Pig slurry as a nutrient source in wheat/corn succession

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ABSTRACT

Wheat and corn are important grains in the agricultural scenario of Brazil, and demand adequate supply of nutrients, particularly nitrogen, in crop succession. The use of pig slurry (PS) as a full and/or partial alternative to mineral fertilization in crop areas has been identified as an important alternative for the disposal of this waste. Therefore, the objective of this study was to evaluate the utilization of PS as fertilizer in wheat/corn succession under some plant parameters and grain yield. The experiment was conducted under field in randomized block design with four replications and five treatments, three with PS (40, 80, 160 $m^3 ha^{-1}$) and two controls (no fertilization and mineral NPK fertilization), which were applied manually in the soil shortly after sowing the crops. The application of PS proved to be a significant source of nutrients in wheat/corn succession. In comparison to NPK fertilization, this increase was only of 5.4% and 4.7% for wheat and corn, respectively. PS is an efficient alternative and it can be used as a source of these nutrients in wheat/corn succession, and the use of 80 $m^3 ha^{-1}$ provides satisfactory results for all evaluated variables.

Keywords: organic fertilizer, nutrient accumulation, *Zea mayz* L., *Triticuma estivum* L.

RESUMO

Dejeto líquido de suínos como fonte de nutrientes na sucessão trigo/milho

O trigo e o milho são cereais importantes no cenário agropecuário do país, que demandam adequado suprimento de nutrientes, principalmente o nitrogênio, quando do cultivo em sucessão. A utilização de dejeto líquido de suínos (DLS) como alternativa total e/ou parcial a fertilização mineral em áreas de lavoura tem sido apontada com uma importante alternativa de descarte desse resíduo. Por isso, o objetivo do presente trabalho foi avaliar o efeito da utilização de DLS como fertilizante na sucessão trigo/milho sobre alguns parâmetros de planta e na produtividade de grãos. O experimento foi conduzido a campo no delineamento blocos ao acaso com quatros repetições e cinco tratamentos, sendo três com DLS (40; 80; 160 $m^3 ha^{-1}$) e duas testemunhas (sem fertilização e fertilização NPK mineral), os quais foram aplicados manualmente sobre o solo logo após a semeadura das culturas. A aplicação de DLS mostrou-se uma importante fonte de nutrientes a sucessão trigo/milho. O DLS é uma alternativa eficiente e pode ser utilizado como fonte desses nutrientes na sucessão trigo/milho, sendo que o uso de 80 m^3 ha^{-1} proporciona resultados satisfatórios para todas as variáveis avaliadas.

Palavras-chave: adubo orgânico, acúmulo de nutrientes, *Zea mayz* L., *Triticuma estivum* L.

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INTRODUCTION

Wheat and corn are staple foods for mankind and corn is also important raw material in the formulation of feed for pig and poultry farming. In recent decades, there has been a significant demand for these grains in the domestic market, driving technologies towards increasing yield and quality of the grains. Brazil is not self-sufficient in wheat production and this is caused by a lot of insecurity of the framers due to either lack of a guaranteed minimum price, or by adverse weather in the South region, its leading producer. Crop failure or low prices may not be enough to pay even the production costs, in which 40% is consisted of modern inputs (Brum & Heck, 2005). On the other hand, corn is important for crop rotation. The increase in grain production, is due more to vertical productivity associated to new technologies than the actual increase in the cultivated area. Fertilizers have the most impact on the final cost of corn production (Araujo *et al.*, 2004), which has high demand for nitrogen fertilization (Gomes *et al.*, 2007; Duete *et al.*, 2008), because nitrogen (N) is a vital plant nutrient, responsible for the formation of various organic compounds and activation of enzymes (Malavolta, 2006). Despite the requirement of nitrogen not being as high in wheat compared to corn (Commission of Chemistry and Soil Fertility - CQFS 2004), an adequate supply of N has been considered vital for desirable industrial quality of grains (Cazetta *et al.*, 2008; Pinnow *et al.*, 2013).

The production chain of swine is one of the major income-generating activities in small farms in southern Brazil, and more recently, it has been expanding to the central west region of the country, which is a significant region in corn production, the main component in animal diet. However, due to the intensification of swine farming in these regions, there is a high supply of pig slurry (PS) which, according to Konzen (1983), consists of the animal hairs, feces, urine, leftover feed, water from troughs and cleaning of the stalls, and other residues resulting from the adopted management practices.

