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Pig slurry in carpet grass pasture: Yield and plant-available nitrogen

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Key words:
Axonopus affinis
agronomic nitrogen efficiency
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manure
perennial pasture

ABSTRACT
This study evaluated the response of carpet grass to pig slurry fertilization in order to estimate the agronomic efficiency and the plant-available nitrogen (N) of such manure. A field test was conducted during two years, following a randomized block design with six replicates of the treatments: 0, 100, 200, 300, 400 and 500 kg N ha^{-1} year^{-1}, which resulted in 0, 60, 120, 180, 240 and 300 m^3 ha^{-1} (2008/09), and 0, 42, 84, 126, 168 and 210 m^3 ha^{-1} (2009/10), according to the N content of the pig slurry used in each year. These treatments were compared with ammonium nitrate (200 kg N ha^{-1} year^{-1}), in order to estimate the plant-available nitrogen of the manure for the pasture. Pig slurry doses increased linearly the dry matter yield. In 2008/2009, it was increased from 2,600 (0 kg N ha^{-1}) to 7,718 kg ha^{-1} (500 kg N ha^{-1}), while in 2009-2010 it ranged from 4,310 (0 kg N ha^{-1}) to 12,321 kg ha^{-1} (500 kg N ha^{-1}). The average agronomic efficiency of the manurewas 15 kg DM kg^{-1} N and it was lower than that found with ammonium nitrate (27 kg DM kg^{-1} N).The estimated plant-available N of the pig slurry was similar between the growing years. The N fraction of this manure available to the pasture was 0.64 (2008-09) and 0.60 (2009-10).

Palavras-chave:
Axonopus affinis
eficiência agronômica do nitrogênio
índice de eficiência do nitrogênio
esterco
pastagem perene

Dejeto líquido de suínos em pastagem de grama-tapete: Produção e nitrogênio disponibilizado

RESUMO
Este estudo avaliou a resposta da grama-tapete à aplicação de dejeto líquido de suíno para determinar a eficiência agronômica e estimar a disponibilidade de nitrogênio desse esterco. O experimento foi realizado em condições de campo durante dois anos, em delineamento em blocos ao acaso, com seis repetições dos seguintes tratamentos: 0, 100, 200, 300, 400 e 500 kg N ha^{-1} ano^{-1}, o que resultou em 0, 60, 120, 180, 240 e 300 m^3 ha^{-1} ano^{-1} (2008/2009) e em 0, 42, 84, 126, 168 e 210 m^3 ha^{-1} ano^{-1} (2009-2010), de acordo com o conteúdo de nitrogênio do dejeto utilizado em cada ano. Esses tratamentos foram comparados com o nitrato de amônio (200 kg N ha^{-1} ano^{-1}). A produção de matéria seca em resposta às doses do dejeto líquido de suíno foi linear. Em 2008/2009 a matéria seca variou de 2.600 (0 kg N ha^{-1}) a 7.718 kg ha^{-1} (500 kg N ha^{-1}), e em 2009-2010, oscilou entre 4.310 (0 kg N ha^{-1}) e 12.321 kg ha^{-1} (500 kg N ha^{-1}). A eficiência agronômica média do dejeto foi de 15 kg MS kg^{-1} N e inferior à obtida com o nitrato de amônio (27 kg MS kg^{-1} N). A quantidade de N disponível do dejeto variou pouco entre os anos. A fração de N disponibilizada desse esterco para a pastagem foi de 0,64 (2008-09) e de 0,60 (2009-10).

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Introduction

Nitrogen (N) is the primary nutrient on which pig slurry (PS) application doses have been based, since this kind of manure typically contains the majority (70 to 80%) of the total N as ammonium, which is an available form of N for plants. To estimate the crop recovery of soil-applied manure N, its agronomic efficiency can be measured. Such efficiency represents the ability of the plant to increase yield in response to N applied (Fageria et al., 2007). Because forage nutrient concentration tends to fluctuate little, the nutrient removal is primarily a function of dry matter yield (DMY), which is influenced more by species.

In addition to ammonium present in the manure, organic N will slowly mineralize over time to supply plant-available N. Depending on the manure, methods used for field application, soil and weather, among other factors, most of the organic N will mineralize in the first year after application, decreasing in subsequent years. In this way, 80% of the total N of PS (an availability factor of 0.80) is estimated as plant-available N in South Brazil, in the first years after application(CQFS-RS/SC, 2004). On the other hand, this guideline was obtained from a restricted number of studies (Eckhardt et al., 2016), and all related to annual crops. There are also recommendations on perennial pasture.

