Revista Ciência Agronômica
ISSN: 0045-6888
ISSN: 1806-6690
Universidade Federal do Ceará

Meneses, Abner José Girão; Cândido, Magno José Duarte; Pompeu, Roberto Cláudio Fernandes Franco; Souza, Henrique Antunes de; Guedes, Fernando Lisboa

Morphogenesis of elephant grass fertilized with organic compost from solid waste in small ruminants1

Revista Ciência Agronômica, vol. 49, no. 4, October-December, 2018, pp. 699-707
Universidade Federal do Ceará

DOI: 10.5935/1806-6690.20180079

Revista Ciência Agronômica, v. 49, n. 4, p. 699-707, out-dez, 2018
Centro de Ciências Agrárias - Universidade Federal do Ceará, Fortaleza, CE
www.ccarevista.ufc.br

Scientific Article
ISSN 1806-6690

Morphogenesis of elephant grass fertilized with organic compost from solid waste in small ruminants[1]

Morfogênese do capim-elefante adubado com composto orgânico proveniente de resíduos sólidos de pequenos ruminantes

Abner José Girão Meneses[2]*, Magno José Duarte Cândido[3], Roberto Cláudio Fernandes Franco Pompeu[4], Henrique Antunes de Souza[5] and Fernando Lisboa Guedes[4]

ABSTRACT - This study evaluated the biomass flow of irrigated *Pennisetum purpureum* cv. Cameroon fertilized with different levels of organic compost made from waste derived from production and slaughter of sheep and goat farming. The experiment was conducted in a cut and carry of elephant grass for four 60 day-cycles. The treatments consisted of levels of organic compost (0; 13.3; 26.6; 39.9; 53.2; 79.8) ton ha^{-1}, besides a mineral treatment with nitrogen and potassium of 720 and 900 kg ha^{-1} yr^{-1}, respectively. This was a split plot randomized block design with repeated measures over time, in which levels were assigned to plots, and cycles, to subplots. Morphogenetic characteristics of elephant grass were influenced by levels of the compost. Forage production rate had increased linearly with levels of the compost in all cycles, while the forage accumulation rate responded quadratically to doses of compost in cycles 1 and 2. The contrast analysis between organic x mineral fertilization revealed, for all cycles, except the first, superiority of morphogenetic indices for mineral fertilizer. It can be concluded that the elephant grass responded to the organic compost and it is recommended the use of 70.63 ton ha^{-1}.

Key words: C:N ratio. Biomass flow. Leaf elongation rate. Mineralization. *Pennisetum purpureum.*

RESUMO - Avaliou-se o fluxo de biomassa do *Pennisetum purpureum* cv. Cameroon irrigado submetido a doses de composto orgânico proveniente de resíduos da produção e abate da ovinocaprinocultura. O experimento foi realizado em capineira de capim-elefante, durante quatro ciclos de 60 dias. Os tratamentos foram doses do composto orgânico (0; 13,3; 26,6; 39,9; 53,2; 79,8) toneladas·ha^{-1}, além de um tratamento mineral (nitrogênio e potássio) equivalente a 720 e 900 kg ha^{-1} ano^{-1}, respectivamente. Foi utilizado um delineamento em blocos casualizados em esquema de parcelas subdivididas, com medidas repetidas no tempo, sendo as parcelas as doses e as subparcelas os ciclos. As características morfogênicas do capim elefante foram influenciadas pelas doses do composto. A taxa de produção de forragem apresentou efeito linear crescente com as doses do composto para todos os ciclos avaliados, enquanto a taxa de acúmulo de forragem respondeu de forma quadrática nos ciclos 1 e 2 às doses do composto. A análise de contraste entre a adubação orgânica x mineral, revelou em todos os ciclos, exceto no primeiro, superioridade dos índices morfogênicos para a adubação mineral. Conclui-se que o capim-elefante foi responsivo ao composto orgânico sugerindo-se uma dose de 70,63 toneladas ha^{-1}.

Palavras-chave: Relação C:N. Fluxo de biomassa. Taxa de alongamento foliar. Mineralização. *Pennisetum purpureum.*

DOI: 10.5935/1806-6690.20180079
*Author for correspondence
Received for publication on 07/08/2016; approved 02/02/2018
[1]Parte da Dissertação de Mestrado em Zootecnia do primeiro autor, apresentada na Universidade Federal do Ceará/UFC, pesquisa apoiada pela Embrapa e FUNCAP
[2]Instituto Federal de Educação, Ciência e Tecnologia do Ceará/IFCE, Campus Crato-CE, Brasil, abnergirao@yahoo.com.br
[3]Departamento de Zootecnia, Universidade Federal do Ceará/UFC, Fortaleza-CE, Brasil, magno@ufc.br
[4]Pesquisador da Embrapa Caprinos e Ovinos, Sobral-CE, Brasil, roberto.pompeu@embrapa.br, fernando.guedes@embrapa.br
[5]Pesquisador da Embrapa Meio-Norte, Teresina-PI, Brasil, henrique.souza@embrapa.br

INTRODUCTION

Sheep and goat farming is a relevant agricultural activity in the Brazilian economy. Brazil ranks 18th in world position, with 25.4 million animals (ANUALPEC, 2014). However, the activity generates waste, which, when improperly disposed, causes severe environmental impacts. Composting is a technique that allows the reuse of the by-product derived from the activity in the production system, minimizing environmental problems and enhancing its use as organic fertilizer. According to Bellaver and Konzen (2010), composting adds fertilizing value to waste, reducing the population of pathogenic bacteria, in addition to favoring the beneficial bacteria of the composted material.

