P, K, Ca and Mn showed that the effect of 300 m^3 ha^{-1} LSM was statistically equal to mineral fertilization. For extractions of Mg, Fe, Zn and Cu doses of 200 and 300 m^3 ha^{-1} did not differ statistically from mineral fertilization. Among the doses of LSM, there was increasing linear effect, with increases in the variables DMY (30.89%), PH (14.94%), CP (17%), N (53.01%), P (40.79%), K (27.84%), Ca (35.17%), Mg (29.6%), S (47.13%), Fe (31.2%), Zn (31.6%) and Mn (23.04%). For Cu extraction, there was a quadratic effect with the highest extraction in the dose of 26.36 m^3, obtaining an increase of 19.94% in relation to treatment without application. It is important to study different LSM dosages to avoid risk of heavy metal toxicity. The LSM is an alternative in place of mineral fertilization for *Urochloa ruziziensis* grass.

Keywords: crude protein content, neutral detergent fiber, acid detergent fiber, mineral nutrition of plants, pasture quality, tropical forages, wastewater.
Abbreviations: ADF_Acid detergent fiber; Ca_Calcium; CP_Crude proteína content; Cu_Copper; DM_Dry mass; DMY_Dry mass yeld; Fe_Iron; K_Potassium; LSM_Liquid swine manure; Mn_Manganese; Mg_Magnesium; N_Nitrogen; NDF_Neutral detergent fiber; P_Phosphorus; PH_Plant height; S_Sulfur; TDMY_Total dry mass yeld; Zn_Zinc.

Introduction

In recent years, Brazilian swine farming has highlighted worldwide and is currently the fourth largest swine producer and exporter in the world. An increase of 5.6% is estimated in swine meat production in Brazil compared to 2018 along with an increase in exports around 23.3% (CONAB, 2019). However, this activity is considered potentially polluting, as it uses abundant water in its production process, reflecting the excessive production of leachate (Sousa et al., 2014; Yuan et al., 2018). This huge slurry volume passes through a biodigester, where the gaseous part is destined for energy production and the liquid part is stored in ponds or tanks to later be applied in pastures or crops as fertilizer.
Wastewater from swine waste may represent an important fertilizer or a potential environmental risk, depending on how the resource is managed (Egewarth et al., 2015; Boitt et al., 2018). There is a risk in using swine waste as pollutant to soil and groundwater, if the soil adsorption capacity and crop need is not considered (Lourenzi et al., 2013; Orrico Junior et al., 2013).
The risk in the application of swine liquid manure can be reduced when the technical criteria of recommendation for its application in the soil are obeyed. Therefore, it is necessary to know the manure composition to calculate the volume that should be applied to the culture system (Lavoisier, 1789; Moraes et al., 2017)
A well-planned fertilization with swine liquid manure can bring benefits (Erthal et al., 2010; Matos et al., 2017), increasing the availability of macro and micronutrients in the soil (Angers et al., 2010; Matos et al., 2017; Tavanti et al., 2017). This increases the absorption of water and nutrients by plants (Galbiatti et al., 2011; Gomes et al., 2017) and amount and biodiversity of the soil fauna community (Silva et al., 2014). Long-term, swine wastewater increases microbial activity and soil organic matter (Morales et al., 2015).
Pasture production is limited when N, P and K are not adequate. These nutrients are among the main constituents of swine wastewater, therefore, their use can contribute to

animal production in pasture, increasing the supply of forage in quantity and quality for animals (Serpa Filho et al., 2013; Pandolfo and Veiga, 2016; Boitt et al., 2018).

In time of fodder scarcity alternatives are sought to mitigate the impact on zoological indices of grazing animals by integrated system. One of the forage used in this system is ruziziensis grass (*Urochloa ruziziensis*) due to the large emergence capacity of its seeds in over-sowing, excellent soil cover and easy management and late flowering, which favors grazing time (Aukar, 2011). It can be used by animals during the off-season of soybean crop, contributing to improve performance in this period, without compromising the production of subsequent crop. One of the disadvantages could be the susceptiblity to pasture leafhopper.

In view of the above, the objective of this study was to evaluate the productivity, nutritional value and mineral extraction of *Urochloa ruziziensis* in the first year of implantation in response to fertilization with liquid swine manure.

Results and discussion

For the variables plant height (PH) and crude protein (CP), the highest values were observed for the application of mineral fertilization. Regarding the variable neutral detergent fiber (NDF), we observed that the lowest value was for the application of mineral fertilization. For the variable acid detergent fiber (ADF) there was no significant difference between the values observed for the doses of LSM and mineral fertilization. Total dry mass yield (TDMY) for the dose of 300 m^3 ha^{-1} was statistically equal to mineral (Table 1).

Production characteristics of Urochloa ruzizienseis grass as a function of the treatments applied

Mineral fertilization increased plant height (PH) about 9.27%, compared to the higher doses of LSM. In all treatments, PH was above 30 cm before grazing, recommended by Guedes (2012). The ruziziensis grass tends to increase TDMY, when managed in PHs above 40 cm. This fact was proven in all treatments, especially in the highest dose of LSM and mineral fertilization that were equal.

