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Residual effect of pig slurry on common carpet grass pasture

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Key words:
nitrogen uptake
dry matter yield
manure

ABSTRACT

This study investigated the residual effects of pig slurry (PS) applied to common carpet grass pasture (*Axonopus affinis*) for two years (September 2008-March 2010) on dry matter yield and forage-nitrogen uptake from October 2010-May 2011. A field experiment was conducted in a randomized complete block design with four replications. The treatments were 102, 204, 306, 408, and 510 m^3 ha^{-1} pig slurry applied for two years; one mineral nitrogen rate (1,250 kg ha^{-1} ammonium nitrate) for two years; and no nitrogen fertilization (control). The pasture was cut at intervals of 48, 34, 43 and 69 days, which corresponded to 266, 300, 343, and 412 days after the last fertilizer application, respectively. Dry matter yield increased by 398 kg ha^{-1} for each 100 m^3 of PS applied, the equivalent of 317 and 564 kg ha^{-1} for each 100 kg ha^{-1} of inorganic and organic N applied, respectively. The residual effect of PS on dry matter yield and forage-nitrogen uptake ranged from 11-45% and 8-40%, respectively, indicating a gradual release and availability of N in PS, which can help reduce the amounts of nitrogen applied to pasture.

Palavras-chave:
esterco
absorção de nitrogênio
produção de forragem

Efeito residual de dejeto líquido de suínos em pastagem de grama-tapete comum

RESUMO

Verificou-se, neste estudo, o efeito residual de dejeto líquido de suíno aplicado em pastagem de grama-tapete comum (*Axonopus affinis*) durante dois anos (setembro 2008 a março 2010), por meio da avaliação da produção de matéria seca e da absorção do nitrogênio na forragem, no período subsequente (outubro 2010 a maio 2011). Um experimento no campo foi realizado em delineamento de blocos completos casualizados, com quatro repetições. Os tratamentos foram cinco doses de dejeto (102, 204, 306, 408 e 510 m^3 ha^{-1} por dois anos), ausência de adubação nitrogenada (tratamento-controle) e uma dose de nitrogênio mineral (1.250 kg ha^{-1} de nitrato de amônio, por dois anos). A pastagem foi cortada em intervalos de 48, 34, 43 e 69 dias, que corresponderam a 266, 300, 343 e 412 dias após a última aplicação dos fertilizantes, respectivamente. A taxa de produção de matéria seca aumentou em 398 kg ha^{-1} para cada 100 m^3 do dejeto de suínos previamente aplicados, equivalente a 317 e 564 kg ha^{-1} para cada 100 kg ha^{-1} da forma inorgânica ou orgânica de nitrogênio, respectivamente. O efeito residual do dejeto líquido de suínos na produção de matéria seca variou de 11 a 45% e na absorção do nitrogênio da forragem variou de 8 a 40%, indicando liberação gradual ou disponibilidade do N no dejeto, o que contribuiria para a redução das quantidades de nitrogênio a serem aplicadas na pastagem.

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Introduction

Pig slurry (PS) is an organic alternative to chemical nitrogen (N) fertilizers that can increase production of winter and summer crops (Seidel et al., 2010; Moraes et al., 2014; Basso et al., 2016) and of cover crops (Aita et al., 2006). Many studies have found an increase in dry matter yield (DMY) of pastures in response to PS fertilization (Vielmo et al., 2011; Miranda et al., 2012; Zanine & Ferreira, 2015). A significant part of the organic N retained in the soil after PS application is derived from immobilized ammonium-N, which is slowly released over many years (Sorensen & Amato, 2002). These N forms may remain in the soil at the end of the growing season, benefitting subsequent crops, which is known as the residual effect. Thus, the amount of N available in the years following PS application should be determined and considered during fertilization planning (Yagüe & Quílez, 2013).

It has been suggested that manures may only have a benefit on soil productivity, over and above their nutrient content, when large inputs are applied over many years (Edmeades, 2003). In fact, residual PS fertilizer applied to *Brachiaria brizantha* (Hochst ex A. Rich) Stapf. pastures only increased nutrient levels in the leaves and soil starting a year after application (Teixeira et al., 2012).