In Brazilian subtropics, the natural grasslands still represent the base for cattle farming. In these lands, 40% of the vegetation cover is composed of bahiagrass (*Paspalum notatum*) and carpet grass (*Axonopus affinis*) (Machado Júnior et al., 1999). This grass also has been tested for response to heavy metals, as promising bioremediation alternative in contaminated soils, mainly in regions of copper and gold with great importance for the development of rehabilitation of clean technologies in areas degraded by mining (phytoremediation) (Cardón et al., 2010).

The objectives of this research were to evaluate the dry matter yield of a perennial carpet grass pasture under PS fertilization, aiming to determine the N agronomic efficiency and to estimate the N plant availability of this kind of manure.

Material and Methods

The experiment was carried out for two years (2008-2010) in a perennial pasture of carpet grass, at Epagri Station, in Chapecó, Santa Catarina, Brazil, at 679 m of altitude, 27° 7' S and 52° 37' W. The temperatures and rainfall occurring during the experimental period are shown in Figure 1. Before the experiment, the analysis of the 0-5 cm soil layer (Oxisol) showed: clay: 62.3 g dm^{-3}, sand: 11.7 g dm^{-3}, silt: 25.8 g dm^{-3}; pH_{H2O}: 5.7, extractable P: 12 mg dm^{-3}, extractable K: 196 mg dm^{-3}, organic matter: 58 g dm^{-3}, exchangeable Al: 0.1 $cmol_c$ dm^{-3}, exchangeable Ca: 7.7 $cmol_c$ dm^{-3}, exchangeable Mg: 4.1 $cmol_c$ dm^{-3}, $CEC_{pH\,7.0}$: 18.3 $cmol_c$ dm^{-3}, base saturation: 67.7%, Al saturation in effective CEC: 0.75%.

Pig slurry source was a stabilization pond located near the experimental field. Manure total nutrient (N, P, K, Ca, Mg, Cu, Zn and Mn) and dry matter (DM) contents, and the value of pH were determined according to Tedesco et al. (1995) (Table 1). The PS doses were calculated to provide 0, 100, 200, 300, 400 and 500 kg N ha^{-1} $year^{-1}$, which resulted in 0, 60, 120, 180, 240 and 300 m^3 ha^{-1} (2008/2009), and 0, 42, 84, 126, 168 and 210 m^3 ha^{-1} (2009/2010). Since the total N and DM contents of the PS changed according to the cutting and the years of the experiment (Table 1), the PS doses were different between years, in order to test the same N dose in the 2008/2009 and 2009/2010 growing periods. The treatments were compared with the 625 kg ha^{-1} $year^{-1}$ of ammonium nitrate (AN), to provide 200 kg N ha^{-1} $year^{-1}$, in order to estimate the plant-available N of the manure. It was based on 200 kg N ha^{-1} $year^{-1}$ because this is the dose recommended for field test according to the South Brazil research guidelines for warm-season grasses (CQFS-RS/SC, 2004).

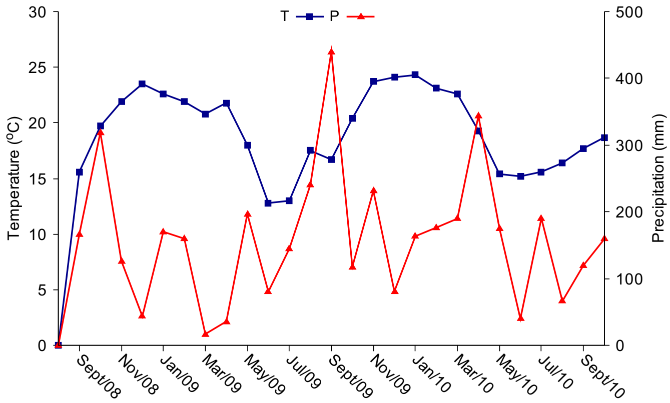


Figure 1. Monthly precipitation (P) and mean air temperature (T) during the experimental period (2008-2010)

