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Agronomic traits, chemical composition and silage quality of elephant grass fertilized with poultry litter

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The high generation of organic residues from the intensive farming of chickens has induced their use as fertilizer for forage crop production. This aimed to evaluate the effect of poultry litter application on agronomic traits and quality of silage of elephant grass. The experiment was conducted in the experimental field of Boa Vista Farm, in district of Cachoeira de Santa Cruz, Viçosa, State of Minas Gerais, in sandy argisol. The experimental period was from November 2014 to February 2015 and the treatments consisted of four levels of fermented poultry litter (0, 4, 8 and 12 ton.ha^{-1}) with five repetitions. Evaluations consisted of measurements of plant height, stem diameter, number of plants.ha^{-1} and green mass yield. In relation to silage, measurements of gas losses, effluents and total losses were performed using the four treatments cited and four repetitions. There was a positive linear effect (P<0.01) of poultry litter level on plant height and a quadratic effect (P<0.01) of poultry litter level on the number of plants.ha^{-1}, with maximum at 9.1 ton.ha^{-1} of poultry litter. There was no treatment effect (P>0.05) on the stem diameter, green mass yield and silage quality.

Key words: Organic waste, *Pennisetum purpureum* Schum, poultry litter, productivity, qualitative parameters.

INTRODUCTION

Elephant grass is widely used in Brazil for cattle production, especially dairy animals, because of its high potential for forage production. However, researches have many times revealed problems such as increase in production costs, mainly for nitrogen fertilizers and rangeland degradation (Olivo et al., 2014).

On the other hand, Brazil as the second largest producer and first largest exporter of broiler meat in the world increased the generation of organic waste from the intensive farming of chickens, which requires proper environmental disposal, since the disposal at random in the environment causes risks of contamination (Tavares and Ribeiro, 2007; Costa et al., 2009).

Poultry litter has important concentrations of nitrogen, phosphorus, potassium, and micro minerals such as copper and zinc (Oviedo-Rondon, 2008; Lima et al., 2016). According to Costa et al. (2015), there is a necessity for studies on the use of poultry litter as organic fertilizer in the productivity of cultures.

The use of organic fertilizer provides greater

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Table 1. Soil chemical properties of the experimental area before the application of treatments with poultry litter for elephant grass planting.

pH	P	K	Ca	Mg	Al	H+Al
			(mg/dm³)			
5.8	17.3	60	2.6	1.6	0.0	2.97
SB	**CTC (t)**	**CTC (T)**	**V**	**M**	**OM**	**P-rem**
	(cmol$_c$/dm³)		(%)		(dag/kg)	(mg/L)
4.35	4.35	7.32	59	0	4.97	32.0
Zn	**Fe**	**Mn**	**Cu**	**B**		
		(mg/dm³)				
5.9	163	78.5	1.9	0.4		

H+Al: Potential acidity; SB: sum of bases; CTC (t): effective cation exchange capacity; CTC (T): potential cation exchange capacity; V: base saturation; m: aluminum saturation, OM: organic matter; P-rem: remaining phosphorus.

environmental sustainability, by preserving natural resources through nutrients recycling, avoiding water contamination and harnessing materials available on the agricultural property, in addition to the reduction of production costs (Ariati et al., 2017).

The benefit of the use of organic waste as fertilizers of forage plants occurs in productivity, directly, through the provision of nutrients readily available in the soil solution, or indirectly, through the modifications of the physical, chemical and biological properties of the soil (Zárate et al., 2010; Mangieri and Tavares Filho, 2015). Therefore, organic fertilizers improve root environment and stimulate the plant development (Kiehl, 1985; Menezes et al., 2004).

Silage making is a strategy to store the excessive production of elephant grass in the rainy season for supplementation during the forage scarcity and weight losses in ruminant livestock at the dry season (Ajayi, 2011). This strategy is especially important in the case of the small farmers with low producing dairy cows, predominant in the tropics (Olivo et al., 2014). However, elephant grass may have high values of moisture, which may affect the quality of the silage by undesirable fermentation (Brant et al., 2017), and indicates the necessity for evaluation of its silage quality.