PS has fertilizing and pollutant potential, and caution in its use with agricultural crops has already been documented, especially as a source of N, phosphorus (P) and potassium (K) (CQFS, 2004; Ceretta *et al.*, 2005; Konzen, 2006; Seidel *et al.*, 2010; Correa *et al.*, 2011; Costa *et al.*, 2011; Cassol *et al.*, 2012). Besides being a way of disposing this waste, its use in agricultural crops is a way of alleviating pollutant potential and providing the cycling of these nutrients within their own production units.

In this sense, some studies have aimed to evaluate the effect of PS on the production of cover crops in winter (Ceretta *et al.*, 2005; Aita *et al.*, 2006), on the decomposition of straw on the surface (Aita *et al.*, 2006; Giacomini *et al.*, 2008), on soil nutrients and chemical properties (Lourenzi *et al.*, 2011; Lourenzi *et al.*, 2013) and on the dynamics of transformation of nitrogen in the soil (Aita *et al.*, 2006; Aita & Giacomini, 2008). However, little is known of its nutritional value in two important gramineae, seen as major exporters of nutrients and grown in succession. Therefore, the aim of this study was to evaluate the effect of PS as fertilizer on plant growth and yield in wheat/corn succession.

MATERIAL AND METHODS

The experiment was conducted on field in the period of June 2012 to March 2013. The soil of the experimental area is classified as Rhodic Eutrudox, (Embrapa, 2006) and the climate as subtropical climate with hot summers (CFa) according to Köppen classification system (Moreno, 1961). Rainfall during the period is presented in Figure 1.

The area where the experiment was conducted had been cultivated under no-tillage system over the last 10 years, the last year remaining under fallow. In March 2013, three months before the sowing of wheat and the installation of the experiment, sampling was conducted in soil layer 0-10 cm and it presented the following characteristics: pH (1:1 in water) = 4.8; SMP index = 5.5; clay = 650 g kg^{-1}, organic matter = 29 g kg^{-1}; potassium = 252 mg dm^{-3}, calcium = 3.4 $cmol_c$ dm^{-3}; magnesium = 1.7 $cmol_c$ dm^{-3}, aluminum = 1.0 $cmol_c$ dm^{-3}, phosphate = 13.00 mg dm^{-3}. Seeking to increase pH to 6.0, liming was also done in March as recommended (CQFS, 2004), followed by subsoiling and plowing operations.

The experimental design was in randomized blocks with six treatments and four replications structured in plots of 9 m^2. The treatments were three doses of PS (40, 80, 160 m^3 ha^{-1}), mineral NPK, and no fertilization, as the bottom control. Mineral NPK fertilization was quantified as recommended for each crop (CQFS, 2004) with an expected yield of 3.0 Mg ha^{-1} for wheat and 12 Mg ha^{-1} for corn. Urea (175 kg ha^{-1}), triple superphosphate (150 kg ha^{-1}) and potassium chloride (100 kg ha^{-1}) were used as the source of NPK, respectively. PS was obtained from a swine production unit in the region, whose characterization and respective amounts of N, P (P_2O_5) and K (K_2O) added to each treatment and crop is shown in Table 1. The treatments were applied by casting after sowing of crops, while N coverage was done at wheat tillering (30 days after emergence) and V4 for corn.

The sowing of wheat (cultivar Quartzo, classified as bread wheat, of medium cycle and plant height) was manual, in rows spaced at 0.17 meters, density of 300 viable seeds per square meter. The sowing of corn (DKB 250 VT Pro) was spaced at 0.45 m, performed manually, with a density of 6.30 seeds per linear meter, thus ensuring population of 70,000 plants ha^{-1} after thinning.

The dry matter (DM) of the shoots at flowering was evaluated, which for wheat was measured when 50% of the plot had spikes in bloom, and for corn when 50% of the spikes had exposed stigmas. For wheat, this assessment was made by cutting the plants close to the ground in an area of 0.25 m² in each plot. For corn, sampling was done on five random plants in the plot. Samples were taken to a circulating air oven at 65 °C until constant weight. After being dried, the samples were weighed and crushed in electric forage, and homogenized; a sub sample was then removed and referred to the laboratory for tissue analysis to determine the content of N, P and, K. In the laboratory, samples were ground in a Willey grinder, proceeding to the wet digestion method described by Tedesco *et al.* (1995).

