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Soil chemical properties and maize yield under application of pig slurry biofertilizer

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manure
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ABSTRACT
Organic materials subjected to a process of anaerobic digestion in a digester produce biofertilizer that can be used in agriculture as nutrient source. The objective of this study was to evaluate the effect of pig slurry biofertilizer on soil chemical properties and on corn yield and nutrient concentrations in leaves and kernels. The experiment was conducted in the field from November 2012 to April 2013, and was arranged in a randomized block design with seven treatments and four replicates. The treatments consisted of doses of pig slurry biofertilizer (0; 40; 80; 120; 160; 200 and 240 m^3 ha^{-1}), applied to the soil surface in a single application, at stage V_2 of corn plants. Thirty-three days after biofertilization, soil samples were collected in each plot. Corn was harvested 129 days after sowing. Doses up to 240 m^3 ha^{-1} of pig slurry biofertilizer applied to soil with good fertility did not influence soil chemical properties and corn yield. The use of pig slurry biofertilizer had no detectable effect on nutrient concentrations in corn leaves and kernels.

Palavras-chave:
adubação orgânica
esterco
resíduo
efluente

Atributos químicos do solo e produtividade de milho com aplicação de biofertilizante de dejetos suínos

RESUMO
Materiais orgânicos submetidos a um processo de digestão anaeróbia, por meio de biodigestor, produzem biofertilizante que pode ser utilizado na agricultura como fonte de nutrientes. O objetivo do presente trabalho foi avaliar o efeito de biofertilizante de dejeto líquido de suínos em atributos químicos do solo, na produtividade e no teor de nutrientes nas folhas e nos grãos de milho. O experimento foi realizado em condições de campo, de novembro de 2012 a abril de 2013. Empregou-se delineamento experimental em blocos ao acaso, com sete tratamentos em quatro repetições. Os tratamentos foram constituídos por doses de biofertilizante de dejeto líquido de suínos, 0; 40; 80; 120; 160; 200 e 240 m^3 ha^{-1}, aplicadas na superfície do solo, de uma única vez, no estádio fenológico V_2 do milho. Aos 33 dias após a aplicação do biofertilizante foram coletadas, em cada parcela, amostras de solo. A colheita foi realizada aos 129 dias após a semeadura do milho. A aplicação de até 240 m^3 ha^{-1} de biofertilizante de dejeto líquido de suínos, em solo com boas condições de fertilidade, não alterou os atributos químicos do solo e não influenciou na produtividade de milho. O uso de biofertilizante de dejeto líquido de suínos não afetou os teores de nutrientes no tecido foliar nem nos grãos de milho.

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Introduction

In piggery, the system used by most producers is to pen the animals in small feedlots, resulting in the generation of large amounts of waste in liquid form (Giacomini et al. 2014). Pig slurry consists of feces, urine, uneaten feed, animal hair, and varying amounts of water from the waterers and cleaning of the installations (Sousa et al., 2014).

In the pig pens, each sow produces 35-40 L of waste per day, and in the finishing phase, the daily production of manure per animal varies from 12 to15 L (Seidel et al., 2010).

Pig slurry can be used in agriculture as a nutrient source for plants, and its use as organic fertilizer allows greater nutrient cycling in the environment (Lourenzi et al., 2014). Several reports in the literature mention improvements in soil fertility and increases in crop yields when using pig slurry as organic fertilizer, without having gone through biodigestion (Ceretta et al., 2003; 2005; Scherer et al., 2010; Lourenzi et al., 2014). However, successive applications of this organic fertilizer can promote excessive increases in P, Cu and Zn in soil, posing a potential contamination risk of soil and surface and subsurface water bodies (Ceretta et al., 2010; Girotto et al., 2010; Veiga et al., 2012).

Pig slurry can be digested in an anaerobic process in a biodigester, by which biogas is produced, useful as fuel, as well as biodigester effluent, also called biofertilizer, suitable as fertilizer in agriculture (Vilela Júnior et al., 2003; Silva et al., 2012). In the anaerobic digestion, various types of bacteria convert complex organic compounds into components with simpler structure (Silva et al., 2012). As a result, the nutrients in the biofertilizer are more readily available to plants than those in undigested organic fertilizer (Vilela Júnior et al., 2003). Furthermore, the biodigester can reduce 90% of chemical oxygen demand (COD) and biochemical oxygen demand (BDO) and up to 99% of coliforms (Silva et al., 2012).