Thus, considering the technical production indices for sheep and goat farming, such as average prolificacy rate (1.5 offspring year^{-1}); mortality (10%) and average weight of carcasses with one year of age (20 kg animal^{-1}) (PRIMO *et al*., 2014; SOUZA *et al*., 2016), it is estimated a production of 22 thousand tons of carcasses that added 1.5 or 2.0 tons of structuring materials (manure and waste of farming) used in the composting process, which would generate 60.5 thousand tons of compost annually.

Elephant grass (*Pennisetum purpureum* cv. Cameroon) stands out for presenting high biomass yield and adaptation to semi-arid conditions, besides positive responses when subjected to organic fertilization. Several authors have found benefits to productivity in different varieties of this grass when subjected to organic fertilization (BRAIDAII; CASSOLI, 2009; CABRAL *et al*., 2011; EMERECIANO NETO *et al*., 2016; GEWEHR *et al*., 2010; PARENTE *et al*., 2012). The understanding of the morphogenetic behavior of this grass on such conditions presumes improvements in management adopted that raise production rates.

Therefore, this study aimed to evaluate the morphogenetic characteristics of *Pennisetum purpureum* cv. Cameroon under increasing levels of organic compost made from waste derived from production and slaughter of small ruminants during four growth cycles.

MATERIAL AND METHODS

The experiment was conducted in the experimental area of Embrapa Goats and Sheep in Sobral, state of Ceará (34º2' South latitude and 40º21' West longitude, at an altitude of 70 m), from December 2013 to August 2014. The climate of the region is BShw, according to Köppen, hot semiarid. Data relating to average conditions of temperature, relative humidity, rainfall and solar radiation ofthe cycles (1, 2, 3, 4) were (28.5; 27.7; 27; 27.9 °C), (89; 92; 97.7; 88%) (77; 279; 374; 10 mm) (1416.7; 1441.4; 1327.6; 1420.1 kJ m^2), respectively collected by a weather station belonging to the National Institute of Meteorology (INMET, 2014).

Before the experiment, soil samples were taken for soil fertility evaluation. Chemical properties of the soil in the layers 0.0-0.20 and 0.20-0.40 m depth are shown in Table 1. Also, according to Alvarez *et al*. (1999), the soil has sandy loam texture.

Composting of solid waste derived from the slaughter of sheep and goats was carried out at Embrapa Goats and Sheep, in a 128 m^2 masonry, colonial roof and concrete floor. Composting cells had 3.5 x 2.0 x 1.60 m (width, depth, height, respectively), and whose assembly consisted of wooden planks fitted into channels, anchored in concrete columns.

Compost piles were continuously loaded, passively aerated, that is, there was no turning of the windrow because of the presence of carcasses, and aeration occurred by convection. Water was inserted only at the time of assembling the pile, the first layer had 0.40 m structuring materials (50% goat and/or sheep manure and 50% remains of chopped elephant grass from animal feeders and tree pruning material). The structuring material corresponded to 1.5 - 2.0 times the weight of solids used in the process.

The second layer was composed of solid remains of small ruminants. These remains were positioned in rows 0.20 m from the side walls and from each other. Then, it was added to the solid remains a quantity of water corresponding to 40% of its total weight. The third layer was formed by the same structural waste and other layers were formed successively until reaching the maximum cell height, the last layer being formed only by goat and/or sheep manure. The composting period lasted approximately 120 days.

Chemical characteristics of the compost used in the study, determined according to Abreu, Andrade and Falcão (2006), are listed in Table 2. The moisture of the organic compost after 120 days is approximately 10%. It is noteworthy that, at the end of the composting process, the material showed no fecal coliform, total bacteria and *E. coli*, complying with Resolution 375/2006 of CONAMA that "sets criteria and procedures for agricultural use of sewage sludge generated in sewage treatment plants and their derivatives, and other measures", which was used as a standard reference given the lack of specific legislation for this compost made from waste derived from production and slaughter of animals.

The study used elephant grass (*Pennisetum purpureum*) cv. Cameroon cultivated for five years in Fluvic Neosol of flat topography and provided with low pressure fixed sprinkler irrigation (operating pressure

Table 1 - Chemical properties and particle size of soil collected in the experimental area

Layer (m)	pH	OM	P	K	Ca	Mg	H+Al	Al	B	CEC
		$g dm^{-3}$	------ $mg dm^{-3}$ -------		------------------------------- $mmol_c dm^{-3}$ -------------------------------					
0-0.2	7.0	16	36	31.0	50	19	13	0	74.2	87.2
0.2-0.4	7.2	7	36	31.0	54	17	12	0	76.1	88.1
	V	ESP	S	Na	Cu	Fe	Zn	Mn	B	
	--------- % --------		------ $mg dm^{-3}$ -------		------------------------------- $mg dm^{-3}$ --------------------------------					
0-0.2	85	5.08	11	102	0.5	54	1.5	38.0	0.38	
0.2-0.4	86	4.84	8	98	0.5	32	1.0	20.0	0.23	
	Clay		Silt		Total sand		Coarse sand		Fine sand	
	-- $g kg^{-1}$ --									
0-0.20	254		216		530		60		470	
0.2-0.4	239		251		510		70		440	

pH - potential of hydrogen; OM - organic matter; P - phosphorus; K - potassium; Ca - calcium; Mg - magnesium; H+Al - potential acidity; Al - aluminum; S - sulfur; Na - sodium; Cu - copper; Fe - iron; Zn - zinc; Mn - manganese; B - boron; CEC - cation exchange capacity; V - base saturation and exchangeable sodium percentage (ESP). Source: Research data