This study aimed at evaluating the development of elephant grass in response to the application of increasing levels of poultry litter at planting, as well as the quality of the silage produced.

MATERIALS AND METHODS

Location and period of the experiment

The experiment was conducted at the Boa Vista Farm belonging to the Federal University of Viçosa, located in the district of Cachoeira de Santa Cruz, municipality of Viçosa, State of Minas Gerais, between October 2014 and January 2015. The geographical coordinates of the experiment site are 20°45’ South latitude, 42°51’ West longitude and 703 m altitude.

The climate of the region of Viçosa, according to the classification of Köppen (1948), is Cwa (mesothermal), subtropical, with mild and dry winter, and well-defined dry and rainy seasons. The average annual temperature was 21°C, ranging from 31 to 12°C for the maximum and minimum temperature, respectively. The historical rainfall of the area is 1340 mm. However, in 2014 it was 782 mm, which represented 42% below the historical average of the region. Information on the climatic conditions during the experimental period was recorded at Main Climatological Station of Viçosa located at the Federal University of Viçosa, approximately 15 km from the experimental area.

Setup of the experiment

Prior to the experiment, *Brachiaria decumbens* and *Brachiaria brizantha* predominated in the area, which were used as reserve pasture for lactating cows. Thus, before planting elephant grass, soil samples were taken at random in several places of the experimental field, with the aid of a probe, at the 0 to 20 cm layer, to analyze the chemical and physical characteristics of the soil, according to the Commission on Soil Chemistry and Fertility (Comissão de Química e Fertilidade do Solo, 2004).

Soil tillage with plowing and harrowing was carried out in the dry season, in September 2014, so that all existing plants in the experimental area entered senescence. Plowing was done at approximately 0.3 m depth and harrowing was done to decompress the initial layer of the soil. In November 2014, the planting was done in rows, spaced 1 m between furrows and 30 cm deep.

The experiment consisted of four treatments (0, 4, 8 and 12 $ton.ha^{-1}$ of poultry litter) and five replications, totaling 20 experimental plots. Each experimental unit was five m long and 4 m wide, a total area of 20.0 m^2, with four rows of plants, the working area was considered 5 m^2, the two central rows, also discarding 50 cm at each end.

Soil and fertilizer characteristics

The soil of the experimental area is sandy argisol, suitable for crops with low fertility requirements (Table 1).

The poultry litter used consisted of a flock of broiler chickens and coffee husks. This organic residue came from an industrial poultry farm located in the municipality of Coimbra, state of Minas Gerais, fermented for 60 days on a wet basis. Five poultry litter subsamples performed a single plot for laboratory analysis.

The results of the analysis of the poultry litter used in this study are the following:

N (%) = 3.48; P (%) = 0.96; K (%) = 2.56; Ca (%) = 1.88; Mg (%) = 0.48; S (%) = 0.45; CO = 21.5; C/N = 6.18; pH (H_20) = 7.2; DM (%) = 43.3.

The mineral analyses were determined in the acid extract (nitric acid with perchloric acid), dry matter at 65°C, and oven humidity at 75°C. The levels of poultry litter were determined based on quantities found in the literature (Farias et al., 1986; Arruda et al., 2014).

Agronomic evaluations

Growth parameters measurements occurred after 110 days of elephant grass planting in a central linear meter of the experimental plot. Among those, include the plant height from the ground level up to the ligule of the highest leaves, the stem diameter close to the ground surface by means of a caliper, the number of plants and weight in a linear meter in order to estimate the total number and yield per hectare. After weighting, the plants were chopped, sampled and frozen for feed analyses, following the methodologies of Detmann et al. (2012).

Elephant grass silage

Samples of elephant grass harvested at 110 days and chopped were stored in experimental bucket silos with a capacity of 3.8 L, equipped with caps coupled to Bunsen valves to allow the escape of gases from the fermentation. At the bottom of the silos, it was placed in 0.6 kg of dry sand, separated from the forage by a cotton cloth, to quantify the effluent produced.