Close to harvest, ten random plants of the plot were evaluated as regards plant height (PH), having the ground level and the insertion of the flag leaf as reference for both crops. For wheat, the number of grains per spike (G/S), and for corn, stem diameter (SD) were measured with a digital caliper at the height between the first and second node of the stem.

For wheat, the plants were harvested in an area of 2.72 m² from the center of each plot, and for corn, cobs were collected from ten random plants, disregarding the borders of the plot. The determination of yield was calculated after threshing, cleaning and correction of humidity (13%), considering the harvested area of wheat and the number of plants harvested for corn. The weight of a thousand grains (TGW) was determined for both crops using four replications of 100 units of each plot and for wheat, the hectoliter weight (HW) was measured through a specific device in an unloading grain cooperative in the region.

The analysis of variance was carried out and when significant, the Dunnett test was applied to compare each treatment of PS with each control at 5% error probability ($p > 0.05$), using the software GENES (Cruz *et al.*, 2006).

RESULTS AND DISCUSSION

As regards dry matter (DM) yield in the shoots of wheat, Table 2 shows an increase of 26, 52 and 33%, respectively, for doses of 40, 80 e 160 m^3 ha^{-1}, compared to the production without fertilizer application, but not significantly differing from that obtained with mineral fertilizer. The 52% oppose the 34% found by Assmann *et al.* (2007) in DM yield in oats+rye grass intercropping, and the 104% found by Aita *et al.* (2006) in black oat in monoculture when using 80 m^3 ha^{-1}.

This DM response may be associated with the amount of nutrients applied via PS, because even at the lowest dose of PS (40 m^3 ha^{-1}), sufficient nutrients were added and nutritional demand of N, P and K in wheat was met, similarly to mineral fertilization (Table 1). Even without significant difference, the highest DM yield in the shoots of wheat was achieved with the dose of 80 m^3 ha^{-1}, which would approximate doses of 65 and 86 m^3 ha^{-1}, respectively found by Aita *et al.* (2006) and Ceretta *et al.* (2005), and maximum technical efficiency in the black oat yield.

In corn, there was no difference in DM yield among doses of pig slurry and mineral fertilizer control. However, compared to control without fertilizer, there was an increase in DM yield of 35.03, 44.25 and 44.35% for doses of 40, 80 e 160 m³ ha^{-1}of PS, respectively. It was observed that, by doubling the amount of PS from 80 to 160 m³ha^{-1}, the increase in DM yield was insignificant, which, according to Ceretta *et al.* (2005), nutritional inefficiency occurs by PS with the increase of the dose, as found by doubling the dose of 40 to 80 m³ha^{-1}. Using 63.3 m³ ha^{-1}of PS as the source of 140 kg N ha^{-1} in growing wheat on oat straw, Giacomini & Aita (2008) did not find any difference in DM yield compared with mineral fertilization. However, in comparing these studies, it is interesting to note that soil, straw, hybrid and PS between both are different. In addition, the treatment of only 40 m³ ha^{-1} of PS presented a similar