Seidel et al. (2010) analyzed how the application of swine manure influences the corn crop in no-tillage system and and saw that treatments with manure did not differ from treatments that received mineral fertilization. Silva et al. (2015) compared the influence of mineral fertilization and swine manure on the bromatological characteristics of *Brachiaria decumbens* at different cutting heights. These authors reported a greater mineralization of organic matter present in swine manure, optimizing its potential as organic fertilizer and ensuring production of dry matter equivalent to plants with mineral fertilization.

Supporting our results, Penn et al. (2013) studied the effect of swine manure sludge on forage growth and observed that there was an increase in biomass production and plant height, compared to chemical fertilization.

Application of LSM doses in part or total showed significant differences on PH and TDMY with increasing linear adjustment (Figure 1).

There was an increase of 14.94% in PH when compared to the highest dose of LSM applied, compared to no-LSM treatment. This increase is related to the higher availability of N in the highest doses, as it promotes an increase in the growth of the aerial part of the plant (Castro et al., 2016).

The nutrients provided through LSM stimulated the growth of the forage plant (Serafim and Galbiatti, 2012). Research on forage plants confirms that the application of swine effluents promotes the increase in plant growth due to the nitrogen supply in the manure (Brustolin-Golin et al., 2016; Pandolfo and Veiga, 2016; Galindo et al., 2018).

Plant height is a characteristic that has a direct relationship with the morphological and physiological aspects of the plant, structural components and the quantity and quality of the forage produced (Fagundes, 2012).

The plant height has a positive correlation with TDMY, justifying the 30.89% increase in TDMY for the higher volume of LSM applied, compared to the dose without application of LSM. According to Aukar (2011) *Urochloa ruziziensis* produces 14 to 15 t ha^{-1} year of dry mass. However, in this study the dry mass values were higher in all treatments.

The use of LSM provided an increase in TDMY and the nutritional value of forage. These responses were also observed by Costa et al. (2009) and Quaresma et al. (2011) on Marandu and Tifton 85 (*Urochloa brizantha* cv. marandu and *Cynodon spp* cv. Tifton 85) weeds, respectively, evidencing the potential use of LSM as an alternative for fertilization in forage plants.

The increasing linear effect in TDMY was also found by Barnabas et al. (2007) with fertilization of 0; 50; 100 and 150 m^3 ha^{-1} of wastewater in Marandu grass (*Urochloa brizantha* cv. marandu). Orrico Junior et al. (2012), studied the effect of four doses of swine effluents (0; 100; 200 and 300 kg ha^{-1} equivalent N) on dry mass production of piatã grass (*Urochloa brizantha* cv. piatã).

According to Pariz et al. (2010) *Urochloa ruziziensis* plants showed TDMY of 1,100 to 7,193 kg ha^{-1} of dry matter, depending on the planting system and soil fertility conditions.

Serafim (2010), evaluated swine farming wastewater in Marandu grass pasture and found that the application of 600 m^3 provided an accumulated dry mass yield of 22,779 kg DM ha^{-1} year. This is a value below those found in this study with 23,404; 25,426 and 27,448 of accumulated dry mass yield in doses 100; 200 and 300 m^3 ha^{-1} year of LSM (sum of the 10 applications), respectively.

Silva et al. (2019) studied three cultivars of *Urochloa brizantha* to identify which cultivar is most sensitive to fertilization with wastewater of swine, using doses ranging from 0.0 to 14.0 g dm^3 pot^{-1}. They found that regardless of the cultivar the increase in doses promoted the increase in plant height, which was occurred in the present study.

Fertilization with nitrogen sources accelerated growth (Galindo et al., 2018) and influenced the plant height. They reported that greater availability precludes plant's absorption, which was not achieved in this study.

Nutritive value of Urochloa ruzizienseis grass as a function of the treatments

The CP content was increased with the increase in LSM doses. However with the exception of mineral fertilization (8.96%), the contents in the different LSM doses were below 7% which is the minimum percentage necessary for adequate nutrition of ruminants, according to Van Soest (1994). According to Montanari et al. (2013) leaf anatomy and high proportion of stem to leaves and low protein level is observed in tropical grasses due to their photosynthetic cycle of C4.

In mineral fertilization, there was an increase of 37.84% in the CP content over the 300 m^3 ha^{-1} LSM dose. The lowest CP content in the LSM doses may be related to variations in nutrient concentration due to the storage of liquid residue. However, we verified that the increase in doses raises nitrogen level and consequently the crude protein values.

Bernardi et al. (2018) analyzed the response of forage grasses of the *Brachiaria*, *Cynodon* and *Panicum* genus to nitrogen fertilization, in terms of dry matter production, crude protein and efficiency of nitrogen use. They concluded that nitrogen fertilization influences the production of dry matter and crude protein with consistent increases, with a more pronounced effect in relation to crude protein production.

The LSM doses increased the CP content linearly. The highest LSM dose provided an increase in CP content of 17.06% over the LSM dose without application (Figure 2).

Although it has a linear effect, the CP content at the highest LSM dose was 6.50%, considered below the minimum appropriate for ruminant's nutrition. The N variation in the LSM is among the important causes for the lowest CP levels throughout the experiment.