Table 2 - Mean values of chemical attributes of the compost

Nin	$N-NO_{3^-}$	$N-NH_{4^+}$	Nt	C	C:N
----------------------------- $mg kg^{-1}$ ----------------------------			------------------- $g kg^{-1}$ ------------------		
355	250	105	20.3	175	9
P	K	Ca	Mg	S	Na
--- $g kg^{-1}$ ---					
9	15.7	21.9	5.5	2.8	2.1
B	Cu	Fe	Mn	Zn	pH
--- $mg kg^{-1}$ ---					
20	30	2.051	175	138	6.7

Nin - inorganic nitrogen; $N-NO_3^-$ - nitrate; NH_4^+ - ammonium; Nt - total nitrogen; C - carbon; P - phosphorus; K - potassium; Ca - calcium; Mg - magnesium; S - sulfur; Na - sodium; pH - potential of hydrogen ($CaCl_2$); B - boron; Cu - copper; Fe - iron; Mn – manganese; Zn - zinc. Source: Research data

<2.0 kgf cm^2). Daily irrigation was performed during the night to minimize the loss of water, especially by the effect of the wind, as well as potential losses of nutrients by volatilization due to the high temperatures during the day. The amount applied corresponded to evapotranspiration of 7.52 mm day^{-1}, with 73% efficiency of application; so that the water level used to calculate the relative efficiency of water use was 10.3 mm day^{-1}. At the beginning of each cycle, the irrigation system was evaluated by rain gauges (Fabrimar®) at 50 cm height throughout the experimental area with spacing of 3.0 x 3.0 m, to determine the uniformity in water distribution in the experimental area at each cycle.

The treatments were levels of the organic compost (equivalent to 0; 13.3; 26.6; 39.9; 53.2; 79.8 t ha^{-1}, in addition to treatment with application of nitrogen and potassium equivalent to 720 and 900 kg ha^{-1} yr^{-1}, respectively). This was a split plot randomized block design with repeated measures over time. The seven treatments and four repetitions, totaling 28 plots or experimental units of 25 m^2 each, formed by the levels of the organic compost and the growth cycles of the grass (four in number), the subplots.

The amount of compost to be applied to the grass was determined to provide an amount of nitrogen equivalent to 120 kg ha^{-1} $cycle^{-1}$ and was based on nitrogen content and moisture of the compost and on the need to meet the demand required by the grass for intensive production (FONSECA *et al*., 2010), with cuts made every 60 days (ANDRADE; GOMIDE, 1971), and amounts of the organic compost were applied at once after the standardization cut. The levels tested were: zero; half the standard level; standard level; one and a half the standard; twice and three times the standard level. For the additional treatment, per cycle, it was held the application of 120 to 150 kg ha^{-1} N (urea) and K_2O (potassium chloride), respectively; the application was split into two, the first performed at the beginning of each cycle (five days after cutting) and the second, in the middle of the cycle (thirty days after cutting). In both the two sources used (organic and mineral), it was considered as a standard the dose equivalent to 720 kg N ha^{-1} yr^{-1}. The distribution of organic and mineral fertilizers was made on the surface across the area of the plot.

For biomass flow test, in each plot, two tussocks were tagged seven days after cutting. Three tillers were randomly identified with colored rings in each of the tussocks. With the use of a millimeter ruler, at every five days, the marked tillers were measured, in which, pseudostem height was determined from the distance of the highest ligule to the base of the stem, the total length of the blades from ligule, when expanded, or from the ligule of the newly expanded leaf, when emerging. The length of senescent portion was obtained by the difference of the total length of the leaf blade at the time of its full expansion and the length of its green portion. The marked tillers were evaluated for leaf elongation rate (LER), stem elongation rate (SER) and leaf senescence rate (LSR).

It was also determined the gravimetric indices for stem elongation, leaf elongation and leaf senescence, from ten tillers collected at each plot at the end of the cycle (60 days), which were taken to the laboratory and separated into stems, expanded leaf blades and emerging leaf blades. All fractions were measured for total length and weight, and then dried in a forced ventilation oven at 65 °C for 72 hours and weighed to obtain the weight index per length unit of the emerging leaf blade (α1), of the expanded leaf blade (α2) and of stems (β).