A randomized block design with six replicates was used. The experimental units consisted of 6 x 5 m plots. The PS and AN doses were fractionated into four parts and top-dressed soon after the pasture cuttings. Since the PS contained phosphorus and potassium and the PS doses were high, 220 kg ha^{-1} $year^{-1}$ of triple superphosphate (= 90.2 kg P_2O_5) and 155 kg ha^{-1} of potassium chloride (= 93 kg K_2O) were applied in the control and AN treatments, in both years. The soil analysis indicated P, K, Ca, Mg, S and micronutrient contents above the recommended critical levels, i.e., high nutrient availability (CQFS-RS/SC, 2004). Under such conditions, no response to application of these nutrients is expected, which makes it possible to test the effect of the N applied with PS and AN.

A standardization cutting was performed in September 2008, when the pasture received the first PS application, corresponding to ¼ of the total annual N applied. The three remaining fractions were applied immediately after the cuttings made in the spring-summer of both years. All DMY estimations were obtained by cutting the pasture with a power mower set at a height of about 8 cm. The clipping was removed from the plots with the help of rakes. The pasture was cut when the plots treated with AN reached an average height of 20 cm.In the first year, the cuttings occurred at December 1, 2008, and February 5, March 18, August 14 and October 19, 2009. In the following year, the cuttings occurred at December 7, 2009, and January 28, March 8, May 3, August 12 and October 20, 2010. After the material collected in each plot was weighed, a sample was taken for DMY determination. The N agronomic efficiency (NAE) was calculated according to Fageria et al. (2007) by using Eq. 1, and represents the yield per unit of available N in the soil.

Table 1. Physical and chemical characteristics of the pig slurry applied in the experimental period (2008-2010)

Application	pH	DM (%)	P	K	Ca	Mg	Cu	Zn	Mn	Total N	Mineral N
			kg m^{-3}								
1st/spring Sept/08	7.1	1.1	0.4	0.9	0.8	1.0	5.0	13.7	8.1	2.2	1.3
2nd/spring Dec/08	7.5	1.2	0.3	0.3	0.4	0.5	16.0	30.2	10.9	1.3	1.2
3rd/summer Feb/09	7.3	0.7	0.4	0.7	0.2	0.2	4.8	8.0	8.1	1.6	1.2
4th/summer Mar/09	7.3	1.3	0.3	0.8	0.5	0.2	15.3	19.7	6.7	1.9	1.1
Average 2008/09	7.3	1.1	0.4	0.7	0.5	0.5	10.3	17.9	8.4	1.7	1.2
1st/spring Oct/09	6.9	3.3	1.0	0.8	0.7	0.4	33.5	49.5	22.1	2.9	1.5
2nd/spring Dec/09	7.7	1.4	0.8	0.6	0.8	0.4	55.8	31.2	13.7	2.3	1.3
3rd/summer Jan/10	7.6	1.5	0.5	0.5	0.5	0.2	21.4	30.0	12.2	1.8	1.3
4rd/summer Mar/10	7.3	2.9	0.8	0.7	0.7	0.5	28.6	40.8	19.2	2.9	1.3
Average 2009/10	7.4	2.3	0.8	0.6	0.7	0.4	34.8	37.9	16.8	2.5	1.4

$$NAE = \frac{DMY_{PS\ or\ AN\ rate} - DMY_{control}}{N} \quad (1)$$

where:

$DMY_{PS\ or\ AN\ dose}$ - DMY obtained with PS or AN;
$DMY_{control}$ - DMY obtained without N application; and,
N - quantity of N applied with PS or AN.

The efficiency index (EI) of PS in supply N to the pasture was calculated according the Eq. 2 (Scherer et al., 1995).

$$EI = \frac{DMY_{PS200} - DMY_{control}}{DMY_{AN200} - DMY_{control}} \quad (2)$$

where:

DMY_{PS200}- DMY obtained with PS application calculated to provide 200 kg N ha^{-1};