Complementation can be performed, when the CP content in the forage is less than 7, according to Van Soest (1994). However, protein is a high-cost item in the formulation of supplements for cattle (Silva et al., 2015). Orrico Junior et al. (2013) observed a 19.84% increase in CP content in Piatã grass under irrigation when swine wastewater doses of 300 m^3 ha^{-1} were applied. Gomes et al. (2014) found that irrigation positively influenced the CP content in Piatã grass upon application of swine effluents doses.

Homem et al. (2016) evaluated the production of forage and root accumulation in *Brachiaria decumbens* cv. Basilisk with the use of swine wastewater as fertilizer, with doses ranging from 0 to 675 mL pot^{-1}. They found that the crude protein content was increased linearly with the increase in doses. A similar trend was observed in this work in relation to the doses used.

In mineral fertilization, there was a 4.83% reduction in the NDF content compared to the LSM dose of 300 m^3 ha^{-1}. There were no differences in ADF contents between LSM doses and mineral fertilization. A similar result was obtained in an experiment with LSM doses and mineral fertilization in carpet grass pasture (*Axonopus* sp.) (Kottwitz, 2012).

There was no difference in NDF and ADF upon only the LSM doses. The mean NDF content was 61.07%, below the values observed by Benett et al. (2008), which evaluated doses of 0; 50; 100; 150 and 200 kg ha^{-1} of N in marandu grass (*Urochloa brizantha* cv. marandu) (cutting interval of 30 days), which found variations from 64.65 to 69.70%. The value observed in the present study guarantees better use of nutrients by ruminal microorganisms in the diet and consequently better animal performance, because the improvement of the nutritional value of fodder is related to low levels of NDF (<65%), and higher ability of animals to intake (Van Soest, 1994).

The ADF content is related to the digestibility of dry mass and reflects the concentration of lignin in the cell wall that limits the degradation of structural carbohydrates in the rumen. The average ADF content was 31.94%. This content is close to those observed in a greenhouse by Silva et al. (2019) who found 34.41 to 36.30%; 33.31 to 35.25%; for piatã and marandu weeds fertilized with swine wastewater, respectively. Orrico Junior et al. (2013) found ADF variation from 31.96% to 36.76% in increasing doses of N (0; 100; 200 and 300 kg ha^{-1}) in Piatã grass.

The higher ADF levels cause longer digestion and the less consuming of fodder by animal. According to Nussio et al. (1998), fodder with ADF levels of 40%, or more, have low consumption and lower digestibility.

Nutrient extraction by Urochloa ruzizienseis grass as a function of the treatments applied

There was greater extraction of N and S in mineral fertilization. The 300 m^3 ha^{-1} LSM and mineral fertilization were statistically equal on average dry matter yield (DMY) and for the extractions of P, K, Ca and Mn. In the extractions of Mg, Fe, Zn and Cu, doses 200 and 300 m^3 ha^{-1} did not differ statistically from mineral fertilization (Table 2).

Mineral nitrogen and sulfur were 56.34 and 37.36% higher in mineral fertilization at the highest dose of 300 m^3 ha^{-1} of LSM.

Based on the results we found that the dose of 300 m^3 ha^{-1} LSM can be considered as an alternative dose for fertilization of *Urochloa ruziziensis* in place of mineral fertilization.

In a study developed by Menezes et al. (2018) on maize nutrients extraction and export, fertilized with swine manure, the extraction of NPK nutrients followed a decreasing order in the vegetative period K>N>P and in the reproductive period N>K>P presenting a total accumulation in the aerial part of 179.2, 70.97 and 86.60 kg ha^{-1} of NPK, respectively.

Eguchi et al. (2017) evaluated the minerals present and extracted from the mass of Marandu grass fertilized with chicken manure and managed without and with soil scarification. They found that for the nutrients analyzed (N, P, K, Mg, Ca, Cu, Zn) mineral fertilization can be replaced by manure. The increase in the dose of chicken manure, consequently causes an increase in the extraction of K, Ca, Mg, P, Zn and Cu in marandu grass forage mass production.

Comparing the LSM doses, a growing linear effect was observed for N and P levels. The application of LSM provided higher nitrogen and phosphorus extraction, with an increase of 53.01 and 40.79%, respectively, compared to treatment without LSM application (Figure 3).

The highest mean concentration of N was found for the highest dose of LSM with N extraction of 41.36 kg ha^{-1} per cut. This value is higher than the value found by Mendonça et al. (2014), which evaluated the extraction of macronutrients in *Urochloa ruziziensis* in a consortium with maize and found N concentration of 34.5 kg ha^{-1}. However, the highest extraction of N was diluted in the largest DM in the present study where 10.55 kg of N per tonne produced in the highest dose of LSM.

Regarding P, the appropriate levels according to Raij et al (1996) are 0.8 to 3 g kg^{-1} in DM. In the present study, even in treatment without the application of LSM, the contents ranged from 12.03 to 12.91 g kg^{-1} in the DM. This high concentration of P in forage in all treatments is probably due to the residual effect on the soil left by the crop before implantation of the experiment.

The experimental area had been cultivated with soybean, which had to be desiccated. The soybean has a low C/N ratio (Silva et al. 2006), which favors its decomposition and mineralization, contributing to the phosphorus available in the soil, since 77 % of P can be recycled from the cultural remains and used by plants (Jones and Woodmanse, 1979).

