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Dry matter production and nitrogen use efficiency of giant missionary grass in response to pig slurry application[1]

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ABSTRACT - This study assessed the effect of successive applications of pig slurry on the dry matter (DM) production and the nitrogen use efficiency of giant missionary grass along two years. A total of 55, 110, 165, 220 and 275 m^3 of pig slurry/ha/year were applied in order to supply 100, 200, 300, 400 and 500 kg of total N/ha/year, respectively. These treatments were compared with the ammonium nitrate (200 kg of N/ha/year) source of N and with a control (no nitrogen application). Annually, nitrogen was applied in four divided doses, after the cutting of forage grasses, which takes place five times a year. The total DM yield did not differ between years and increased linearly as a function of pig slurry application, ranging from 2,698 kg of DM/ha/year (control) to 11,371 kg of DM/ha/year (275 m^3 of pig slurry/ha/year). There was an increment of 32.3 kg of DM/m^3 of pig slurry/ha or 17.7 kg of DM/kg of N/ha. The highest average daily DM accumulation rate (66.8 kg of DM/ha/day) was achieved with the highest pig slurry rate, from February/2007 to April/2008. Nitrogen use efficiency did not differ across pig slurry rates (19.0 kg of DM/kg of N), but it was lower than that obtained with ammonium nitrate (30.3 kg of DM/kg of N). The efficiency index of pig slurry ranged from 0.52 to 0.72.

Key Words: *A. jesuiticus* × *A. scoparius*, organic fertilization, pasture

Introduction

Giant missionary grass is a hybrid resulting from the natural interbreeding between *Axonopus jesuiticus* and *A. scoparius* (Valls et al., 2000) and ocurrs in Vale do Itajaí, in the state of Santa Catarina, southern Brazil. Its excellent forage yield (Tcacenco & Soprano, 1997; Deschamps & Tcacenco, 2000), stoloniferous growth, high palatability, as well as its ability to tolerate cold, trampling, drought, and excess moisture (Dufloth, 2002) are sufficient reasons to proceed with research into this grass species, allowing for the establishment of management practices and maximization of its performance.

High response to phosphorus, potassium, and nitrogen fertilization was reported by Tcacenco (1994) and Tcacenco & Soprano (1997), but no information is available yet about its yield after pig slurry application. As this residue is produced in large amounts on pig farms, its use as fertilizer is the most viable recycling option (Scherer et al., 1995). However, according to Brinck et al. (2003), it is important that pig slurry be applied to pastures with high response to N and high capacity to retrieve it from the soil, as the produced DM is the major determining factor for its uptake.

It is the demand for nitrogen by the crops that determines the necessary amounts of pig slurry, which are often split and applied after the cutting or grazing cycles. Studies carried out in Brazil, with natural pasture (Durigon et al., 2002; Scheffer-Basso et al., 2008b) and tropical grasses, such as Tifton 85 (*Cynodon* sp.) (Scheffer-Basso et al., 2008a; Vielmo et al., 2011) and *Brachiaria brizantha* (Hochst. ex A. Rich.) Stapf) (Medeiros et al., 2007) revealed an increase in DM yield after the use of pig slurry.

The hypothesis assumed in the present study is that giant missionary grass is responsive to pig slurry fertilization, mainly due to the nitrogen content found in this type of organic fertilizer, which is made available in its mineral form. The study assessed DM production and nitrogen use efficiency of this grass, thus contributing towards technologies that allow integrating animal production systems through the recycling of swine waste and stimulation of forage production.

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Material and Methods

The study was conducted from 2007 to 2009, in Chapecó, western region of the state of Santa Catarina, a town located at 679 m of altitude, with 27° 07'S latitude and 52° 37'W longitude. The climate is subtropical of the type Cfa (Mota et al., 1971) (Figure 1) and the soil is classified as dystrophic oxisol (Embrapa, 1999).