$DMY_{control}$ -DMY obtained in absence of N fertilization (PS or AN); and,

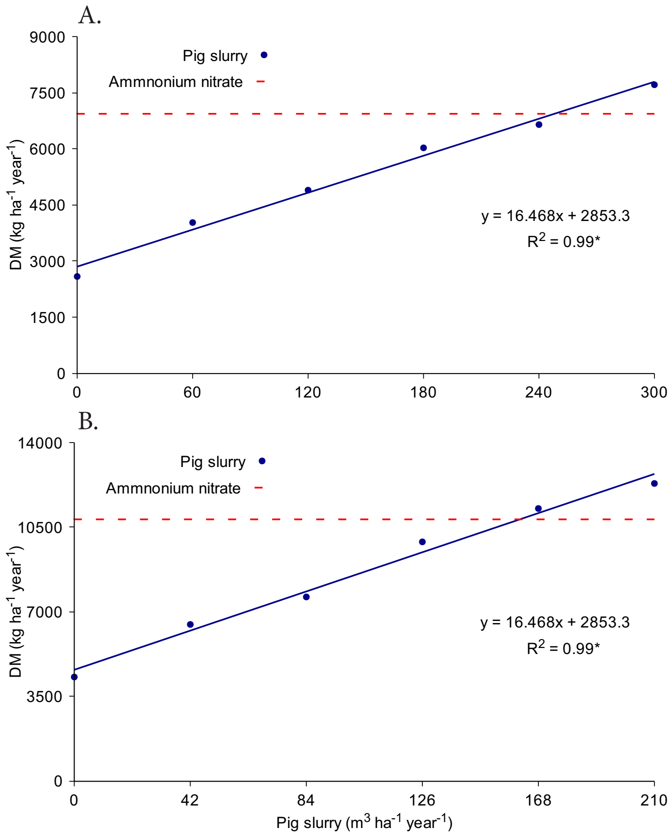
DMY_{AN200} - DMY obtained with AN application calculated to provide 200 kg N ha^{-1}.

Data were submitted to analysis of variance, and the F test significance was verified considering the N treatments as plots and the years as subplots. When significance was found, means were compared by Tukey test ($p < 0.05$) and the effect of PS doses was evaluated through regression analysis. The regression results of the DMY as a function of PS doses and AN were illustrated according to Ragagnin et al. (2013).

Results and Discussion

The pasture DMY increased linearly in response to PS rates during the two years (Figure 2). It indicates that the DMY potential of the pasture can surpass that obtained at the highest N dose applied, when this nutrient is applied as PS.

Although the PS rates were different between the years, this factor can be compared since the same N doses were applied in each year (100 to 500 kg N ha^{-1} year^{-1}). The PS doses were different between the years as a consequence of the N content in the manure, which changed in each period of application (Table 1). Positive and linear response to PS has been reported for natural pastures (Scheffer-Basso et al., 2008), Tifton 85 (Vielmo et al., 2011) and giant missionary grass (*A. jesuiticus* x *A. scoparius*) (Miranda et al., 2012). These reports and our results indicate



* $p < 0.05$

Figure 2. Dry matter (DM) yield of carpet grass in response to pig slurry and ammonium nitrate (625 kg ha^{-1} year^{-1}) application in 2008-09 (A) and 2009-10 (B)

that the maximum DMY changed with the pasture and the site where it is growing. In our work, the maximum DMY increase was 197 and 185%, in 2008/2009 and 2009/2010, respectively. In natural pasture, Scheffer-Basso et al. (2008) found 108% increase of DMY by applying 40 m^3 PS ha^{-1}. In giant missionary grass, Miranda et al. (2012) observed 321% increase of DMY in response to application of 275 m^3 PS ha^{-1} year^{-1}.

In the first year (Figure 2A) of this study, there was no difference between the three higher doses of PS and AN, but in the following year, the yield with the highest PS dose exceeded that obtained with AN (Table 2). This shows that the amount of N supplied by the PS doses lower than 80 to 120 m^3 ha^{-1} year^{-1} was not sufficient to increase the DMY, as obtained with AN. This lower efficiency of PS, compared with AN, was reported for other pastures. Barnabé et al. (2007) verified that the DMY of *Brachiaria brizantha* fertilized with

150 m³ PS ha⁻¹ (499 kg N ha⁻¹) did not differ from the DMY obtained with ammonium sulfate (60 kg N ha⁻¹). Miranda et al. (2012), in the same experimental area where the present study was carried out, found that the effect of 165 m³ PS ha⁻¹ year⁻¹, or 300 kg N ha⁻¹ year⁻¹, on the DMY of giant missionary grass, was similar to that obtained with 200 kg N ha⁻¹ year⁻¹ in the form of AN (625 kg ha⁻¹ year⁻¹), indicating the lower efficiency of PS in N supply compared with the AN. In the second year (Figure 2B), the DMY increase was higher (average of 60%). The pasture-growing environment was more favorable for the production potential in this year, mainly the higher available water or rainfall conditions (Figure 1). Besides providing better environmental conditions for higher production at each cut, it allowed one more cutting in relation to the first year. In 2008/2009 and 2009/2010, the angular coefficients of the regression equations fit to the data were 16.46 and 38.58 kg DM m⁻³ PS applied, respectively (Figure 2).