Maggi et al. (2011) quantified the nutrient leaching in the cultivated soil fertilized with swine liquid manure. They reported that high extraction of soil P with small losses occurs when P is supplied through the application of swine wastewater and not by mineral fertilization.

Phosphorus extraction was 51 kg ha^{-1} upon application of 30 m^3 ha^{-1} LSM. This is different from the content observed by Mendonça et al. (2014) evaluating this same cultivar, whereas they found phosphorus extraction of 5.1 kg ha^{-1} in DM. Thus, the *Urochloa ruziziensis* grass was shown to be good P extractor, because phosphorus and calcium are the elements that most limit the growth of forage, and it is necessary to supply through mineral supplementation to meet the needs of grazing animals.

There was an increasing linear effect of the LSM doses on the extraction of potassium and sulfur (Figure 4).

Potassium extraction was 27.84% higher at the dose 30 m^3 ha^{-1} LSM, compared to treatment without application. However, when considering the appropriate levels proposed by Raij et al. (1996) from 12 to 30 g kg^{-1}, the values in all experiments were below, ranging from 7.32 to 7.71 g kg^{-1}. This occurred due to the management in the highest PH and higher DMY, which were favored by the P and N availability present in the soil.

Cassol et al. (2012) studied the availability of macronutrients and maize yield in oxisol fertilized with liquid swine manure, in which doses. The potassium content in the soil increased in fertilized treatments. According to the authors, the highest accumulation occurs in the highest doses and in the first 5 cm of the soil.

There was probably potassium recycling of the previous crop remnants, because the concentrations extracted from 25.05; 27.18 and 29.30 kg ha^{-1} were higher than the applied amount 13.6; 18.7 and 24 kg^{-1} by fertilization in the doses of LSM of 10; 20 and 30 m^3 ha^{-1}, respectively.

Mean S concentration was increased by 47.13% with dose application of 30 m^3 ha^{-1} of LSM, compared to control treatment. The mean cut contents extracted by the plant were in the increasing order of 77.6; 89.8; 102.09 and 114.31 kg ha^{-1} per dose, which means a variation of 25.04 to 29.11 g kg^{-1} in DM, values well above the concentration considered appropriate (0.8 to 2.5 g kg^{-1} of S) by Raij et al. (1996).

Although a sulphur supply has entered via LSM fertilization of 35.4; 70.8 and 106.2 kg ha^{-1} per application, the largest extraction probably came from the soil organic matter mineralization experiment (Table 3), since S is considered a structural nutrient of organic matter (Lawlor et al., 2001).

For calcium and magnesium extraction, there was increasing linear effect as a function of the LSM doses (Figure 5).

The highest LSM dose increased about 35.17 % of Ca extraction, compared to the dose without the application of LSM, while the extraction at the highest dose was 113.84 kg ha^{-1}. Mendonça et al. (2014) verified Ca extraction of 10.8 kg ha^{-1} for *Urochloa ruziziensis* grass. Raij et al. (1996) evaluated the calcium levels in forage. The variation was from 27.33 to 29.11 g kg^{-1} in DM, exceeding the values of 3 to 6 g kg^{-1} in the DM considered as adequate.

This is due to the available calcium already present in the soil, as well as to the input, via LSM being higher than that extracted by the plant in the highest LSM doses. From a nutritional point of view, grasses are deficient in calcium, and there is a need for complementation via mineral supplementation to meet the needs of grazing animals. However, using LSM may be an alternative to mitigate these deficiencies.

The use of LSM at the highest dose provided an increase of 29.60% Mg in relation to the dose without the application of LSM. In all treatments, the levels ranged from 2.19 to 2.29 g kg^{-1} within the range of 1 to 4 g kg^{-1} in the DM, considered as adequate (Raij et al., 1996). The mean extraction per cut in the highest dose of LSM was 8.93 kg ha^{-1} DM of magnesium, higher than the value obtained by Mendonça et al. (2014), while evaluated mineral extraction in *Urochloa ruziziensis* in consorsium with maize and obtained Mg extraction of 7.4 kg ha^{-1} in the DM.

There was a linear increasing effect of the LSM doses on iron and manganese extraction (Figure 6).

At 30 m^3 ha^{-1} of LSM, there was an increase of 31.2% of extracted iron, with 1169.3 g kg ha^{-1}, but below the values of 2002 to 3217 g kg ha^{-1} obtained by Lima et al. (2016) in *Brachiaria hibrida*. In plants, the iron contents is ranged from 285.79 to 299 mg kg^{-1} in the DM, which is appropriate according to Carvalho et al. (2003), who found foliar Fe contents on average 100 to 487 mg kg^{-1} in Brachiaria.

In the extraction of manganese there was an increase of 23.04 % in the highest LSM dose in relation to the dose without application. The mean extraction per cut was 210.38 g kg ha^{-1} at the highest dose. The values close to that were reported by Lima et al. (2016) in *Brachachia hibrida*, where iron extraction ranged from 805.3 to 1174.6 g kg ha^{-1}. In plant, the levels ranged from 52.15 to 56.2 mg kg^{-1} of DM, are considered low. Raij et al., (1996) recommended that adequate concentrations should be 50 to 250 mg kg^{-1}. In this study, the values found for manganese were close to the bottom limit.