Elephant grass was compacted with a wooden stick. After compaction, the experimental silos were sealed with adhesive tape, weighed and stored. After 84 days of fermentation, they were again weighed to determine the losses by gases and open. After silage removal, the set (bucket, cap, sand, and cotton cloth) was weighed to quantify the effluent produced.

Silages at the top and bottom of the silos were discarded and the rest homogenized. Sub-samples of 500 g were collected for pre-drying in a forced air ventilation oven at 60°C for 72 h to obtain the dry matter content. These sub-samples were sent to the Plant Tissue Analysis Laboratory for analysis of the total N content (Tedesco et al., 1995), whose value was multiplied by the conversion factor 6.25 to estimate the crude protein content (Association of Official Analytical Chemists, 1995).

The losses of gases and effluent were quantified by weight difference and expressed as percentage of the total ensiled material in natural matter.

Experimental design

The experimental design of the field experiment was in randomized blocks with four treatments (0, 4, 8 and 12 $ton.ha^{-1}$ of poultry litter) and five replications. In the case of silages, the experimental design was completely randomized with four treatments (levels of poultry litter) and four replicates. The experimental data were tested by analysis of variance and regression at 5% of significance, using the Minitab program (Ryan and Joiner, 1994).

RESULTS

Soil chemical properties

The use of poultry litter improved the soil chemical properties, with higher values of P, K, Ca, Mg, SB, CTC (t), CTC (T), OM, Zn and Mn (Table 2), even after cultivation and harvest of elephant grass at 110 days of experimental period during the rainy season.

Production-related variables

There were increasing responses of poultry litter levels on some variables evaluated in elephant grass at 110 days after planting. There was an increasing linear effect ($P < 0.01$) of the poultry litter level on the plant height and quadratic effect ($P<0.01$) of the poultry litter level on the number of $plants.ha^{-1}$, with maximum value at 9.1 $ton.ha^{-1}$ of poultry litter. There was no effect ($P > 0.05$) on stem diameter and green mass yield (Table 3).

The content of protein and K increased and the contents of P, Ca, Mg, Zn, Fe, Mn, Cu and B reduced in the elephant grass plant at 110 days after planting with the use of poultry litter (Table 4).

There was no significant effect ($P > 0.05$) of treatment for gas losses, total loss and pH after 60 days of elephant grass ensiling, but there was a cubic effect on effluent loss (Table 5).

DISCUSSION

Soil chemical properties

In general, the soil of the study area had high fertility, meeting the requirements of low-demanding crops, but for elephant grass there is a need for fertility improvements. In the area, there was dominance of *Urochloa decumbens* grass pasture, since the area had not been used for agricultural exploration for more than 10 years. It is noteworthy that the levels of Ca, Mg and K presented high values at the 0 to 20 cm layer (Comissão de Química e Fertilidade do Solo, 2004).

Fertilizer characteristics

According to Menezes et al. (2004), the chemical composition of the poultry litter can be modified according to the material used to line the poultry houses and the number of times that the bedding material is used. However, according to these authors, the average doses of nitrogen vary from 2 to 5%; P_2O_5 from 1.5 to 3% and K_2O from 2 to 4%. In this study, all the three macronutrients are inside the presented ranges.

For soil fertility parameters, organic compounds bring

Table 2. Soil chemical properties, after harvesting elephant grass at 110 days, in areas fertilized with increasing levels of poultry litter in the municipality of Viçosa State of Minas Gerais, 2015.

Poultry litter level	pH	P	K	Ca	Mg	Al	H+Al
		(mg/dm^3)			(cmol$_c$/dm^3)		
0 ton.ha^{-1}	6.3	4.1	31	2.6	1.3	0.0	3.46
4	6.4	6.9	42	3.3	1.7	0.0	3.46
8	6.3	7.6	43	3.0	1.6	0.0	3.30
12	6.2	14.9	52	3.2	1.6	0.0	3.63
	SB	**CTC (t)**	**CTC (T)**	**V**	**m**	**OM**	**P-rem**
		(cmol$_c$/dm^3)			(%)	(dag/kg)	(mg/L)
0 ton.ha^{-1}	3.48	3.98	7.44	53	0	3.73	18.9
4	5.11	5.11	8.57	60	0	4.54	21.2
8	4.71	4.71	8.01	59	0	3.60	21.9
12	4.73	4.73	8.03	59	0	3.99	21.2
	Zn	**Fe**	**Mn**	**Cu**	**B**		
			(mg/dm^3)				
0 ton.ha^{-1}	2.5	73.2	54.5	1.5	0.1		
4	4.4	72.0	107	1.7	0.2		
8	4.3	85.0	76.7	1.6	0.2		
12	5.2	74.9	91.8	1.6	0.2		