Forage production (FPR) and accumulation (FAR) rates were estimated during the growth period, from the elongation (LER), and senescence (LSR) rates of leaf blade, and the stem elongation rate (SER) and tiller population density (TPD), according to the equation described in Davies *et al*. (1993):

$FPR=\{[(LER \times \alpha 1) + (LSR \times \alpha 2)] + (SER \times \beta)\} \times TPD$;

$FAR= [(LER \times \alpha 1) + (SER \times \beta)] \times TPD$;

Where:

FPR = forage production rate (kgDM$ha^{-1}day^{-1}$); *FAR* = forage accumulation rate (kg DM$ha^{-1}day^{-1}$); *LER* = leaf elongation rate (cm tiller day^{-1}); *α1* = gravimetric index of emerging leaf blades (gcm^{-1}); *TLSR* = total leaf senescence rate (cm tiller day^{-1}); *α2* = gravimetric index of emerging adult leaf (gcm^{-1}); *SER* = stem elongation rate (cmtillerday^{-1}); β = gravimetric index of stem (g cm^{-1}) and *TPD* = tiller population density (tillerha^{-1}).

Data were analyzed by analysis of variance (F-test), means comparison test and regression analysis, in which the interaction between fertilizer levels × cycle was broken down only when significant at 0.05 probability. To compare the effect of cycles, the Tukey’s test was applied at 0.05 probability. In the regression analysis, selection of the models was based on the significance of linear and quadratic coefficients using the Student’s t-test, at 0.05 probability level.

Subsequently, a contrast analysis compared the additional treatment (mineral fertilizer) and treatments with organic fertilizer. Statistical analyses were performed using SISVAR software (FERREIRA, 2011).

RESULTS AND DISCUSSION

Considering the analysis of variance, except for leaf appearance rate (LAR), there was a significant effect for the linear model for the other variables (Table 3). Regarding the effect of cycles, there were significant results for all variables, with higher values for cycle 1.

This was due to the greater availability of nutrients resulting from the application of the organic compost, made only once at the beginning of the experiment, promoting plant growth, also justified by the low C:N ratio of the material that promoted higher mineralization than immobilization. According to Prado *et al.* (2016), how much lower the C:N ratio, the higher rate of decomposition, mineralization and the availability of nitrogen to plants, which favors the morphogenic indexes.

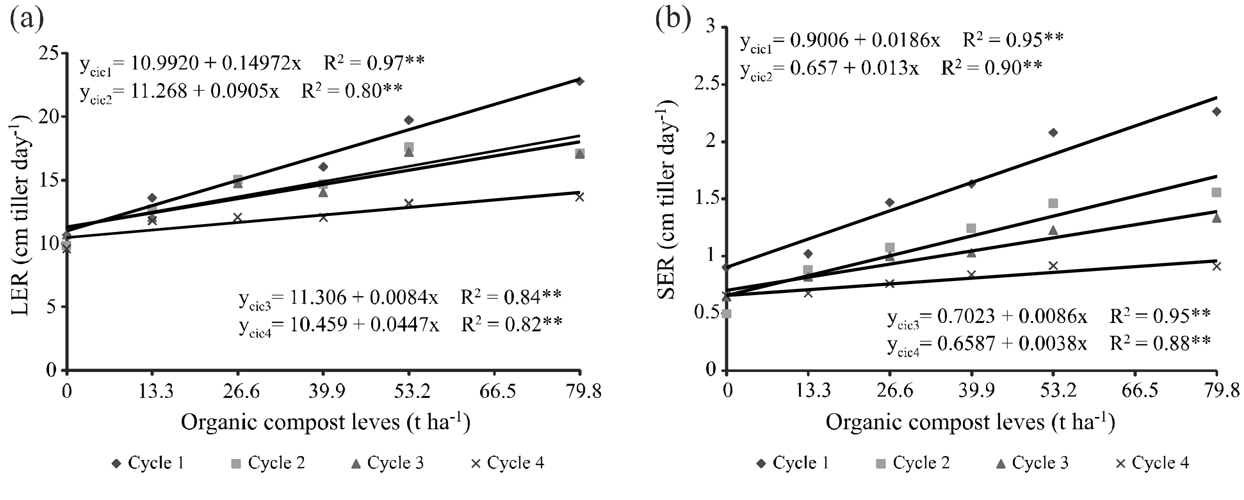
Figure 1 illustrates the interaction (levels x cycles) breakdown for leaf (LER) (Figure 1a) and stem (SER) (Figure 1b) elongation rates, indicating a significant effect for all growth cycles. In both variables, there was an increasing linear effect of the organic compost application levels on LER and SER of elephant grass in cycles 1; 2; 3 and 4. LER presented estimated values of 10.9 and 22.9 cm $tiller^{-1}day^{-1}$ in cycle 1, while in cycle 4, values were 5.18 and 15.5 cm $tiller^{-1}day^{-1}$ related to level 0 and 79.8 t ha^{-1} of organic compost, respectively. The decreasing response of LER and SER over the cycles may be due to reduced availability of nutrients in the successive growth cycles, since the compost was applied only once at the beginning of the experiment, with no supplementation with mineral fertilizers, that is, the only source was the organic compost.