For extraction of Zn and Cu, there was an increasing linear effect for zinc and quadratic effect for copper (Figure 7).

The highest LSM dose provided an increase in Zn extraction of 31%, compared to control treatment. The mean extraction of Zn in the highest dose of LSM was 128.11 g kg ha^{-1}. It is below the values found by Lima et al. (2016) who studied biofertilizers and fertilizers in *Brachiaria hibrida* and found Zn conceptions ranging from 161.1 to 240.1 g kg ha^{-1} while the values ranged from 31.2 to 33.23 mg kg^{-1} in the DM. In all treatments, the concentrations are in the appropriate interval according to Perondi et al. (2007) which is 20 to 50 mg kg^{-1}.

The highest mean extraction of Cu (64.75 g kg ha^{-1}) was occurred at 26.36 m^3 ha^{-1} of LSM, with an increase of 20%, compared to control treatment. This value is close to the values (56 to 76.7 g kg ha^{-1}) obtained by Lima et al. (2016) in *Brachiaria hibrida*.

Cu concentration ranged from 15.91 to 18.1 mg kg^{-1} in DM, above the ideal suitable for Urochloa from 4 to 14 mg kg^{-1} in DM (Raij et al., 1996).

Copper extraction was much lower than that provided via LSM fertilization and, with the exception of iron, microminerals had a residual effect of fertilization, requiring soil monitoring over the years.

LSM has a variable composition in organic and inorganic components. So it is necessary to monitor soil characteristics in order to comply with environmental legislation and prevent soil saturation with undesirable chemical components, protecting the environment (Silva, 2018). The risk to human and animal health is due to the presence of heavy metals such as zinc, copper, chromium, cobalt, manganese and iron in the LSM composition which can be high.

Table 1. Bromatological production and composition of ruziziensis grass fertilized with liquid swine manure and mineral fertilization.

Variables	Doses ($m^3\ ha^{-1}$) 0	100	200	300	Fertilization Mineral	CV (%)
PH (cm)	52.92	53.97	56.58	60.71	66.34	3.50
TDMY (kg ha^{-1})	21.545	23.420	25.622	28.151*	31.888*	10.28
CP (%)	5.47	6.04	6.11	6.50	8.96	3.80
NDF (%)	60.92	60.98	61.15	61.26	58.20	1.80
ADF (%)	32.13*	31.37*	31.96*	32.31*	31.36*	1.81

The means in the lines followed by * do not differ from each other by the Dunnet test (P>0.05).

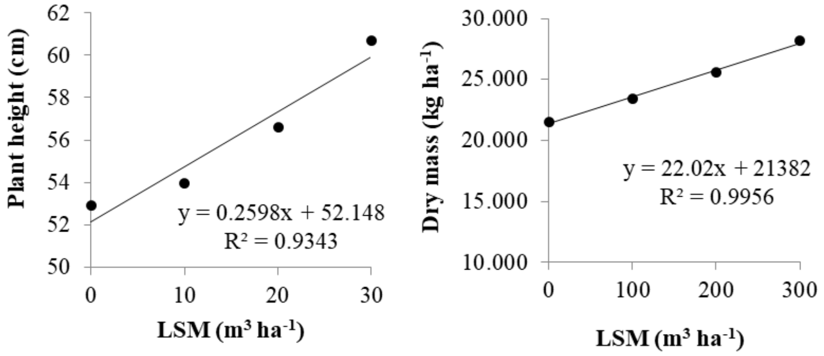

Figure 1. Plant height (cm) average of seven cuts according to the doses of LSM applied by cutting and Total dry mass productivity (kg ha^{-1}) in function on the total volume applied at the end of the cycle.

Table 2. Average extraction by macro and micronutrient cutting by *Urochloa ruziziensis* grass as a function of LSM doses and mineral fertilization.

Variables	Doses ($m^3\ ha^{-1}$ $corte^{-1}$) 0	100	200	300	Fertilization Mineral	CV (%)
DMY (kg ha^{-1})	3077	3345	3660	4021*	4555*	10.28
N (kg ha^{-1})	27.00	32.29	35.72	41.78	65.32	12.77
P (kg ha^{-1})	37.01	40.49	44.98	51.93*	63.39*	12.54
K (kg ha^{-1})	23.10	24.98	26.79	29.59*	35.11*	15.11
S (kg ha^{-1})	82.07	83.77	101.04	117.05	160.79	17.57
Ca (kg ha^{-1})	86.71	92.31	100.04	117.05*	128.91*	12.73
Mg (kg ha^{-1})	7.06	7.43	8.02*	9.13*	10.17*	14.21
Fe (g ha^{-1})	920	956	1046*	1199*	1272*	10.54
Mn (g ha^{-1})	172.92	184.39	190.89	214.54*	241.99*	10.12
Zn (g ha^{-1})	96.21	109.01	121.63*	125.44*	140.49*	12.65
Cu (g ha^{-1})	54.58	58.84	65.91*	63.97*	97.16*	27.36

The means in the lines followed by * do not differ from each other by the Dunnet test (P>0.05).