This study investigated the residual effects, on common carpet grass (*Axonopus affinis* Chase) pastures' dry matter yield and N uptake, of PS application in the year subsequent to two years of slurry applications. Carpet grass is a grazing- and cold-resistant, warm-season grass that is among the most important grasses of natural grasslands in southern Brazil.

Material and Methods

The experiment was conducted at Epagri Station, Chapecó in the state of Santa Catarina, Brazil (27° 7' S, 52° 37' W, 679 m elevation). The climate in the region is humid subtropical (Cfa). The study was performed between December 2010 and May 2011 following two years (2008-2010) of PS fertilization on a common carpet grass pasture.

The treatments consisted of five PS application rates, calculated to provide 100, 200, 300, 400, and 500 kg ha^{-1} year^{-1} N, one ammonium nitrate (AN) application rate equivalent to 200 kg ha^{-1} N, or no nitrogen fertilization (PS0 + AN0) (Brustolin et al., 2016). The soil in the experimental area is an Oxisol, with clay testure in the 0-0.05 m layer. Before each application, PS was analyzed for concentrations N in the inorganic, organic and total fractions, according to Tedesco et al. (1995), in order to calculate the appropriate amount of PS to be applied in each treatment (Table 1).

After two years of PS or AN applications, the soil chemical attributes were analysed (Table 2) according to Tedesco et al. (1995), after which this study started, in October 2010. The experiment was conducted in a randomized complete block design with four replications. The residual PS effect was estimated by quantifying dry matter yield (DMY) and forage-nitrogen uptake (FNU).

The pasture was cut when plants in the plots that received ammonium nitrate reached an average height of ~18 cm, and then at intervals of 48 (December 2010), 34 (January 2011), 43 (February 2011), and 69 (May 2011) days, corresponding to 266, 300, 343, and 412 days after the last application of N fertilizers. The plants were cut from the inner 1 × 5 m (5 m^2) area of each 30 m^2 plot, to an 8-cm stubble height, with a power mower. Samples were taken for dry matter (DM) content

Table 1. Pig slurry (PS) and ammonium nitrate (AN) rates and the equivalent amounts of inorganic, organic, and total nitrogen (N) applied for two years (2008-2010) on common carpet grass pastures

Previous fertilization (qty ha^{-1} 2years^{-1})	Inorganic N	Organic N	Total N
	kg ha^{-1} 2years^{-1}		
1,250 kg AN	400	0	400
102 m^3 PS*	128	72	200
204 m^3 PS	256	144	400
306 m^3 PS	384	216	600
408 m^3 PS	512	288	800
510 m^3 PS	640	360	1000

*Rates based on the nitrogen content of pig slurry (Brustolin et al., 2016) calculated according to methods described by Tedesco et al. (1995)

Table 2. Soil chemical attributes and critical levels (CL) at the beginning of the experiment (October 2010) in plots without nitrogen fertilization (N0) and after two years of pig slurry (PS) and ammonium nitrate (AN) applications on common carpet grass pasture

Soil attribute	Previous fertilization (qty ha^{-1} 2 years^{-1})							CL
	N0	AN (kg ha^{-1})	PS (m^3 ha^{-1})					
		1,250	102	204	306	408	510	
pH H_2O	5.8	5.4	5.6	5.7	5.5	5.5	5.4	5.5
P (mg L^{-1})	21.3	14.9	25.8	15.4	17.2	20.0	21.7	> 9.0
K (mg L^{-1})	240.3	170.3	200.0	186.3	197.0	181.0	153.0	> 90.0
Organic matter (g dm^{-3})	52.0	51.0	56.0	55.0	57.0	52.0	53.0	> 50.0
Al (cmol$_c$ dm^{-3})	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-
Ca (cmol$_c$ dm^{-3})	7.0	6.0	6.1	6.3	6.5	6.8	5.8	> 4.0
Mg (cmol$_c$ dm^{-3})	4.5	3.2	3.8	4.0	4.0	4.3	3.6	> 2.0
H+Al (cmol$_c$ dm^{-3})	5.6	4.6	6.6	6.4	6.9	6.7	7.1	-
CEC (cmol$_c$ dm^{-3})	17.8	14.3	17.2	17.2	18.0	18.3	17.0	-
S (mg L^{-1})	11.0	11.0	11.3	12.6	18.0	17.0	19.3	> 10.0
B (mg L^{-1})	0.3	0.3	0.3	0.3	0.3	0.3	0.3	≥ 0.3
Mn (mg L^{-1})	8.5	11.3	10.2	9.5	12.1	10.8	10.2	> 5.0
Zn (mg L^{-1})	3.4	3.0	4.1	5.2	6.4	7.5	8.2	> 0.5
Cu (mg L^{-1})	2.8	2.0	2.4	2.7	2.9	3.3	3.8	> 0.4