Table 3 - Analysis of variance and effects of interactions between levels of the organic compost made from waste from production and slaughter from small ruminants and the cycles on morphogenetic variables of elephant grass

Levels tha^{-1}	LER	SER	LSR	LAR Leaf tiller day^{-1}	FPR	FAR
	----------------- cm tiller day^{-1}		-----------------		---------- kg DM ha^{-1}	----------
0	10.17	0.67	3.13	0.16	107.65	74.40
13.3	12.53	0.85	3.80	0.16	140.55	117.67
26.6	14.21	1.08	4.15	0.18	202.66	174.21
39.9	14.18	1.19	4.10	0.17	245.16	208.90
53.2	16.91	1.42	5.24	0.18	254.14	211.51
79.8	17.65	1.52	5.55	0.18	311.67	272.59
F significance	**	**	**	ns	**	**
CV_1(%)	17.9	15.5	19.9	10.5	22.6	25.2
Cycles						
	16.30[a]	1.56[a]	5.26[a]	0.15[a]	261.03[a]	215.51[a]
2	14.47[b]	1.12[b]	4.69[ab]	0.18[b]	220.92[b]	181.39[b]
3	14.28[b]	1.00[b]	4.16[b]	0.18[b]	187.88[c]	158.43[bc]
4	12.04[c]	0.79c	3.1c	0.18_b	171.39[c]	150.86[c]
F significance	25.35**	84.09**	30.24**	21.05**	24.06**	15.59**
CV_2(%)	11.9	15.4	18.4	8.2	18.8	20.4
LSD	1.29	0.13	0.60	0.01	30.26	27.58
L x C	**	**	**	ns	**	**

LER - leaf elongation rate; SER - stem elongation rate; LSR - leaf senescence rate; LAR - leaf appearance rate; FPR - forage production rate; FAR - forage accumulation rate, CV_1: coefficient of variation of the plot. CV_2: coefficient of variation of the subplot. Y_{LER} = 11.01 + 0.0922x. R^2 = 0.91; Y_{SER} = 0.729 + 0.011x. R^2 = 0.94; Y_{LAR} = 0.729 + 0.011x. R^2 = 0.94; Y_{FPR} = 118.53 + 2.587x. R^2 = 0.95; Y_{AFR}= 90.88+2.416x. R^2 = 0.94. LSD - least significant difference; (L X C)- Levels x Cycles. Means followed by different letters are significantly different (P<0.05) by Tukey's test[ns] (non-significant) and significant at 0.01 (**) and 0.05 (*). Source: Research

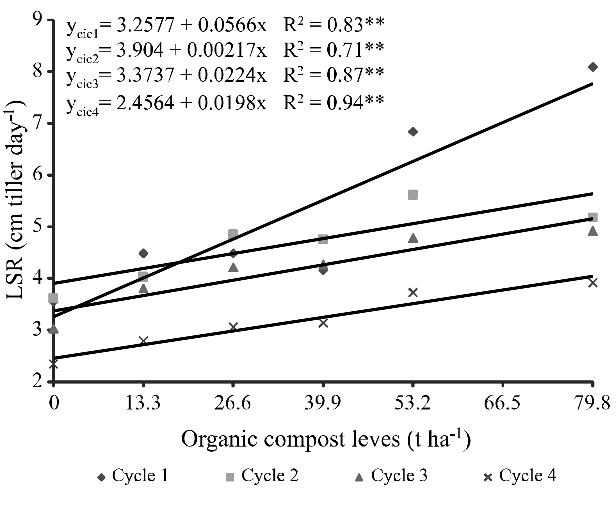
Figure 1 - Effect of interactions between levels of organic compost made from waste from production and slaughter of small ruminants and the cycles on the leaf elongation rate (a) and stem elongation rate (b) of elephant grass, where y = estimated values from the regression equation of each variable analyzed; significant at 1% (**) probabiliy. Source: Research data



Although it is known that the release of nutrients from high quality organic composts is slow and gradual (MORAES *et al.*, 2014; THEUNISSEN; NDAKIDEMI; LAUBSCHER, 2010), it is possible that the weather conditions (high temperatures and humidity), combined with irrigation, have accelerated the release of nutrients into the soil solution in the first growth cycles of elephant grass with the application of organic compost, which raised mineralization rates (low C: N ratio) in the soil, leading to increased productivity of grass. According to Silva *et al.* (2014), the availability of nutrients in the soil solution is complex, dynamic and influenced by the quality of the waste (contents and ratios between C, N, P, S, lignin, cellulose and polyphenols), the activity of biota and the soil and climate conditions (pH, texture, moisture, temperature and soil aeration). Noteworthy, Souza *et al*. (2012) analyzed the same organic compost, under controlled conditions, and reported increases in chemical properties in an Oxisol, and confirmed the effect of the compost on morphogenetic characteristics of elephant grass, especially in the first growth cycles. Primo *et al*. (2014) worked with the same organic compost, but like substrate and observed better quality in production seedlings of *Leucaena leucocephala*.

The leaf senescence rate (LSR) showed a positive linear effect of levels of organic compost made from waste derived from production and slaughter of small ruminants in all growth cycles (Figure 2), with decreases of 32.6 and 92.6% when comparing cycle 1 to cycle 4 in the levels 0 and 79.8 t ha^{-1}compost, respectively. The growth of plant that responds to organic compost levels with high leaf and stem elongation rates promotes senescence of leaves formed first, once it increases respiratory carbon losses by the increased mutual shading (KEECH *et al*., 2007; LOPES *et al.*, 2016). Although the increase of the organic compost in the soil accelerates the metabolism of the plant, in order to promote the growth of tissues, which increases the losses due to senescence, there may be a reduction by the early harvest time, with consequent production of better quality forage (POMPEU *et al*., 2010).