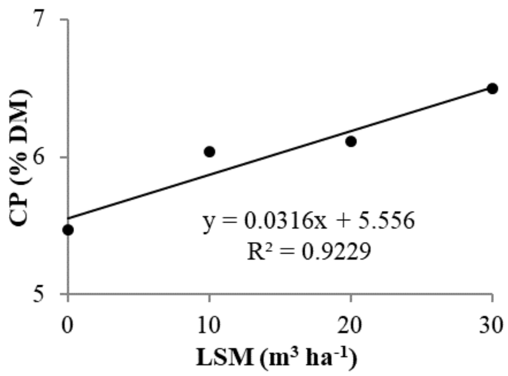

Figure 2. Crude protein content (%) average of seven cuts according to the LSM doses applied by cut in the forage of *Urochloa ruziziensis*.

Table 3. Chemical and granulometric characteristics of the soil of the experimental area at a depth of 0 to 0.20 m.

Chemical and granulometric composition of soil														
pH CaCl2	K	P	Al	H+Al	Ca	Mg	SB	CEC	V	m	OM	Clay	Silt	Sand
	mg dm^{-3}		cmolc dm^{-3}						%			g kg^{-1}		
4.8	3.43	12.8	0.32	15.85	1.81	1.78	3.59	19.44	18.11	9.13	5.41	611	20	369

K = Potassium; P = Phosphorus; Al = Aluminum; H + Al = Hydrogen plus Aluminum; Ca = Calcium; Mg = Magnesium; SN = Sum of bases; CEC = Cation exchange capacity at pH 7.0; V = Base Saturation; m = aluminum saturation; OM = Organic matter.

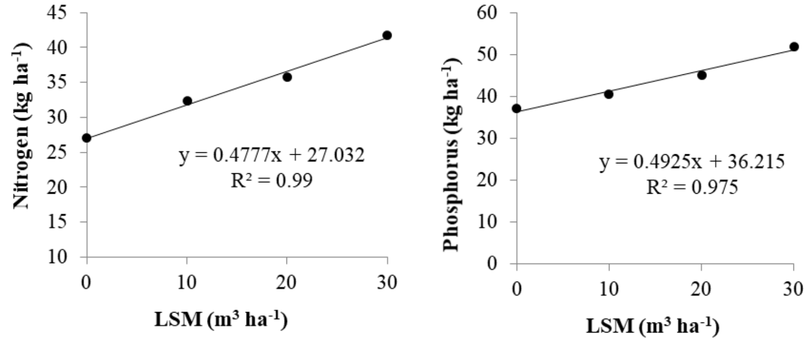

Figure 3. Nitrogen extraction (N) and phosphorus (P), mean values of seven cuts, in function on the LSM doses applied by cut in the forage of *Urochloa ruziziensis*.

Table 4. Chemical composition (mg L^{-1}) mean of LSM samples applied in experimental plots.

Average chemical composition of LSM (mg L^{-1})									
N	P	K	Ca	Mg	S	Mn	Fe	Zn	Cu
3750	2670	506	5170	1390	3540	41.3	38.8	11.7	13.8

N= Nitrogen; P= Phosphorus; K= Potassium; Ca= Calcium; Mg= Magnesium; S= Sulfur; Mn= Manganese; Fe= Iron; Zn= Zinc; Cu= Copper

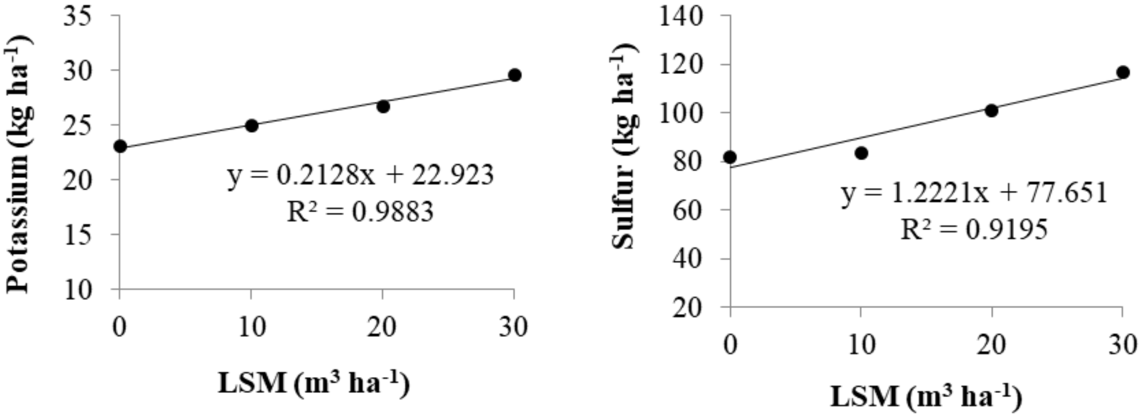

Figure 4. Potassium extraction (K) and sulfur (S), mean values of seven cuts, in function on the LSM doses applied by cut in the forage of *Urochloa ruziziensis*.

Table 5. Nutrients applied (kg ha^{-1}) via LSM in ten total applications at doses of 100, 200 and 300 m^3 ha^{-1}.