Before treatments, soil from the 0-5, 5-10 and 10-20 cm layers was sampled and analyzed for clay content and chemical attributes (Tedesco et al., 1995; Table 1). The experimental plots measured 6 m × 5 m (30 m²), with a useful area of 5 m². A randomized block design with five replications was used. The treatments consisted of (a) five pig slurry applications, calculated based on the total N content of the slurry, to supply 100, 200, 300, 400 and 500 kg of N/ha/year, totaling 55, 110, 165, 220 and 275 m^3 of pig slurry/ha/year, for the mean of the two years; (b) one application of ammonium nitrate (200 kg of N/ha/year) and (c) no N application (control). Given that pig slurry contains considerable amounts of P and K (Table 2), and as its doses were high (Table 3), 300 kg/ha/year of triple superphosphate and of potassium chloride were applied to the control and ammonium nitrate treatments. In addition, as the soil revealed P, K, Ca, Mg, S and micronutrient contents above the recommended critical levels (CQFS-RS/SC, 2004) at study onset, and as under such conditions there is no response to the application of these elements, it was possible to test the effect of the N applied with pig slurry by differentiating it from other nutrients in terms of chemical composition.

Table 1 - Chemical attribute and clay content at soil layers of 0-5 cm, 5-10 cm and 10-20 cm before treatments

Attribute	Soil layer		
	0 – 5 cm	5 – 10 cm	10 – 20 cm
Clay (%)	59.0	61.4	63.1
pH in water	5.8	5.9	5.9
SMP buffer index	5.8	5.9	5.8
P (mg/dm^3)	12.3	10.0	8.1
K (mg/dm^3)	246.3	177.1	109.3
OM (%)	4.2	3.9	3.5
Al ($cmol_c/dm^3$)	0.0	0.1	0.2
Ca ($cmol_c/dm^3$)	6.8	6.6	5.9
Mg ($cmol_c/dm^3$)	3.5	3.3	3.2
H + Al ($cmol_c/dm^3$)	5.5	5.2	5.7
CEC ($cmol_c/dm^3$)	16.3	15.5	15.1
V (%)	65.7	65.5	61.5
Al saturation (%)	0.0	1.2	3.4
Ca/Mg	2.0	2.0	1.9
Ca/K	14.8	26.1	40.5
Mg/K	7.5	3.0	21.1
Zn (mg/dm^3)	1.9	1.0	0.7
Cu (mg/dm^3)	1.1	1.0	1.0
Mn (mg/dm^3)	4.5	2.7	1.4
Fe (g/dm^3)	1.2	1.0	1.1

Annually, ammonium nitrate and pig slurry applications were subdivided into four doses, given after the cutting of pasture, in September/2007 (after staging), December/2007, February/2008 and April/2008 (Year 1), and in September/ 2008, December/2008, February/2009 and March/2009 (Year 2). The cuttings were made on 12/20/07, 02/19/08, 04/08/08, 06/24/08 and 09/16/08 (Year 1), and on 11/18/08, 02/03/09, 03/24/09, 08/13/09 and 10/20/09 (Year 2). The giant missionary grass was cut with a power mower whenever the plots treated with ammonium nitrate reached

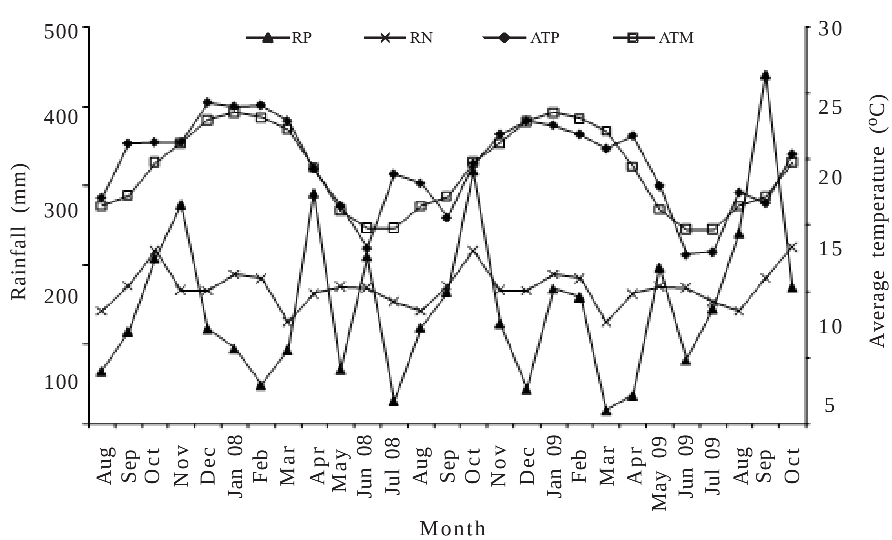

Figure 1 - Monthly average temperatures (AT) and rainfall (R) recorded during the experimental period (P) and regional normals (N).