Figure 2 - Effect of interactions between levels of organic compost made from waste from production and slaughter of small ruminants and the cycles on the leaf senescence rate of elephant grass, where y = estimated values from the regression equation of each variable analyzed; significant at 1% (**) probability. Source: Research data



The forage production rate (FPR) exhibited an increasing linear effect with raising levels of organic fertilizer in all cycles (Figure 3a). The observed values for cycle 1 were estimated at 167.4 and 378.52 kg DM ha^{-1} day^{-1}, while, for cycle 4, values were 89.26 and 274.04 kg DM kg DM ha^{-1} day^{-1} referring to levels 0 and 79.8 t ha^{-1} organic compost. In turn, the forage accumulation rate (FAR) responded quadratically to compost levels in cycles 1 and 2, with a maximum point of 305.07 and 252.90 kg DM ha^{-1} day^{-1}, respectively, for levels of 67.84 and 73.42 t ha^{-1} of the organic compost (Figure 3b), representing an average application of 70.63 t ha^{-1} of the organic compost. This demonstrates a positive effect of the input up to such levels with increased losses by senescence since then, due to the high availability of nutrients, mainly N, from high organic N mineralization rates. According to Fagundes *et al*. (2006), the plant growth rate, responding to nitrogen levels, with high leaf and stem elongation rates, favors the senescence of leaves formed first, since it increases competition for assimilates.

In studies considering the use of organic compost from animal waste, Costa *et al.* (2009) and Orrico Júnior, Orrico and Lucas Júnior (2010) reported low values of C: N ratio, indicating that part of the nitrogen will be readily available for uptake by plants or even for possible losses, such as by leaching or volatilization during this period. Considering the proximity of levels to the points of highest FAR for cycles 1 and 2, these results confirm the hypothesis that there has been excess of nutrients, especially N, causing acceleration in plant metabolism, with consequent leaf loss by senescence (LOPES *et al*., 2013).

Moreover, in cycles 3 and 4, there was an increasing linear response according to increasing levels of the organic compost, probably due to a possible decrease in the organic fertilizer mineralization, i.e., disregarding the first two cycles, which may have been benefited from a more intense mineralization, in the last two evaluations, there was a gradual release of nutrients.

Figure 3 - Effect of interactions between levels of organic compost made from waste from production and slaughter of small ruminants and the cycles on the forage production rate (a) and the forage accumulation rate (b) of elephant grass, where y = estimated values from the regression equation of each variable analyzed; significant at 1% (**) probability. Source: Research data

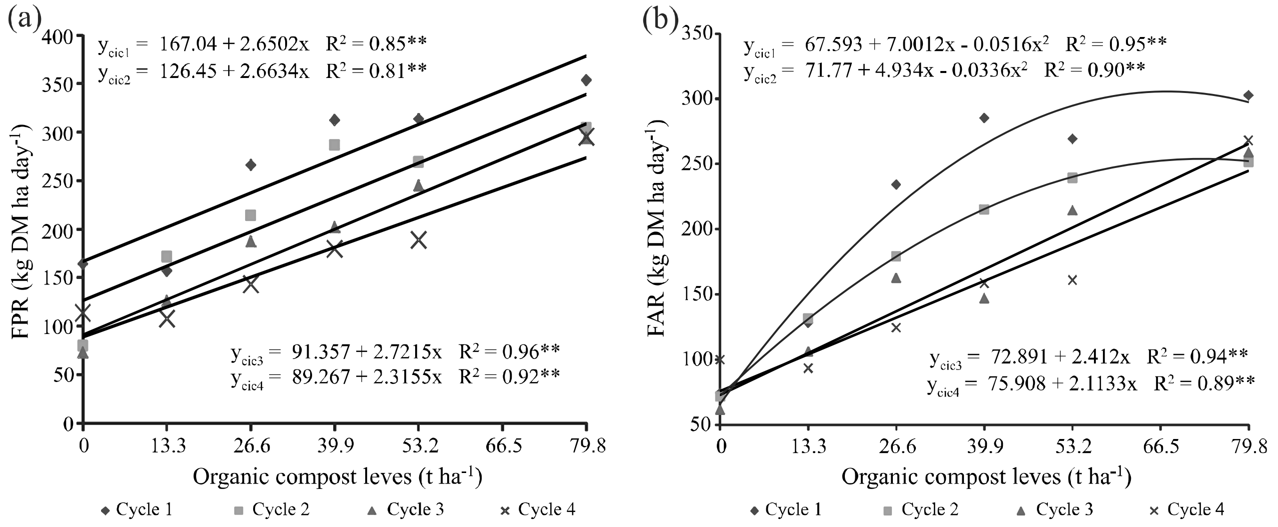


Table 4 - Contrast between the levels of the organic compost and nitrogen fertilization