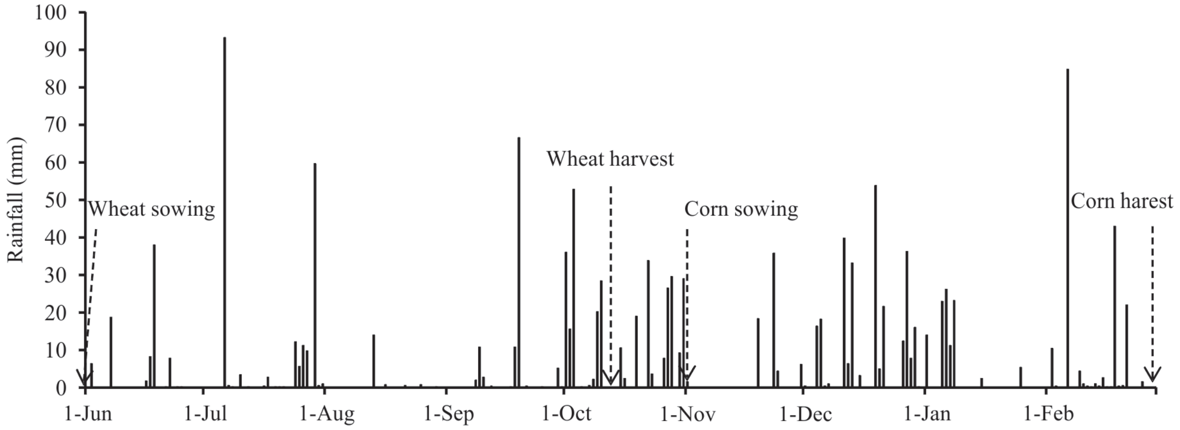

Figure 1: Distribution of rainfall during the study period. Data collected from the meteorological station INMET (National Institute of Meteorology), located 1000 meters from the experiment.

response to the mineral control, as opposed to the necessary 63.3 m³ ha^{-1} of the authors. This can also be associated with the amount of readily available N (ammonium) supplied via the PS, which was 57.9 kg ha^{-1} in the work of Giacomini & Aita (2008) and 74.4 kg ha^{-1} in the present work.

The number of G/S in wheat crop did not differ with the application of PS compared to any of the controls. If the high input of nitrogen by PS is considered, Teixeira Filho *et al.* (2010) found no response in number of G/S when nitrogen fertilization in irrigated wheat crop was studied. However, Cazetta *et al.* (2008) and Espindula *et al.* (2010) found positive linear response to the number of G/S with increasing doses of N in wheat up to 120 kg ha^{-1}.

Wheat PH had an increase of 5.5 cm at the dose of 160 m³ ha^{-1} of PS compared to mineral fertilizer control (Table 2). This response, by increasing doses of N via PS, corroborates the work of Espindula *et al.* (2010) who found linear and positive response of wheat PH with increased supply of N. Greater plant height is possibly associated not only to the high input of readily available N (411.2 kg ha^{-1}), in relation to the demand of the crop (60 kg ha^{-1}), but may also be more closely related to the anticipation of N supply. It depends on the PS having been all applied at sowing in relation to mineral NPK, corroborating the results of Teixeira Filho *et al.* (2008) in which all the nitrogen was applied in early sowing of wheat, as not all genotypes respond to different doses of N.

Corn PH was not lower in the PS treatments compared to mineral NPK. However, compared to the control without fertilizer, it was equal to the treatment with 40 m³ ha^{-1} of PS and superior to the others. The variable SD was superior when applying 160 m³ ha^{-1} of PS, supporting Mata *et al.* (2010) who found a gain in the use of cattle manure,

Table 1: Characteristics of pig slurry in N (total N and N-NH_4^+), P (P_2O_5), K (K_2O), DM (Dry matter), pH, density and respective amounts added to the system by each treatment in the fertilization of wheat and corn

Treatments	Total N	N-NH_4^+	P_2O_5	K_2O	DM	pH	Density
	Characterization of PS[1]						
	kg m^{-3}		g kg^{-3}				kg m^{-3}
Wheat	3.64	2.57	18.57	21.74	38.31	7.6	1,017
Corn	2.73	1.86	19.08	23.71	43.84	7.9	1,024
	Amount applied						
Wheat	kg ha^{-1}						
40 m³ ha^{-1}	145.6	102.8	28.8	34.0	1,558.4	—	—
80 m³ ha^{-1}	291.2	205.6	57.6	68.0	3,116.9	—	—
160 m³ ha^{-1}	582.4	411.2	115.2	136.2	6,233.8	—	—
Mineral NPK	—	60.0	30.0	20.0	—	—	—
Corn							
40 m³ ha^{-1}	109.2	74.4	34.4	42.6	1,795.7	—	—
80 m³ ha^{-1}	218.4	148.8	68.8	85.1	3,591.4	—	—
160 m³ ha^{-1}	436.8	297.6	137.6	170.2	7,182.7	—	—
Mineral NPK	—	190.0	165.0	80.0	—	—	—

[1]The concentrations of N are for wet basis and concentrations of P_2O_5 and K_2O on dry basis, these obtained from values of P and K multiplied by 2.29 and 1.205, respectively, determined by the method described by Tedesco *et al.* (1995).