H+Al: Potential acidity; SB: sum of bases; CTC (t): effective cation exchange capacity; CTC (T): potential cation exchange capacity; V: base saturation; m: aluminum saturation, OM: organic matter; P-rem: remaining phosphorus.

Table 3. Growth parameters of elephant grass at 110 days according to organic fertilization with poultry litter at planting in Viçosa, 2015.

Item	Poultry litter (ton.ha^{-1})					P-value	RE
	0	4	8	12	SEM		
Plant height (cm)	61.0	77.8	82.2	96.9	0.04	0.001	1
Stem diameter (mm)	16.0	16.1	16.4	17.0	0.47	0.486	
Plants (×1,000/ha)	90.0	112.0	140.0	126.0	7.86	0.004	2
Yield (ton.ha^{-1} GM)	43.4	56.2	48.2	62.5	6.51	0.222	

SEM: Standard error of the mean; RE: regression equation: [1] 62.7 + 2.8X. r^2 = 0.62; [2] 87.3 + 10.3X- 0.569X^2; R^2 = 0.52; GM: green mass.

benefits, favoring the increase in pH, SB, CTC (T) and V (%), as well as a decrease in H+Al. In this study, there was a slight increase in pH, Ca, SB, CTC (t), CTC (T) and Mn with poultry litter compared to the soil before the experimental period (Table 2).

The dry matter of the poultry litter with coffee husks has values ranging from 70 to 78%, even derived from the same poultry farm, and may vary depending on the management, the composition of the feed and the waste of the feeders and drinkers (EMBRAPA, 2008). Thus, knowledge of this value is important in the calculation of nutrient replacement required by crops. In the present study, the dry matter content was 43.32%, below the value of 87% obtained by Lima et al. (2016).

The low dry matter content of the poultry litter, which led to lower mineral content than those reported by EMBRAPA (2008), may have been one of the factors for the lack of response of elephant grass to organic fertilization (Table 3). In this case, higher levels of poultry litter should be used, which could become uneconomical due to the price of this product in the Zona da Mata of Minas Gerais.

Production-related variables

Forage crop production is affected by, among other factors, the climatic characteristics of the site and the fertilization of the soil. The minimum temperature averages found for the experimental period from October

Table 4. Mean content of dry matter (DM), crude protein (CP), macro- and micro-minerals in elephant grass plants fertilized with poultry litter, harvested at 110 days after planting.

Poultry litter level	DM	CP	P	K	Ca	Mg
	%	%DM		($cmol_c/dm^3$)		
0 ton.ha^{-1}	32	7.69	0.16	1.48	0.37	0.53
4	33	7.50	0.13	1.80	0.25	0.36
8	36	6.56	0.14	1.96	0.22	0.41
12	35	8.06	0.13	2.36	0.21	0.34
	S	**Zn**	**Fe**	**Mn**	**Cu**	**B**
	$cmol_c/dm^3$			(mg/kg)		
0 ton.ha^{-1}	0.10	37	561	77	8	8.7
4	0.07	22	308	41	5	5.7
8	0.07	24	293	56	4	6.7
12	0.07	17	432	56	4	7.7

Table 5. Gas loss, effluent loss and total loss, as percentage of the ensiled material, and pH in elephant grass silage with opening of silos after 84 days.