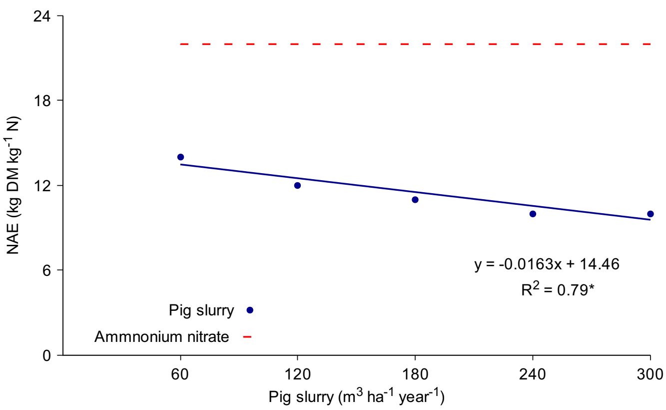
Plant response to N application varies with soil moisture, and higher response for grasses fertilized with N can be expected, since the soil moisture content is adequate (Sun et al., 2008). Miranda et al. (2012) reported 11,371 kg DM ha⁻¹ year⁻¹ and 32 kg DM m⁻³ ha⁻¹ in giant missionary grass fertilized with doses of up to 275 m³ ha⁻¹ year⁻¹, in the average of the two years. In this study, the maximum DMY of 2009-2010 (12,321 kg ha⁻¹ year⁻¹; Table 2) can be assumed as high, since the carpet grass is a native species and was never subjected to any process of breeding.

Nitrogen agronomic efficiency (NAE) did not vary with PS doses, but it was highest ($p < 0.05$) in the second year of the experiment (Figure 3). In addition, they were lower

Table 2. Total dry matter yield (DMY)ofsubtropical pasture dominated by carpet grass in response to nitrogen applied as pig slurry (PS) or ammonium nitrate (AN), in two years

Nitrogen (kg ha⁻¹ year⁻¹)	2008-2009		2009-2010	
	Fertilizer (qty ha⁻¹ year⁻¹)	DMY (kg ha⁻¹ year⁻¹)	Fertilizer (qty ha⁻¹ year⁻¹)	DM (kg ha⁻¹ year⁻¹)
0	0	2,598 dB	0	4,310 dA
100	60 m³ PS	4,034 cB	42 m³ PS	6,477 cA
200	120 m³ PS	4,904 cB	84 m³ PS	7,633 cA
300	180 m³ PS	6,036 bB	126 m³ PS	9,910 bA
400	240 m³ PS	6,651 abB	168 m³ PS	11,273 abA
500	300 m³ PS	7,718 aB	210 m³ PS	12,321 aA
200	625 kg AN	6,927 abB	625 kg AN	10,811 bA

Means followed by lowercase letter in the column and uppercase letter in the row do not differ by Tukey test ($p < 0.05$)



* $p < 0.07$

Figure 3. Nitrogen agronomic efficiency (NAE) of pig slurry and ammonium nitrate (625 kg ha⁻¹ year⁻¹) of carpet grass pasturein 2008-09

($p < 0.05$) than the values obtained with AN. As the N applied to the pasture increased, NAE showed a barely detectable statistically significant trend of decrease in 2008-09, and did not achieve significance in 2009-10 (y=-0.0252x + 21.26, $R^2 = 0.55$).