Table 2 - Physicochemical attributes of pig slurry applied to giant missionary grass in two assessment years

Attribute	Year 1				Year 2			
	Sep/07	Dec/07	Feb/08	Apr/08	Sep/08	Dec/08	Feb/09	Mar/09
pH in water	6.90	7.10	7.30	7.30	6.90	7.50	7.00	7.50
DM (%)	0.77	0.46	0.68	5.82	0.70	0.89	0.61	1.14
P (kg/m^3)	0.45	0.18	0.21	0.80	0.46	0.37	0.39	0.54
K (kg/m^3)	0.68	0.40	0.53	0.62	0.89	0.85	0.64	0.95
Ca (kg/m^3)	0.29	0.09	0.46	14.61	0.95	1.24	0.22	0.45
Mg (kg/m^3)	0.13	0.10	0.18	7.24	0.26	1.24	0.21	0.16
Fe (kg/m^3)	0.10	0.10	0.19	0.46	0.21	0.46	0.04	0.09
Cu (g/m^3)	3.95	5.45	9.93	36.5	4.95	8.17	5.67	17.23
Zn (g/m^3)	12.00	51.00	14.65	71.18	12.19	75.09	8.84	19.42
Mn (g/m^3)	2.06	6.22	6.61	34.25	7.45	42.51	8.26	9.92
Total N (kg/m^3)	2.09	1.21	1.13	3.72	2.38	1.98	1.67	2.51
Mineral N (kg/m^3)	1.77	1.00	0.95	1.32	1.33	1.22	1.16	1.22

Table 3 - Mean amount of pig slurry applied to giant missionary grass relative to nitrogen doses

N dose (kg/ha/year)	Pig slurry (m^3/ha)										
	Year 1 (2007-2008)					Year 2 (2008-2009)					Mean
	Sep	Dec	Feb	Apr	Total	Sep	Dec	Feb	Mar	Total	
100	12	21	22	7	62	10	13	15	10	48	55
200	24	42	44	14	124	20	26	30	20	96	110
300	36	63	66	21	186	30	39	45	30	144	165
400	48	84	88	28	248	40	52	60	40	192	220
500	60	105	110	35	310	50	65	75	50	240	275

an average height of 20 cm, leaving residues of approximately 8 cm. The mean daily dry matter accumulation rate (DMAR) was calculated by dividing DM by the number of days between the cuttings; nitrogen use efficiency (NUE = $DM_{dose\text{-}Nx} - DM_{no\ N}$)/kg of $N_{dose\text{-}Nx}$), according to Menegatti et al. (2002) and; the efficiency index (EI) of pig slurry (Scherer et al., 1995), using the equation: EI = [$DM_{PS\ 200\ kg\ N}$ - $DM_{control}$]/[$DM_{Ammonium\ nitrate\ 200\ kg\ N)}$ – $DM_{control}$), which can also be expressed in percentage.

Data were submitted to analysis of variance, using the model with split plots in time (main plot = N doses; subplot = cuttings or year), and the means were compared by Tukey test at 5% error probability. Pig slurry applications were assessed by regression analysis using the SISVAR software (Ferreira, 2000).

Results and Discussion

Dry matter yield did not differ between the analyzed years, showing a linear increase with pig slurry applications (Figure 2), indicating that it is possible to obtain a positive response from pig slurry applications at larger doses than those tested here. For Tifton 85, Scheffer-Basso et al. (2008a), Drumond et al. (2006) and Vielmo et al. (2011) described a quadratic response to pig slurry application at doses of 180, 200 and 320 m^3/ha/year, respectively. The average increase in DM yield observed in this study was higher than that obtained for natural pasture fertilized with 180 m^3 of pig slurry/ha, with 25 kg of DM/m^3 of pig slurry (Scheffer-Basso et al., 2009b), and for oats (*Avena* sp.) + Italian ryegrass (*Lolium multiflorum* Lam.), with 21.2 kg of DM/m^3, fertilized with 80 m^3 of pig slurry/ha/year (Assmann et al., 2007).