	Nutrients applied via LSM (kg ha^{-1})									
Doses	N	K	P	Ca	Mg	S	Mn	Fe	Zn	Cu
100	375	50.6	267.5	517	139	354	4.13	3.88	1.17	1.38
200	745	101.2	535	1034	278	708	8.26	7.76	2.34	2.76
300	1125	151.9	802.5	1552	417	1062	12.39	11.64	3.51	4.14

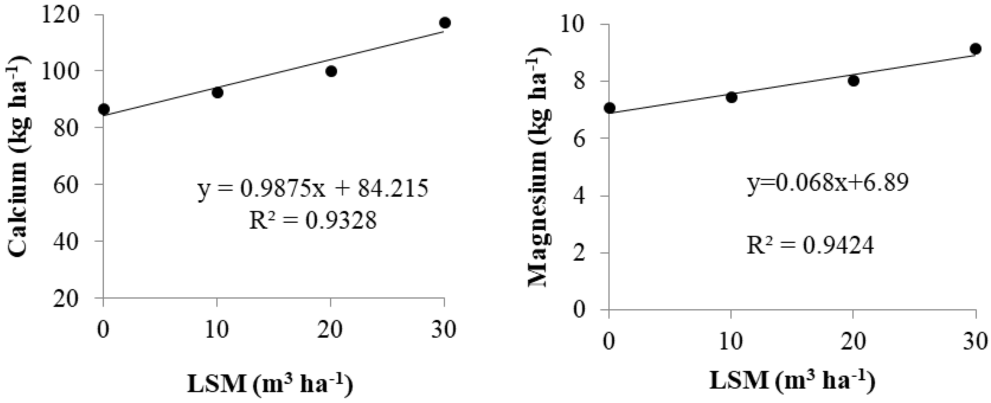

Figure 5. Calcium (Ca) and magnesium extraction (Mg), mean values of seven cuts, in function on the LSM doses applied by cut in the forage of *Urochloa ruziziensis*.

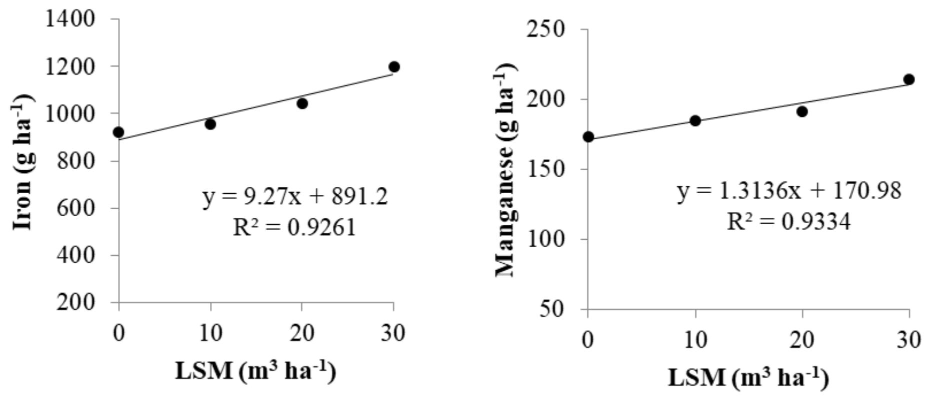

Figure 6. Iron (Fe) and manganese extraction (Mn), mean values of seven cuts, in function on the LSM doses applied by cut in the forage of *Urochloa ruziziensis*.

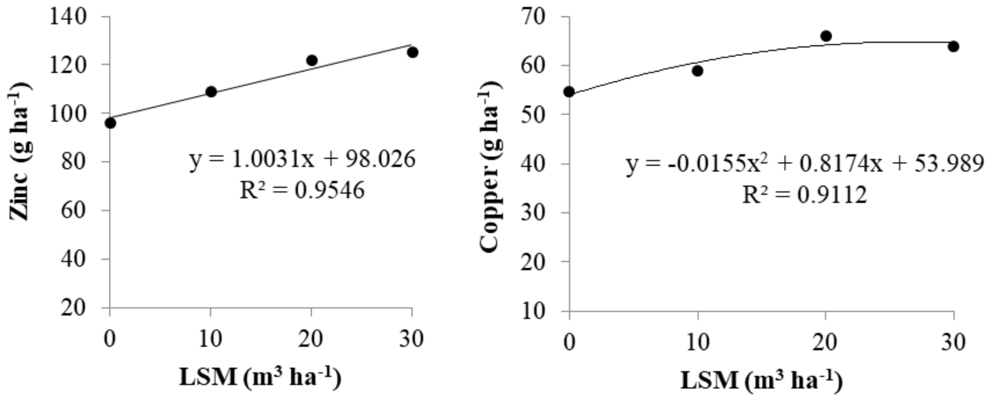

Figure 7. Zinc (Zn) and copper (Cu) extraction, mean values of seven cuts, in function on the LSM doses applied by cut in the forage of *Urochloa ruziziensis*.

These elements are commonly used as supplements in animal feed to satisfy mineral requirements and improve animal growth performance (Feng et al., 2018).

Changes in the metabolism of plants may occur to increase chance of survival and to develop mechanisms by which excessive amounts of heavy metals can be absorbed and transformed into physiologically tolerable forms (Cobbett, 2000; Hall, 2002). According to the food chain, it is consumed by animals and later by humans, which is why studies on doses to be applied are important.