Although a high amount of total N was applied with the highest PS rate, the trend of the pasture response was linear (Figure 1). Then, the pasture yield loss can not be achieved, regardless of the high input level of N and thus the NAE was similar across the tested rates. Moreover, it indicates that the increased quantity of applied N was recovered by the pasture, reducing the impact of N fertilization, or PS fertilization based on the N content, on environmental quality and ecosystem health. Since the NAE was similar between the PS rates, the optimal N dose must be the one that results in more DMY produced by the pasture (500 kg N ha⁻¹ year⁻¹). Then, it is no more related with the crop production per kg of N applied. The NAE obtained in this study was in the range reported by Vielmo et al. (2011) for Tifton 85 (24 to 9 kg DM kg⁻¹ N after fertilization with 144 and 576 kg N ha⁻¹ year⁻¹, applied with 80 and 320 m³ of pig slurry, respectively). Similar results were reported by Durigon et al. (2002), of 6.6 (autumn) and 20.8 kg DM kg⁻¹ N (spring) for a natural pasture, as well as to those reported by Miranda et al. (2012) for giant missionary grass (19.0 kg DM kg⁻¹ N from pig slurry; 30.3 kg DM kg⁻¹ N from ammonium nitrate). The convergence between our results and those reported by these studies reinforces their consistency.

The fraction of the plant-available N changed from 0.38 to 0.96 according to the cutting, and the average was 0.62 for the two years of evaluation (Table 3).

During the spring (September to December) and summer (December to March), when temperatures favored rapid growth, pasture DMY is related to rainfall and N supply. Low temperatures limit growth during winter and some months of autumn, particularly in the tropics and subtropics. In the same way, when both temperature and water availability favor rapid growth, as occurred in spring and summer (Figure 1), pasture DMY is closely related to N supply. The results are similar to those found for giant missionary grass fertilized with PS (275 m³ ha⁻¹ year⁻¹), between 0.52 (summer) to 0.72 (spring) (Miranda et al., 2012).

These are the first reports of EI for *Axonopus* spp. fertilized with PS, which can contribute to the fertilization guidelines of natural pastures where these species are dominant. The average EI obtained in the present study (0.62) is lower than the EI (0.80) recommended by the fertilization guidelines in South Brazil for PS (CQFS-RS/SC, 2004). The EI of 0.80 was obtained from experiments with non-perennial crops, which may overestimate the value for perennial forage, as indicates the

Table 3. Fraction of the plant-available nitrogen of pig slurry in a carpet grass pasture

Cutting	2008/2009	Cutting	2009/2010
Dec/08	0.59	Dec/09	0.59
Feb/09	0.53	Jan/10	0.38
Mar/09	0.56	Mar/10	0.71
Aug/09	0.77	Mai/10	0.52
Oct/10	0.75	Aug/10	0.43
	-	Oct/10	0.96
Average	0.64	Average	0.60

EI value of 0.95 reported for corn (*Zea mays* L.) (Scherer, 2006). However, higher values of EI were found in some cuttings (Table 3). It is due to the climatic changes along the year, which affect the efficiency of organic fertilizers in nutrient release, as well as the pasture growth. As the pasture is perennial, it has a higher period of nutrient uptake in comparison to annual grain crops and is more affected by the season and weather variations along the year, as also reported by Miranda et al. (2012) for perennial grass.

The results of this study provide new information about the impact of N and/or PS application on the carpet grass, an important native species, as well to subside the use of the manure as alternative N fertilizer on perennial pastures.The values of EI were obtained from a field test, which was conducted during two years. In spite of that, similar values of EI were found in each year (0.60 and 0.64). Moreover, such values are similar to the EI reported by Miranda et al. (2012), working with a hybrid of the same genus (*Axonopus affinis x A. scoparius*).

The yield potential of the carpet grass is underestimated due to limited studies on its response to fertilization. The need to fertilize pasture, in view of the high costs of fertilizers, causes farmers to think about the maximization of existent resources naturally found on rural properties (Zanine & Ferreira, 2015). The results provide new information for selecting N application rates to optimize the forage production, as well to subside the use of the manure as alternative N fertilizer on perennial pastures, since the use of organic manure has advantages like nutrient conservation, slow release, improvement of soil physical conditions and enhanced biological activities (Krishnakumar et al., 2013).

Conclusions

1. Fertilization with pig slurry increases the production of carpet grass pasture. Nitrogen doses of up to 500 kg ha^{-1} $year^{-1}$ applied as pig slurry do not reach the plateau of dry matter yield, allowing quadrupling the daily dose of forage production, without reduction in the agronomic efficiency.

2. Plant-available nitrogen of pig slurry applied in perennial pasture is 62% of the total content of this nutrient in this kind of manure.

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