Despite the positive response of the grass to pig slurry application, the average annual production (Table 4) was lower than that obtained in Urussanga (15,300 kg of DM/ha/year), with 175 kg of N/ha in the form of ammonium

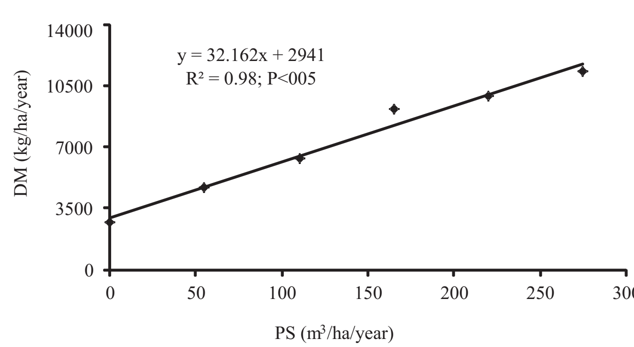

Figure 2 - Annual dry matter production of giant missionary grass as a function of pig slurry (PS) applications. Mean for the two analyzed years.

nitrate (Vieira et al., 1999) with the same grass. This behavior was attributed to droughts during the growth seasons, in both years (Figure 1), because it is well known that pastures have a positive response to high N doses only when soil moisture is appropriate (Sun et al., 2008; Jacobs & Ward, 2010). This effect was also observed by Assmann et al. (2007), who did not obtain a positive response to pig slurry application for the dry matter production of oats + Italian ryegrass during a period of water deficit.

Besides the direct impact of water restriction on pasture growth, droughts caused regrowth delay and, consequently, the last fraction of pig slurry and of ammonium nitrate was applied only at the beginning of the fall, in both years. Due to the reduction in temperatures during this season in southern Brazil, and to the resulting decrease in pasture growth, the demand for nutrients is smaller (Durigon et al., 2002), leading to the underutilization of this fraction of fertilizers.

Although rainfall was adverse to plant growth, pig slurry application allowed average increases in DM yield, from 74% to 322%, which would raise the pasture carrying capacity and, consequently, animal production. At a higher pig slurry dose (275 m^3) there was DM yield higher than that obtained with ammonium nitrate, by nearly 30%. This dose was similar to what Vielmo et al. (2011) used in Tifton 85 (249 m^3/ha/year) to obtain a higher yield (24,200 kg of DM/ha/year), whereas Drumond et al. (2006) obtained 6,325 kg of DM/ha/year with the same cultivar, by applying 200 m^3 of pig slurry/ha/year. For *Brachiaria brizantha*, Barnabé et al. (2007) recommended 150 m^3 of pig slurry/ha/year to replace the mineral nitrogen fertilization.

Only with the application of at least 165 m^3, relative to 300 kg of N/ha/year, was the DM yield similar to that obtained with 200 kg of N/ha/year in the form of ammonium nitrate, indicating the lowest efficiency of pig slurry (Table 4) in nitrogen supply. With 200 kg of N/ha in the form of ammonium nitrate, approximately 27% more dry matter was obtained than with the application of 200 kg of N/ha/year in the form of pig slurry, equivalent to 110 m^3/ha/year. Nitrogen use efficiency did not differ between the pig slurry doses, with a mean of 19 kg of DM/kg of N, and was similar to those obtained by Durigon et al. (2002), which ranged from 19.3 to 13.7 kg of DM/kg of N, with the application of 20 and 40 m^3/ha of pig slurry to natural pasture. Vielmo et al. (2011) described NUE decrease with the increase in pig slurry doses in up to 320 m^3/ha, from 24 to 9 kg of DM/kg of N, in Tifton 85.

In the first year, the interaction between cutting and dose was not significant, and the highest DM yield was obtained with the application of maximum pig slurry dose (Figure 3). The DM yield observed in the spring-summer (December to February in the southern hemisphere) and at the beginning of the fall (April) did not vary significantly, which is desirable for animal management. As the fall advanced, DM yield declined sharply (75%) as a result of the drop in temperature. However, giant missionary grass resumed its growth early on, from the beginning of the winter (June), which eventually led to an increase of around 54% in DM production obtained at the end of the winter (September). Early regrowth at this time is a very important aspect in the selection of perennial species for the establishment of pastures in southern Brazil, given