In Brazil, studies involving the use of biodigesters were related to wastewater treatment and energy use of biogas, but information on the effect of biofertilizers on soil fertility properties is scarce (Silva et al., 2012). The studies published so far focus on vegetables (Vilela Júnior et al., 2003; Santos et al., 2012; Sediyama et al., 2009; 2014) or pasture (Orrico Júnior et al., 2012), but few field studies addressed pig slurry biofertilization of cereals such as corn.

The goal of this study was to assess the effect of pig slurry biofertilizer on soil chemical properties, corn yield and nutrient concentrations in corn leaves and kernels.

Material and Methods

The experiment was conducted in the field from November 2012 to April 2013, at the Federal Institute of Education, Science and Technology of the South of Minas, Muzambinho, Minas Gerais State, Brazil (21° 18’ 00” S; 46° 30’ 00” W; 1033 m asl). During the experiment, the temperature in the experimental area ranged from 15 to 31 °C and the cumulative rainfall in the period was 1395 mm (Figure 1).

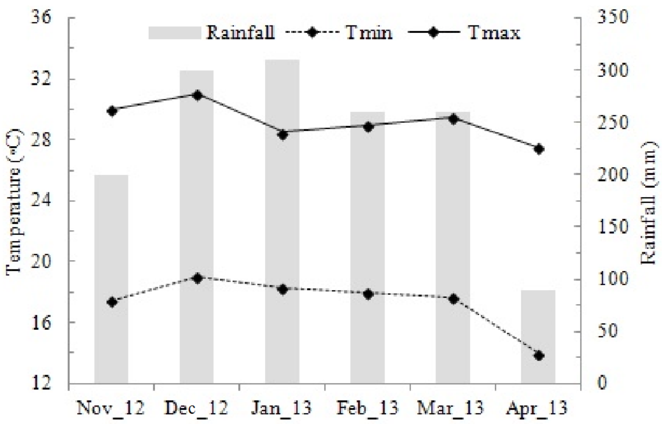
The soil of the experimental area was classified as Oxisol, with clayey texture, on which maize was sown in the 2010/2011 and common bean in the 2011/2012 growing season. Prior to the experiment, composite soil samples were collected (layers 0-0.20 m and 0.20-0.40 m), which were subjected to initial chemical routine analysis (Silva, 1999) (Table 1). In these layers soil particle-size analysis (Camargo et al., 2009) was also performed, and the results were: 500 and 530 g kg^{-1} clay; 170 and 160 g kg^{-1} silt; 330 and 310 g kg^{-1} sand, respectively.

Soil tillage consisted of subsoiling, followed by disk harrowing and two passings with a leveling harrow. No liming was performed in the area, since the base saturation (V%) of the top layer (0-0.20 m) was higher than that considered as adequate for the crop (CFSEMG, 1999).

The experiment, with 7 treatments and 4 replicates, a total of 28 plots, was arranged in a randomized block design. The treatments consisted of rates of pig slurry biofertilizer (0, 40, 80, 120, 160, 200 and 240 m^3 ha^{-1}).

Each plot consisted of five 5-m long rows spaced 0.60 m apart, amounting to a total area of 15 m^2. The evaluated area per plot consisted of the three central rows, disregarding 1.0 m at either end, resulting in a total area of 5.4 m^2.

The corn hybrid Superis Viptera 3, genetically modified, with an insecticidal agent event Bt (*Bacillus thuringiensis*), was sown mechanically (8 seeds m^{-1}), on 19/11/2012. Fertilization at sowing was applied as described by CFSEMG (1999), based on the results of the initial soil analysis (Table 1) and an expected yield of over 8 t ha^{-1}. To this end, 20 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} were applied at planting to all plots, using the sources urea and superphosphate granules. After plant emergence, in the V_2 growth stage, plants were thinned to 4 plants m^{-1}, corresponding to a population of 66,667 plants ha^{-1}.