Treatment	LER	SER	TLSR	LAR Day leaf^{-1}	FPR	FAR	TPD
	--------- cmtillerday^{-1} ----------				-- kg DMhaday^{-1} --		tillerm²
Cycle 1							
Means of the compost levels	16.30	1.56	5.26	0.15	261.03	215.51	56.75
Mean fertilizer mineral	17.01	1.39	5.93	0.15	278.93	232.39	65.50
F significance	ns	ns	ns	ns	ns	ns	ns
Cycle 2							
Means of the compost levels	14.47	1.12	4.69	0.18	220.91	181.38	78.41
Mean fertilizer mineral	17.17	1.50	5.88	0.17	342.19	274.12	92.00
F significance	**	**	**	ns	**	**	*
Cycle 3							
Means of the compost levels	14.28	1.00	4.16	0.18	187.87	158.43	54.83
Mean fertilizer mineral	17.37	1.48	5.52	0.17	404.22	319.22	84.00
F significance	*	**	**	ns	**	**	**
Cycle 4							
Means of the compost levels	12.04	0.79	3.16	0.17	171.39	150.86	59.41
Mean fertilizer mineral	18.79	1.44	4.20	0.20	323.28	291.23	52.00
F significance	**	**	**	*	**	**	ns

LER - leaf elongation rate; SER - stem elongation rate; TLSR - total leaf senescence rate; LAR - leaf appearance rate; FPR - forage production rate; FAR - forage accumulation rate; TPD - tiller population density. Means followed by different letters in the same column are significantly different (P<0.05), by Tukey test; ns (non-significant) and significant at 0.01 (**) and 0.05 (*). Source: Research data

Our findings highlight the need for supplementation with mineral fertilizer or split the fertilization with organic compost to maintain production at high levels, similar to those obtained in the first growth cycle, considering the high mineralization rates of the organic compost. Nevertheless, further studies of economic feasibility are crucial to clarify such issues.

When comparing the effect of mineral fertilizer x fertilization with organic compost made from waste derived from production and slaughter of small ruminants through the contrast analysis in cycle 1, there were no significant ($P>0.05$) responses for any variable analyzed (Table 4), which reinforces the hypothesis of high mineralization of nitrogen from the organic compost, due to the low C: N ratio, increasing forage production rates in this growth cycle. Meanwhile, in cycles 2, 3 and 4, it was observed better values ($P<0.05$) for morphogenetic indices of elephant grass subjected to mineral fertilization, which demonstrates the need for supplemental nutrients. Organic fertilizers are not balanced sources of nutrients, requiring supplementation with mineral fertilizers.

In work with the same compost, but studing the effect in corn yield it was observed that the fertilization with organic compost of waste of animal residue elevated the productivity in second year with application (SOUZA *et al*., 2016). As mentioned by Souza *et al*. (2014) in a study on the use of a byproduct of guava processing, the positive effects of applying organic material were found first in the soil, followed by the leaves, and then appeared in crop yield. Yet, organic compost derived from waste from the breeding and slaughter of small ruminants in rate of 24 Mg ha^{-1} increased the levels of phosphorus, potassium, sodium, and zinc in the surface layer (0.00-0.20 m) of a Haplic Luvisol in relation of mineral fertilization in 616, 21, 114 and 90 % in second crop (SOUZA *et al*., 2016). With this information, in irrigated systems of forage production the organic compost must be applied with mineral fertilizations, in function of physiologic information's showed in Table 4.

CONCLUSIONS

1. Morphogenetic variables of elephant grass responded to the input of organic compost. Accordingly, it is recommended that the dose of 70.63 ton ha^{-1} of organic compound;
2. The application should be split, in view of the reduction in forage production with successive cycles when applied at once.

REFERENCES

ABREU, M. F.; ANDRADE, J. C.; FALCÃO, A. **Análises químicas de resíduos sólidos para monitoramento e estudos agroambientais**. *In*: ANDRADE, J. C.; ABREU, M. F. (Ed.). Campinas: Instituto Agronômico, 2006. p. 121-158.

ALVAREZ V., V. H. *et al*. Interpretação dos resultados das análises de solos. *In*: RIBEIRO, A. C.; GUIMARAES, P. T. G.; ALVAREZ V, V. H. (Ed.). **Recomendação para o uso de corretivos e fertilizantes em Minas Gerais**: 5ª aproximação. Viçosa, MG: Comissão de Fertilidade do Solo do Estado de Minas Gerais, 1999. p. 25-32.

ANDRADE, I. F.; GOMIDE, J. A. Curva de crescimento e valor nutritivo do capim-elefante (*Pennisetum purpureum*, Schum.) Taiwan A-146. **Revista Ceres**, v. 18, n. 100, p. 431-47, 1971.

ANUALPEC 2014: anuário da pecuária brasileira. São Paulo: FNP, 2014. 318 p.

BELLAVER, C.; KONZEN, E. A. Avicultura industrial: avanços tecnológicos na compostagem de resíduos orgânicos. **Revista Avicultura Brasileira**, v. 1188, n. 4, 2010.

BRAIDAII, J. M. A. J. A.; CASSOLI, L. C. Produção de matéria seca de forragem e acúmulo de nutrientes em pastagem anual de inverno tratada com esterco líquido de suínos. **Ciência Rural**, v. 39, n. 8, p. 2408-2416, 2009.

BRASIL. **Ministério do Meio Ambiente Conselho Nacional do Meio Ambiente**. Resolução Conama nº 375, de 29 de agosto de 2006. Disponível em: <http://www.mma.gov.br/port/conama/legiabre .cfm?codlegi=489>. Acesso em: 02 jun. 2015.