Table 4 - Average annual dry matter yield and nitrogen use efficiency (NUE) of giant missionary grass fertilized with nitrogen in the form of pig slurry (PS) and ammonium nitrate (AN)

N dose (kg/ha/year)	PS (m^3/ha/year)	Annual dry matter (kg/ha/year)	NUE (kg of DM/kg of N)
Control	-	2,697d	-
200 (AN)	-	8,763b	30.3a
100 (PS)	55	4,693c	19.9b
200 (PS)	110	6,331c	18.2b
300 (PS)	165	9,152b	21.5b
400 (PS)	220	9,934b	18.1b
500 (PS)	275	11,371a	17.4b

Means designated by the same letter in the column do not differ (P>0.05) by Tukey test.

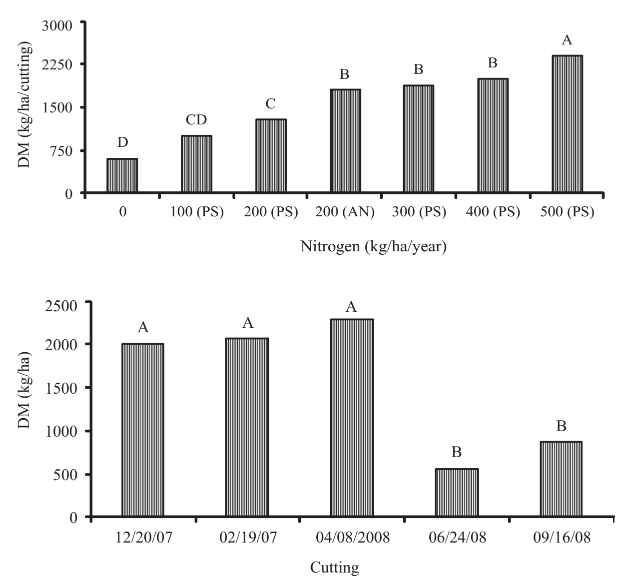

Figure 3 - Average dry matter yield per cutting of giant missionary grass fertilized with nitrogen doses in the form of pig slurry (PS) and ammonium nitrate (AN), and seasonal production in the mean fertilization treatments in the first year of assessment (2007-2008).
Same letters in the columns indicate that the means do not differ (P>0.05) by Tukey test.

that fall-winter is the season in which forage turns out to be scarcer.

In the second year, the DM yield across cuttings varied according to N doses (Table 5). In the first cutting (November/08), performed around 2 months after the first pig slurry application (September/08), the largest yields were obtained with 192 and 240 m^3 of pig slurry/ha/year, which resulted in a 560% increase compared with the control and a 34% increase compared with the ammonium nitrate treatment. From then on, no difference was observed between the three largest pig slurry doses and ammonium nitrate, indicating the lowest efficiency of pig slurry in nitrogen supply. The efficiency index of pig slurry in terms of nitrogen supply ranged from 0.52 (February/09) to 0.72 (November/08). This variation is due to climatic changes, as the efficiency of organic fertilizers in nitrogen release is affected, chiefly by moisture and temperature. The lowest index obtained in this study (0.52) occurred during water restriction and high average temperature (Figure 1). Nonetheless, the value of 0.72 is close to the one recommended by CQFS-RS/SC (2004), which is 0.80 for this type of organic fertilizer.

Only with a higher pig slurry dose was it possible to increase the DM yield in the cutting performed in October/09, compared with the previous cutting (Table 5). With respect to the cutting performed in August/09, which assessed the winter growth of the grass, there was no difference between N doses, which strengthens the assumption that the last fraction of fertilizers was underutilized, as pointed out earlier. Durigon et al. (2002), after assessing the response of a natural pasture in southern Brazil for 48 months, recommended reducing the amounts of pig slurry in fall-winter because of low temperatures, which affect plant growth and diminish the efficiency of the fertilizer.