Tmin and Tmax correspond to minimum and maximum air temperature, respectively

Figure 1. Air temperature and rainfall in the experimental period

Table 1. Chemical analysis of the soil used in the experiment

Layer m	P-Mehlich mg dm^{-3}	OM g dm^{-3}	pH $CaCl_2$	K	Ca	Mg	H + Al	CEC	V %
				mmol$_c$ dm^{-3}					
0.0-0.2	39	26	5.5	4.3	36	13	20	73	73
0.2-0.4	11	13	5.4	2.8	27	9	19	58	67

OM – Organic matter; H + Al – Potential acidity; CEC – Cation exchange capacity; V – Base saturation

The biofertilizer was prepared through a continous anaerobic digestion process in a tubular digester of pig slurry with sewage consisting of waste water of the facilities. In a sample of this organic fertilizer, the pH and water content were determined and the chemical composition of the dry matter (Tedesco et al., 1995) was analysed (Table 2).

The biofertilizer was applied five days after thinning, with a 10 L watering can in a single, regular application on the soil surface. Due to the high water content of the organic fertilizer (Table 2), to avoid variations in soil moisture content in the plots, water was sprinkled in sufficient amounts to guarantee the same volume of liquid (water + biofertilizer) in all plots, immediately after application of the biofertilizer rates.

Nitrogen fertilization, using 90 kg N ha^{-1} in the form of ammonium sulfate, and hand weeding were performed in the growth stage V_4, in all plots. No pest and disease control was necessary during the experiment.

From the evaluated area of each plot, composite soil samples were collected (layers 0-0.10; 0.10-0.20; and 0.20-0.40 m) with a probe, 33 days after biofertilization. One composite sample per layer was mixed from 15 single samples. The soil samples were analysed for routine chemical determinations and the micronutrients Cu and Zn (Silva, 1999).

When about 50% of corn plants were tasseled, leaves from the base of the ear were collected from 25 plants of the observation area of each plot (Cantarella et al., 1997), to determine the macronutrient and Cu and Zn concentrations in the plant tissue (Tedesco et al., 1995).

Table 2. Water content, pH values and chemical composition of the dry matter of pig slurry biofertilizer

Parameters	Concentration
Water content (%)	97.9
pH	8.1
C-org. (g kg^{-1})	106.8
N (g kg^{-1})	19.6
C/N Ratio	5.5
P (g kg^{-1})	23.6
K (g kg^{-1})	159.1
Ca (g kg^{-1})	27.7
Mg (g kg^{-1})	12.2
S (g kg^{-1})	11.4
B (mg kg^{-1})	235
Cu (mg kg^{-1})	30
Fe (mg kg^{-1})	303
Mn (mg kg^{-1})	110
Zn (mg kg^{-1})	177

The ears of the evaluated area of each plot were harvested in April 2013, 129 days after sowing, to determine grain yield, corrected to 12.5% moisture. In 12 ears of the evaluated area of each plot, ear length and diameter were also measured with a digital caliper besides the number of kernels per ear; and 1,000 grain weight. Grain samples of 200 g kernels per plot were ground to determine the concentrations of macronutrients, Cu and Zn in the kernels (Tedesco et al., 1995).

The results of the soil analysis for each layer, the nutrient contents in leaves and kernels, grain yield and yield components were subjected to analysis of variance, using the F test as well as polynomial regression analysis. For this purpose, the statistical program AgroEstat – Version 1.0 (Barbosa & Maldonado Júnior, 2011) was used.

Results and Discussion

The application of pig slurry biofertilizer to the soil surface, at rates of up to 240 m^3 ha^{-1} did not significantly ($p > 0.05$) change pH in $CaCl_2$, organic matter, P-Mehlich, and K^+, Ca^{2+}, Mg^{2+}, Cu, and Zn concentrations in the three assessed soil layers (0-0.1; 0.1-0.2; 0.2-0.4 m) (Tables 3 and 4). The other soil chemical properties evaluated, potential acidity (H + Al) and base saturation (V%) were not affected by fertilization with the biodigester effluent either.

No improvement in soil fertility was observed after the application of pig slurry biofertilizer, due to the high water content (97.9%) of the material used, which caused dilution in the nutrient concentrations of the organic fertilizer. In this experiment, it was not possible to use rates greater than 240 m^3 slurry ha^{-1}, due to the difficulty of applying higher biofertilizer rates with a watering can and the possibility of runoff of the effluent, which could cause contamination of adjacent plots.