Materials and methods

Location of experiment

The experiment was carried out in the experimental area of the Rio Verde Foundation, located in geographic coordinates (13°00'27" S and 55°58'07" W), with an average altitude of 387 m, in the municipality of Lucas do Rio Verde - MT, Brazil. The climate of the municipality, according to the Classification of Köppen, is type Aw, with an average temperature of 25ºC and annual precipitation of 2,300 mm.

Soil characterization

The soil of the experimental area was classified as Dystrophic Oxisol of very clayey texture according to the Brazilian Soil Classification System- SiBCS (Santos, 2018).

The previous crop in the experimental area was soybean that had to be desiccated for the experiment beginning. Soil samples were collected at two depths (0 to 0.20 m) for chemical and granulometric characterization (Table 3), according to a methodology recommended by Teixeira et al. (2017).

Experimental design and treatments

The experimental design was randomized blocks, containing five treatments and four replications. The treatments consisted of four doses of liquid swine manure (LSM) and a mineral fertilization.

The LSM volumes used in the treatments were defined based on the N content contained in the first analysis that was 5 g L^{-1}. Thus, the doses were 0; 50; 100 and 150 kg ha^{-1} of N. Each experimental unit was 11.0 m long and 5 m wide, with spacing between the plots and between the blocks of 5 m. The total volumes applied were: 0; 100; 200 and 300 m^3 ha^{-1} of LSM installments in 10 applications, which corresponded to 0; 10; 20 and 30 m^3 ha^{-1} per application, respectively.

Mineral fertilization consisted of 40 kg of K_2O; 70 kg of P_2O_5 and 50 kg N per hectare according to recommendation for *Urochloa ruziziensis* (Ribeiro et al., 1999).

Source, characterization and preparation of swine manure

The LSM was processed in a biodigester and was composed of waste (feces, urine, feed residues and water). It was stored in ponds that were open and subject to incidence and variations in rainfall and the dilution effect may have occurred in the doses applied during the conduction of the experiment. The doses were fixed in volumes based on the first analysis of the LSM.

Before the application of LSM, samples were collected monthly to analyze its chemical composition. The samples were conditioned and kept under Styrofoam box with ice for macro and micronutrient analysis, heavy metals, according to Table 4.

The doses of LSM were distributed in 10 applications throughout the experiment (March 2014 to January 2015). Table 5 shows the nutrients amount applied in the total volume of LSM during the experimental period. In relation to mineral fertilization, nitrogen was divided into 4 doses of 50 kg ha^{-1} of N, totaling 200 kg ha^{-1} of N.

Planting and conducting the experiment

The sowing of *Urochloa ruziziensis* was performed in January 2014. After 30 days of emergency, uniform cut was performed at 15 cm of residue height. During the experimental period, seven cuts were made (March, April, May, October, November, December/2014 and January/2015).

There was a resting period of four months (June to September 2014), in which the application of LSM was stopped so that the plant remained nourished because there was a concern with the pasture leafhopper (*Deois flavopicta*), since the crop is susceptible.

Traits measured

In each cut, 10 measurements of plant height were performed and three forage samples were collected per plot at residue height of 15 cm, using a square of 0.5 x 0.5 m (0.25 m^2). The samples of the forage collected were packed in paper bags and identified, weighed to obtain green mass and taken for forced air circulation oven at a temperature of 55° C for 72 hours. After that, the plant material was weighed to obtain the dry mass, followed by milling in Willey mill and stored for further laboratory analysis.

In the laboratory analysis of forage, the contents of N, P, K, Ca, Mg, S, Cu, Fe, Mn, and Zn were determined according to the methodology described by Malavolta et al. (1997).

The analysis of dry mass productivity and extracted nutrients was performed for each cut and the data were tabled with the means of the seven cuts for each treatment according to the total volume applied.

Crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Silva and Queiroz (2004).

Total dry mass productivity were obtained through forage accumulation in seven cuts, and for the other variables, the means were made by cut.

The data were compiled using the mean values between the cuts for each dose applied (0, 10, 20, 30 m^3 ha^{-1}), with the exception of dry mass productivity data that considered the total volume applied (0; 100; 200 and 300 m^3 ha^{-1}).

Statistical analysis

The data were subjected to variance analysis. When they were significant, the regression analysis was performed for doses using the statistical program SISVAR (2015) and Dunnett test, to compare the doses of LSM with mineral fertilization, both at 5% probability using the statistical program SAS.

Conclusion

Due to the composition of the diets, there is a risk of toxicity by heavy metals when LSM is applied improperly, and therefore it is important that there are studies with different dosages so that the correct dose of LSM is used. The liquid swine manure is an alternative that can replace mineral fertilization for *Urochloa ruziziensis* grass, especially in regions where there is intensive swine farming. The volume of liquid swine manure of 300 m^3 ha^{-1} promoted dry mass production, without altering the levels of neutral detergent fiber and acid detergent fiber (NDF and ADF), besides improving nutrient concentration in *Urochloa ruziziensis* available for grazing animals.

Acknowledgments

To the BRF – Brazil Foods and to the Coordination for the Improvement of Higher Education Personnel (CAPES).

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