CABRAL, J. R. *et al*. Impacto da água residuária de suinocultura no solo e na produção de capim-elefante. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 15, n. 8, p. 823-831, 2011.

COSTA, M. S. S. *et al*. Compostagem de resíduos sólidos de frigorífico. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 13, n. 1, p. 100-107, 2009.

DAVIES, A. Tissue turnover in the swards. *In*: DAVIES, A. *et al*. (Ed.). **Swards measurement handbook**. 2. ed. Reading: British Grassland Society, 1993. p. 183-216.

EMERECIANO NETO, J. V. *et al*. Produção e estrutura dos pastos de capim-massai adubado com dejetos da produção animal. **Boletim da Indústria Animal**, v. 73, n. 2, p. 111-117, 2016.

FAGUNDES, J. L. *et al*. Características morfogênicas e estruturais do capim-braquiária em pastagem adubada com nitrogênio avaliadas nas quatro estações do ano. **Revista Brasileira de Zootecnia**, v. 35, n. 1, p. 21-29, 2006.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. **Ciência e Agrotecnologia**, v. 35, p. 1039-1042, 2011.

FONSECA, D. M. *et al*. (Ed.). **Capim-elefante**: fundamentos e perspectivas. Recife: IPA: UFRPE, 2010. 144 p.

GEWEHR, C. E. *et al*. Rendimento do capim-elefante com adubação orgânica para uso em cama de aviário. **Revista Brasileira de Agroecologia**, v. 5, n. 1, p. 32-36, 2010.

INSTITUTO NACIONAL DE METEOROLOGIA. Disponível em: <http://www.inmet.gov.br/portal/index.php?r= estacoes/estacoesautomaticas>. Acesso em: 20 dez. 2014.

KEECH, O. *et al*. The different fates of mitochondria and chloroplasts during dark-induced senescence in Arabidopsis leaves. **Plant, Cell & Environment**, v. 30, n. 12, p. 1523–1534, 2007.

LOPES, M. N. *et al*. Fluxo de biomassa em capim-massai durante o estabelecimento e rebrotação com e sem adubação nitrogenada. **Revista Ceres**, v. 60, n. 3, p. 363-371, 2013.

LOPES, M. N. *et al*. Tillering dynamics in massai grass fertilized with nitrogen and grazed by sheep. **Bioscience Journal**, v. 32, n. 2, p. 446-454, 2016.

MORAES, M. T. e*t al*. Changes in a rhodic hapludox under no-tillage and urban waste compost in the northwest of Rio Grande do Sul, Brazil. **Revista Brasileira de Ciência do Solo**, v. 38, n. 1, p. 1327-1336, 2014.

ORRICO JÚNIOR, M. A. P; ORRICO, A. C. A; LUCAS JÚNIOR, J. de. Compostagem dos resíduos da produção avícola: cama de frangos e carcaças de aves. **Engenharia Agrícola**, v. 30, n. 3, p. 538-545, 2010.

PARENTE, H. N. *et al*. Crescimento e valor nutritivo do capim-elefante submetido à adubação orgânica e mineral. **Revista Brasileira de Agropecuária Sustentável**, v. 2, n. 2, 2012.

POMPEU, R. C. F. F. *et al*. Características morfofisiológicas do capim-aruana sob diferentes doses de nitrogênio. **Revista Brasileira de Saúde e Produção Animal**, v. 11, n. 4, p. 1187-1210, 2010.

PRADO, M. R. V. *et al*. Carbono orgânico e nitrogênio total nas frações densimétrico da matéria orgânica sob gestão do solo diferente. **Revista Caatinga**, v. 29, n. 2, p. 263–273, 2016.

PRIMO, A. A. *et al*. Produção e acúmulo de nutrientes de mudas de gliricídia adubadas com composto orgânico proveniente de resíduos da produção e abate de pequenos ruminantes. **Revista Científica de Produção Animal**, v. 16, n. 2, p. 144-153, 2014.

SILVA, V. B. *et al*. Decomposição e liberação de N, P e K de esterco bovino e de cama de frango isolados ou misturados. **Revista Brasileira de Ciência do Solo**, v. 38, n. 1, p. 1537-1546, 2014.

SOUZA, H. A. *et al*. **Atributos químicos do solo tratado com composto orgânico de carcaça e despojo de abate de caprinos e ovinos**. Sobral: Embrapa Caprinos e Ovinos, 2012. 8 p. (Comunicado Técnico, 127). Disponível em: <http://ainfo.cnptia.embrapa.br/digital/bitstream/item/67216/1/COT-127.pdf>. Acesso em:4 de jan. 2014.

SOUZA, H. A. *et al*. Use of organic compost containing waste from small ruminants in corn production. **Revista Brasileira de Ciência do Solo**, v. 40, p. 1-16, 2016.

SOUZA, H. A. *et al*. Uso fertilizante do subproduto da agroindústria processadora de goiabas II: estado nutricional e produção de goiabas. **Revista Brasileira de Fruticultura**, v. 36, n. 3, p. 725-730, 2014.

THEUNISSEN, J.; NDAKIDEMI, P. A.; LAUBSCHER, C. P. Potential of vermicompost produced from plant waste on the growth and nutrient status in vegetable production. **International Journal of the Physical Sciences**, v. 5, n. 13, p. 1964-1973, 2010.