Item	Poultry litter (ton.ha^{-1})				SEM	P-value	RE
	0	4	8	12			
Gas (%)	0.02	1.80	-1.02	0.83	1.36	0.15	
Effluent (%)	2.96	2.02	4.76	2.99	0.82	0.04	1
Total loss (%)	2.98	3.81	3.74	3.81	1.55	0.79	
pH	4.28	4.36	4.25	4.18	0.14	0.66	

SEM: Standard error of the mean; RE: regression equation: [1]$2.96 - 1.38X + 0.372X^2 - 0.0214X^3$; $r^2 = 0.16$.

2014 to January 2015 were 18°C, above the 15°C recommended for the adequate growth of forage plant (Arruda et al., 2014). Nevertheless, the rainfall found for the same period was below the historical average for the region; these data are unfavorable to elephant grass productivity.

The results did not show effect of poultry litter on plant productivity (Table 3). However, the growth of 44% of the elephant grass subjected to organic fertilization is a fact. According to Kiehl (1985), the effect of organic matter on productivity may be direct through the provision of nutrients or changes in soil physical properties, which provides a favorable root environment for the development of plants. In addition to the atypical climatic influence, the greatest benefits may be noticed in the next agricultural years on the productivity of plants.

It is worth mentioning that the use of organic fertilizers promotes a slow and gradual release of nutrients, with the advantage of increasing the organic matter content, gradually solubilizing macro- and micro-nutrients to the soil solution (Menezes et al., 2004). Soil nutrient content, after harvesting elephant grass, at the highest level of fertilization, was the most close to those verified in the soil before planting the grass. Therefore, in the next years of cultivation, it is expected to maintain productivity with annual maintenance fertilization, unlike control treatment, which should lead to soil depletion and consequent productivity reduction.

According to the earlier observation, the practice of organic fertilization in addition to reducing production costs is important to maintain or increase the stock of organic matter and improve the physical and chemical properties of the soil, which is essential to ensure soil quality and, consequently, the sustainability of agroecosystems (Cardoso et al., 2013; Scotti et al., 2015).

Further, it is worth noting that the lack of fertilization effect on grass productivity can be because the experiment was conducted in a year where the rainfall was 42% below the historical average and the low rainfall strongly affected the growth of plants, causing a reduction in productivity.

The poultry litter contains a high concentration of nutrients, since poultry have low rates of utilization of feed (40 to 60%) and the remainder is eliminated via waste. The producer who decides to use organic fertilization should measure the balance of nutrients annually through soil analysis in order to adjust soil nutrient contents according to the plant requirement.

Studies indicate that a small fraction found in the soil surface consists of organic matter and that the incorporation of organic residues into the soil provides an increase in nutrient uptake by the plant, by the increase of microbial activity (Maia and Cantaruti, 2004; Rogeri et al., 2015).

Chemical composition of elephant grass and silage produced

The CP content of elephant grass harvested at 110 days (Table 4) with mean of 7.45% DM obtained in this study is considered adequate and within the standard values recommended by the literature (Queiroz Filho et al., 2000). According to the authors, with the advancing age of the purple elephant grass, from 40 to 100 days there was a quadratic effect on the CP content, with crude protein content estimated at 5.89% at 96 days of age.

According to Van Soest (1994), the minimum CP content in the forage plant is 7% so that there is no reduction in voluntary intake. In this way, the values obtained are within the required standards. The silages presented similar pH values (Table 5). Meantime, only elephant grass silage under fertilization with 12 ton.ha^{-1} of poultry litter is within the desirable range of 3.8 to 4.2 as recommended in the literature (Yitbarek and Tamir, 2014).

Higher values of moisture and pH of silages may affect the quality of the silage. Grass silages can be improved by the use of other foods to increase the dry matter content and of compounds that favor fermentation and by the use of microbial inoculants (Santos et al., 2014; Brant et al., 2017).

Conclusions

Organic fertilization with poultry litter increases the height of the elephant grass plants up to 12 ton.ha^{-1} and the number of plants per hectare, with a maximum value of 9.1 ton.ha^{-1}. Then, level from 9.1 to 12 ton.ha^{-1} of poultry liter seems desirable for elephant grass establishment during the first 110 days of growth. Poultry litter does not influence the silage quality of elephant grass harvested after 110 days of planting.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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