determination, dried at 60 °C for 72 h, then ground. Forage-N content was determined by near-infrared spectroscopy (NIRS), and FNU was calculated by multiplying DMY by forage-N content. After sampling, the entire plots were mowed to the same stubble height, and the plant material was removed from the plot.

The average pasture response in control plots (PS0 + AN0) was estimated from the apparent soil effect (ASE), which was calculated according to methods described by Daudén et al. (2004). The PS apparent residual effect (PSRE) and AN apparent residual effect (ANRE) were calculated for DMY and FNU using Eqs. 1 and 2 (Cela et al., 2011) as follows:

$$\begin{aligned} \text{PSRE} &= \text{DMY or FNU in PSi + N0} - \\ &- \text{pasture response in PS0 + AN0} \end{aligned} \quad (1)$$

$$\begin{aligned} \text{ANRE} &= \text{DMY or FNU in ANj + PS0} - \\ &- \text{pasture response in PS0 + AN0} \end{aligned} \quad (2)$$

where:

i - PS rate;
j - AN rate;
PS0 - no PS application; and,
AN0 - no AN application.

Differences in DMY and in FNU among PS, AN, and control treatments were determined by analysis of variance (ANOVA) followed by the Dunnett's test ($p < 0.05$). Linear regression analysis described the relationship between DMY or FNU and PS rates, computing the F-value to determine the significance of the fitted linear regressions ($p < 0.05$).

Results and Discussion

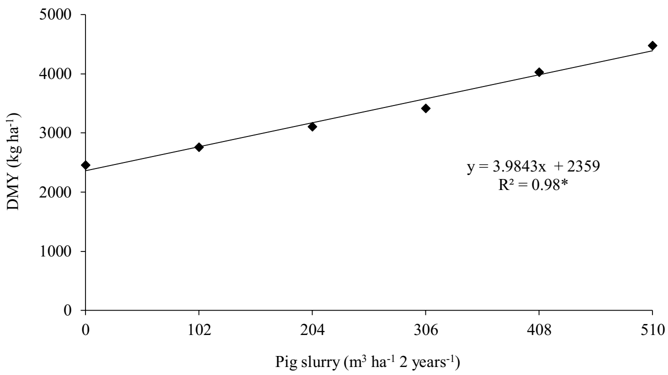
Dry matter yield increased linearly with the rate of PS application (in 2008-2010, Figure 1). This can be attributed to an increasing N supply, as the levels of other nutrients in the soil were already higher than the critical levels indicated by guidelines for southern Brazil (CQFS-RS/SC, 2004) (Table 2). Furthermore, PS application did not affect soil physical attributes, according to a study performed in a contiguous area treated with the same PS application rates used in this study (Agne & Klein, 2014).

Whereas in this study (2010-2011), DMY increased by 3.98 kg DM ha^{-1} year^{-1} for each m^{-3} PS applied (Figure 1), during the period of application (2008-2010) each m^3 PS contributed an average 25,57 kg DM ha^1 year^{-1} (Brustolin et al., 2016). Thus, the residual nitrogen fertilizer did not provide enough N to maximize DMY, which reached a maximum value of approximately 4,500 kg DM ha^{-1} year^{-1} one year after the application of PS, compared to an average DMY of 10,019 kg DM ha^{-1} year^{-1} during 2008-2010 (Brustolin et al., 2016).