Table 2: DM (Dry matter yield - kg ha^{-1}), PH (plant height cm), G/S (grains per spike num.) and SD (stem diameter - mm) of the wheat/corn succession fertilized with mineral NPK and PS (pig slurry)

Treatments	Wheat			Corn		
	DM*	PH	G/S	DM	PH	SD
No fertilizer[1]	4,023.7$^{(-2)}$	82.5	33.2	8,416.8$^{(-2)}$	212.9$^{(-2)}$	19.8
40 m³ ha^{-1} PS	5,041.6$^{(+1)}$	83.1	36.9	11,365.2$^{(+1)}$	223.6	21.6$^{(+1)}$
80 m³ ha^{-1} PS	6,101.4$^{(+1)}$	85.4	37.5	12,141.6$^{(+1)}$	230.8$^{(+1)}$	22.5$^{(+1)}$
160 m³ ha^{-1} PS	5,350.2$^{(+1)}$	88.2$^{(+2)}$	41.0	12,149.4$^{(+1)}$	238.3$^{(+1)}$	23.2$^{(+2)}$
Mineral NPK[2]	5,443.5$^{(+1)}$	82.7	37.2	11,446.2$^{(+1)}$	229.7$^{(+1)}$	21.3
CV (%)	8.1	3.1	10.0	6.4	3.2	4.1
Pr> F	0.0002	0.0430	0.1291	<0.0001	0.0041	0.0018

[1]No fertilizer control, [2]Mineral NPK control; *Means followed by: $^{(+2)}$significant and higher than the mineral NPK control, $^{(+1)}$significant and higher than no fertilizer control; $^{(-2)}$significant and lower than mineral NPK by Dunnett test at 5% probability.

compared to mineral fertilization. The highest SD demonstrates an adequate nutrition of crop because Cruz *et al.* (2008) and Soratto *et al.* (2010) found positive response to this variable with increasing N supply, including a favorable correlation with grain yield, justifying that well-nourished corn plants use the stem as a reserve structure for the supply of grains. Although, such nutritional benefit was observed, attention is brought to the importance of a balanced supply of nutrients most required by the crop, and not only a single nutrient, as shown in Table 1, where the treatment showed excess of N and a low addition of P compared to the culture demand.

With regard to the accumulation of N, P and K by the DM, it can be inferred in general concerning the cultures and the three elements, that the dose of 80 m^3 ha^{-1} of PS favors accumulation of these nutrients in relation to the two controls (Table 3), with higher accumulation than the control without fertilization and not lower than the mineral fertilization control.

These results show the fertilizing potential of PS with satisfactory accumulation of nutrients in DM, as evidenced by Aita *et al*. (2006). It was also observed that the accumulation of such nutrients increased as quantities of PS were doubling. However, the supply of 160 m^3 ha^{-1} did not provide greater accumulation than the mineral fertilizer control, showing a loss of efficiency in the absorption of these elements, which could encumber yield with the transportation of waste, and enhance environmental hazards. Cerreta *et al*. (2005) found a positive response for the accumulation of N, P and K with increasing doses of PS in black oat/corn/turnip succession.

Regarding the variables of production of wheat grain, fertilization with PS influenced only the TGW variable, for which the treatments of 80 and 160 m^3 ha^{-1} provided a higher value than the mineral NPK control (Table 4). If the high input of N is considered in these two treatments with 205.6 and 411.2 kg ha^{-1}, respectively, shown in Table 1, the results oppose those of Espindula *et al*. (2010) and Teixeira Filho *et al.* (2010), who found a negative linear correlation between increased levels of N and TGW. This justifies that higher N availability increases the number of G/S, which may compete for photoassimilates and lack for grain filling. The author raised yet another hypothesis that the increased supply of N increases plant mass, causing self-shading and loss of photosynthetic efficiency of plants, a fact that was not observed in this experiment, as noted in DM yield shown in Table 2. PS probably favored N uptake by the plant until the period of grain filling, depending on the slow net mineralization as verified by Fioreze *et al*. (2012) for very clayey soil.

Wheat PH was not influenced by the treatments (Table 4), although the increased supply of N could reflect in a decrease in PH (Cazetta *et al.*, 2008; Teixeira Filho *et al*., 2010), depending on the increase of G/S and decrease of TGW, as discussed in the preceding paragraph. However, the largest TGW may have been responsible for annulling the decline of PH.