The daily dry matter accumulation rates (DMAR) were affected by dose × cutting in both assessed years, yielding the maximum of 66.8 kg of DM/ha/day at the end of the

Table 5 - Seasonal dry matter yield of giant missionary grass fertilized with nitrogen doses in the form of pig slurry (PS) and ammonium nitrate (AN), in the second year of assessment

N dose (kg/ha/year)	PS (m^3/ha/year)	Seasonal dry matter (kg/ha)				
		Nov/08	Feb/09	Mar/09	Aug/09	Oct/09
Control	-	490dAB	864cA	524dAB	262bB	204cB
200 (AN)	-	2,225cA	2,450aA	1,901abA	871abB	1,107abB
100 (PS)	48	930dB	1,552cA	975cdAB	472abB	411cB
200 (PS)	96	1,752cA	1,704bA	1,340bcAB	676abC	780bcBC
300 (PS)	144	2,383bcA	2,100abA	2,188aA	916aB	1,277abB
400 (PS)	192	2,990abA	2,474aAB	2,266aB	890aC	1,276abC
500 (PS)	240	3,275aA	2,577aA	2,418aB	939aD	1,556aC

Means designated by the same letter, small letter in the column and capital letter on the row, do not differ (P>0.05) by the Tukey test.

Table 6 - Daily dry matter accumulation rate of giant missionary grass fertilized with nitrogen doses in the form of pig slurry (PS) and ammonium nitrate (AN) in two assessment years

N dose (kg/ha/year)	PS (m^3/ha/year)	DM (kg/ha/day)				
	Year 1	Dec/07	Feb/08	Apr/08	Jun/08	Sep/08
Control	-	12.6cA	14.2aA	16.2cA	1.0Bb	1.8cB
200 (AN)	-	25.6abB	34.2bcdB	58.8aA	9.0abC	11.6abcC
100 (PS)	62	6.8bcB	25.0deAB	28.6bA	2.8abC	4.6bcC
200 (PS)	124	17.2bcB	29.2cdA	38.8bA	6.4abC	8.0abcBC
300 (PS)	186	25.8abC	38.8bcB	59.2aA	8.2abD	14.0abD
400 (PS)	248	26.6abC	44.0abB	59.4aA	9.8abD	14.0abD
500 (PS)	310	34.0aC	51.2aB	66.8aA	13.6aD	16.8aD
N dose (kg/ha/year)	Year 2	Nov/08	Feb/09	Mar/09	Aug/09	Oct/09
Control	-	7.8dAB	11.2dA	10.6dAB	1.6aB	3.0dAB
200 (AN)	-	35.2cA	31.8abA	38.8bA	6.0aC	16.0abcB
100 (PS)	48	14.8dAB	20.2cdA	19.8cdA	3.4aC	6.2cdBC
200 (PS)	96	27.8cA	22.0bcA	27.4cA	4.8aB	11.2bcdB
300 (PS)	144	37.8bcA	27.4abcB	44.6abA	6.4aC	18.8abB
400 (PS)	192	47.4abA	32.0abB	46.4abA	6.2aD	18.6abC
500 (PS)	240	51.8aA	33.4aB	49.4aA	6.8aD	22.8aC

Means designated by the same letter, capital letter on the row and small letter in the column, do not differ (P>0.05) by the Tukey test.

summer in the first year, with the highest pig slurry dose (Table 6). In the best growth stage, between February and April/08, DMAR rose 312% with the highest pig slurry dose, compared with the control. Results demonstrate the potential high response of giant missionary grass to N, which is very promising, given that it is a native grass, not yet submitted to any genetic improvement. In Tifton 85, Vielmo et al. (2011) found that DMAR increased 30% with 80 m^3 of pig slurry/ha (152 kg of DM/ha/day) compared to the control (117 kg of DM/ha/day).

It is important to regard the implications of the results obtained in this study, since in the mean for both analyzed years, the lowest pig slurry dose (55 m^3/ha/year) applied to giant missionary grass was quite close to that which is recommended by FATMA (2009), which establishes the maximum of 50 m^3 of pig slurry/ha/year for cultivated land. According to our results, this dose is much lower than the nitrogen demand by the giant missionary grass. For this reason, studies have to be extended to forage grasses, as well as to other types of crops (fruit crops, forests, horticultural crops, etc.), especially in regions where pig slurry production is remarkable, in order to minimize environmental problems and to recycle this type of residue in rural properties.

Conclusions

The dry matter yield of giant missionary grass increases linearly with the application of pig slurry, up to 275 m^3 of pig slurry/ha/year. The pig slurry nitrogen use efficiency corresponds to two thirds of that which is obtained with ammonium nitrate.

Acknowledgments

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