Because roughly 60% of the N applied as PS was available to this pasture in 2008-2010 (Brustolin et al., 2016), it may have accumulated as microbial biomass or other relatively less recalcitrant soil organic compounds. Moreover, some of the PS ammonium-N may have been lost or fixed on clays shortly after its application and some of the organic-N may have been allocated in stems, leaves, and roots, which is made available over time through senescence. Slurry also stimulates microbial activity leading to increased mineralization of organic matter (Zanine & Ferreira, 2015).

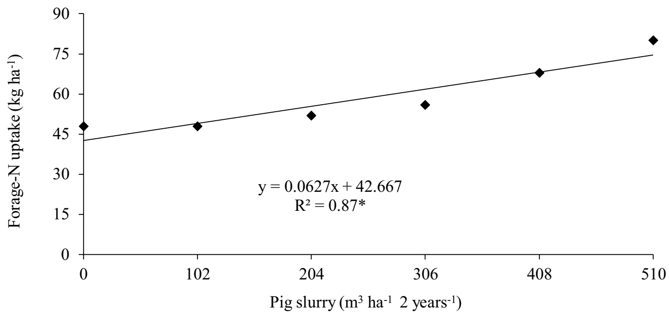
Forage-N uptake (FNU) also increased linearly with PS application rates (Figure 2). Fine-textured soils (high clay) with high organic matter (OM) content, such as the soils in the experimental area (Table 2), are generally less susceptible to nitrate leaching than sandy-textured soils, as they have high water-holding capacity and low water permeability. Thus, FNU results and soil properties in the area suggest that most of the N fertilizer applied was retained in the soil without significant leaching.

The apparent soil effect (ASE) was 2,459 kg ha^{-1} for annual DMY and 48 kg ha^{-1} N for FNU, contributing more than 55% of DMY and 60% of FNU in unfertilized plots (Table 3). The residual PS effect (PSRE) was smaller and increased with previous fertilizer rates. PSRE ranged from 11 (102 m^3) to 45% (510 m^3) for DMY and 8 (204 m^3) to 40% (510 m^3) for FNU. The residual ammonium nitrate effect (ANRE) of 29% for DMY and 8% for FNU was equivalent to 306 m^3 of PS (Table 3). Similar results were reported in studies with *Axonopus* spp. (Miranda et al., 2012; Brustolin et al., 2016) following PS and AN applications. In these studies, the DMY, at an ammonium nitrate application rate of 200 kg ha^{-1} N, was equivalent to a PS rate calculated to provide 300 kg ha^{-1} N. These results indicate that release of N from manure was 50% smaller than from ammonium nitrate.



*p < 0.05

Figure 1. Annual dry matter yield - DMY (2010-2011) of common carpet grass pasture as a function of previous pig slurry rates (2008-2010)



*p < 0.05

Figure 2. Annual (2010-2011) forage-N uptake of common carpet grass pasture as a function of previous pig slurry rates (2008-2010)

Table 3. Dry matter yield (DMY) and forage-N uptake (FNU) of common carpet grass pasture (2010-2011) in response to residual effect of pig slurry (PSRE) and ammonium nitrate (ANRE) previously applied (2008-2010), and apparent soil effect (ASE)

Previous fertilization (qty ha^{-1} 2 years^{-1})	DMY (kg DM ha^{-1})	ASE[1] (%)	PSRE[2] (kg DM ha^{-1})	ANRE[3] (kg DM ha^{-1})	FNU (kg N ha^{-1})	ASE (%)	PSRE (kg N ha^{-1})	ANRE (kg N ha^{-1})
Control (no N application)	2,456 ns	-	-	-	48 ns	-	-	-
1,250 kg AN ha^{-1}	3,400	72	-	941	56	86	-	8
102 m^3 PS ha^{-1}	2,760 ns	89	304	-	48 ns	0	0	-
204 m^3 PS ha^{-1}	3,108 ns	79	652	-	52 ns	92	4	-
306 m^3 PS ha^{-1}	3,420 ns	71	964	-	56 ns	86	8	-
408 m^3 PS ha^{-1}	4,032 ns	61	1,576	-	68 ns	70	20	-
510 m^3 PS ha^{-1}	4,480 *	55	2,024	-	80 ns	60	32	-