Wheat productivity did not differ statistically (Table 4), which can be due to the fact that the area remained fallow in the previous year. Sartor *et al*. (2012) obtained linear increments in wheat yield with increasing doses of PS up to 60m^3 ha^{-1} in three crops, and with this dose, obtaining higher yield than mineral fertilization, with an average of 2,8; 10.55 kg ha^{-1} in the three crops, very similar to the treatment of 40 m^3 ha^{-1} of this study.

Corn did not differ in TGW and yield among treatments of PS and the controls (Table 4). Seidel *et al*. (2010) found no difference in the corn yield with PS in relation to mineral fertilization, suggesting that it is an effective alternative for the farmer. Costa *et al.* (2011) did not obtain satisfactory corn yield grown after fertilized wheat, respectively, with 25 and 38 m^3 $ha^{-1}$of PS, although in the first year, when grown after wheat, the corn development was favored due to residual fertilization of that given to wheat. However,

Table 3: Accumulation of N, P and K by DM ((Dry matter) of wheat and corn shoots, fertilized with mineral NPK and PS (pig slurry))

Treatments	Wheat			Corn		
	N	P	K	N	P	K
	kg ha^{-1}					
No fertilizer(1)	82.1(-2)	10.6	152.6(-2)	97.7(-2)	25.9(-2)	102.0(-2)
40 m^3 ha^{-1} PS	117.7(+1)	13.7	211.4	159.1(+1)	37.7(+1)	126.5(-2)
80 m^3 ha^{-1} PS	123.7(+1)	17.7(+1)	223.3(+1)	158.0(+1)	40.9(+1)	166.3(+1)
160 m^3 ha^{-1} PS	125.4(+1)	19.9(+1)	225.9(+1)	170.7(+1)	41.1(+1)	187.1(+1)
Mineral NPK (2)	126.7(+1)	15.8(+1)	236.5(+1)	159.0(+1)	38.0(+1)	179.8(+1)
CV (%)	11.7	22.0	16.4	15.9	8.5	14.3
Pr> F	0.0025	0.0223	0.0338	0.0068	<0.0001	0.0005

(1)No fertilizer control, (2)Mineral NPK control; *Means followed by: (+1)significant and higher than the no fertilizer control, (-2)significant and lower than the mineral NPK control by Dunnett test at 5% probability.

Table 4: Response of wheat/corn succession in TGW (thousand grain weight - grams), Yield (kg ha^{-1}) and PH (kg hl^{-1}) fertilized with PS (pig slurry) and mineral fertilizer

Treatments	Wheat			Corn	
	TGW*	Yield	HW	TGW	Yield
No fertilizer$^{(1)}$	32.4	2,706.0	79.2	278.0	13,309.9
40 m^3 ha^{-1} PS	31.2	2,808.0	77.3	269.9	13,690.1
80 m^3 ha^{-1} PS	33.1$^{(+2)}$	3,337.0	78.3	264.1	14,685.2
160 m^3 ha^{-1} PS	33.6$^{(+2)}$	2,873.0	78.4	267.2	14,721.0
Mineral NPK$^{(2)}$	31.3	3,165.6	78.5	277.3	14,023.2
General Average	32.3	2,978.0	78.4	271.3	14,085.1
CV (%)	2.7	19.6	1.1	7.2	11.7
Pr> F	0.0009	0.5411	0.0738	0.8075	0.6955

$^{(1)}$ No fertilizer control, $^{(2)}$Mineral NPK control; *Means followed by: $^{(+2)}$significant and higher than the mineral NPK control by Dunnett test at 5% probability.

Sartor *et al*. (2012) found a positive response with increasing doses up to 60 m³ ha^{-1} of PS, reaching a 55% increase in yield compared to the zero dose, with very close values to mineral fertilization. A yield increase of 2.86, 10.33 and 10.60% is observed, compared to control without fertilization for treatments of 40, 80 and 160 m^3 ha^{-1}of PS, respectively. Attention is brought to the low increment provided when the dose of 80 is doubled to 160 m^3 ha^{-1}.

Further studies should address the efficiency of PS doses, as reported by Ceretta *et al*. (2005), and Cassol *et al.* (2005). The latter authors found a maximum technical efficiency at the dose of 143 m^3 ha^{-1}, but warn that it is not feasible to achieve it, as 59 m^3 ha^{-1} would be needed to increase the remaining 10%.

CONCLUSIONS

Compared with the mineral NPK source, PS is an efficient alternative and can be used as a source of nutrients in wheat/corn succession.

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