*Significant by the Dunnett's test ($p < 0.05$) in relation to AN; ns: Non-significant; [1]ASE: PS0 or AN0 *100)/PS or AN treatment; [2]PSRE: Pasture response in PSi + N0 – Pasture response in PS0 + AN0; [3]ANRE: Pasture response in ANj + PS0 – Pasture response in PS0 + AN0

In annual wheat, the ASE contributed more than 64% of the grain yield and PSRE was smaller and increased with increasing PS rate, amounting to 36% of the grain yield (Daudén et al., 2004). In barley (*Hordeum vulgare* L.), cultivated after four consecutive maize (*Zea mays* L.) crops fertilized with PS, the PSRE was equivalent to 77 kg ha^{-1} N of mineral fertilizer, indicating that N fertilization could be reduced by nearly this amount (Yagüe & Quílez, 2013). Thus, our findings indicate that previous PS applications can provide N to subsequent crops and reduce chemical fertilizer inputs in amounts similar to those reported in other studies.

The average PSRE on FNU ranged from 0-5% of the total inorganic N input in 2008-2010 (Figure 3), whereas the residual AN effect on FNU was 2% (data not shown), smaller than the residual effect observed for a similar PS application rate (306 m^3 ha^{-1} = 3.1%). This suggests that PS can provide more residual N than mineral fertilizer, consistent with the organic fraction of N of this manure. A significant part of the organic N retained in the soil after PS application is derived from immobilized ammonium-N, which is slowly released over many years (Sorensen & Amato, 2002). In addition, the PSRE on FNU ranged from 0-8.8% (102-510 m^3 ha^{-1}) for total organic N and 0-3.2% (510 m^3 ha^{-1}) for total N.

In the current study, the residual effects of pig slurry applied for two years were evaluated on a permanent grass pasture grown in subtropical conditions. A linear relationship between PS rates and DMY was found, which increased by roughly 4 kg ha^{-1} for each 1 m^3 PS applied (Figure 1) or the equivalent to ~3 kg for each kg of mineral N. In addition to the well-known advantages of PS fertilization, our findings indicate that this practice can increase the growth of subsequent crops and reduce the cost of nitrogen fertilization.

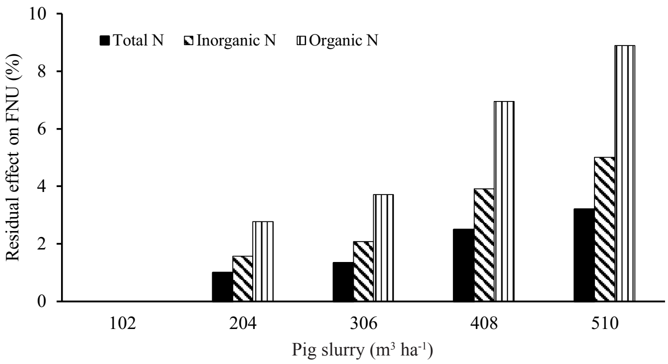


Figure 3. Average residual effect of pig slurry rates on forage-N uptake (FNU) in common carpet grass pastures, considering the previous inputs of total, inorganic, and organic N applied in 2008-2010

The results also indicate that manures should preferentially be applied to crops with long growing seasons (e.g., maize, pasture grass, and winter cereals), which can utilize the N mineralized from the organic N in the manure. On sandy soils or crops with special quality requirements (e.g., low protein in malting barley), high rates of PS application should be used, with caution to prevent N build-up, which may pose an environmental risk. Further studies that determine the optimal application rates based on the mineral N content in the root zone immediately prior to manure application are needed to prevent excess N accumulation in soils with continuous PS application.

Conclusions

1. Dry matter yield and forage-N uptake increased with increasing levels of pig slurry applied to common carpet grass pasture for two years, indicating a gradual release and availability of N in pig slurry, which can help reduce the amounts of N applied to pastures.

2. The residual effect of pig slurry varied with application rate, and compared to unfertilized plots, dry matter yield increased from 11 to 45% (304-2,024 kg ha^{-1}) and forage-nitrogen uptake from 8 to 40% (4-32 kg ha^{-1}).

3. The linear response ($b = 3.98$ kg m^{-3} ha^{-1}) of carpet grass to previous pig slurry application resulted in a maximum dry matter yield of roughly 4,500 kg ha^{-1}.

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