In the 0-0.1 m layer, the concentrations of P-Mehlich, K^+, Ca^{2+}, Mg^{2+}, Cu and Zn were, respectively, 14 mg dm^{-3}; 1.8; 27; 12 $mmol_c$ dm^{-3}; 2.0 and 4.4 mg dm^{-3}, amounts classified as good, average, very good, good, high, high (CFSEMG, 1999). In the 0.1-0.2 m layer, the mean levels of these nutrients were, respectively, 8 mg dm^{-3}; 1.6; 24; 10 $mmol_c$ dm^{-3}; 2.0 and 2.7 mg dm^{-3}, amounts classified as medium, medium, good, good, high, high (CFSEMG, 1999).

Table 3. Values of soil pH, organic matter (OM), P and K, in the three studied layers, as related to the application of pig slurry biofertilizer

Variables	Layer (m)	Biofertilizer rates (m^3 ha^{-1})							Mean	F	CV (%)
		0	40	80	120	160	200	240			
pH $CaCl_2$	0-0.10	4.9	4.9	4.9	5.0	4.9	4.8	4.8	4.9	1.71^{NS}	2.35
	0.10-0.20	4.9	4.9	4.9	5.0	4.8	4.8	4.7	4.9	1.67^{NS}	2.97
	0.20-0.40	4.9	5.0	4.9	5.0	4.8	4.8	4.8	4.9	1.70^{NS}	2.73
OM g dm^{-3}	0-0.10	27	27	27	27	28	28	29	28	0.71^{NS}	8.09
	0.10-0.20	24	24	23	25	23	24	23	24	1.57^{NS}	5.27
	0.20-0.40	16	16	16	16	18	18	16	17	0.38^{NS}	14.90
P mg dm^{-3}	0-0.10	14	12	13	15	14	14	17	14	2.25^{NS}	7.46
	0.10-0.20	8	7	8	10	8	8	9	8	1.13^{NS}	11.28
	0.20-0.40	3	3	3	3	4	5	3	3	0.74^{NS}	11.07
K $mmol_c$ dm^{-3}	0-0.10	1.6	1.7	1.8	1.8	1.7	1.8	1.9	1.8	0.16^{NS}	14.88
	0.10-0.20	1.5	1.9	1.7	1.6	1.1	1.9	1.4	1.6	1.05^{NS}	12.99
	0.20-0.40	1.5	1.0	1.3	1.1	1.1	1.2	0.9	1.2	1.98^{NS}	19.37

^{NS}Not significant by F test ($p > 0.05$); CV - Coefficient of variation

Table 4. Concentrations of Ca, Mg, Cu and Zn in the three studied soil layers, as related to the application of pig slurry biofertilizer

Variables	Layer (m)	Biofertilizer rates (m^3 ha^{-1})							Mean	F	CV
		0	40	80	120	160	200	240			(%)
Ca mmol$_c$ dm^{-3}	0-0.10	28	27	29	26	29	27	26	27	0.91^{NS}	8.33
	0.10-0.20	24	24	23	26	23	24	21	24	1.30^{NS}	11.19
	0.20-0.40	19	20	19	20	21	21	20	20	1.71^{NS}	7.60
Mg mmol$_c$ dm^{-3}	0-0.10	13	12	13	11	12	11	11	12	0.93^{NS}	13.82
	0.10-0.20	10	10	10	11	9	10	8	10	1.88^{NS}	12.45
	0.20-0.40	8	8	8	8	8	8	8	8	0.96^{NS}	10.44
Cu mg dm^{-3}	0-0.10	1.9	2.1	2.1	1.9	2.1	2.0	2.0	2.0	1.49^{NS}	8.41
	0.10-0.20	1.9	2.2	2.1	1.9	2.1	2.0	2.1	2.0	1.13^{NS}	10.46
	0.20-0.40	1.9	2.1	2.3	1.9	2.1	2.0	2.1	2.1	1.43^{NS}	12.24
Zn mg dm^{-3}	0-0.10	4.0	3.9	4.5	4.1	4.7	4.9	4.8	4.4	1.61^{NS}	14.48
	0.10-0.20	2.9	2.5	2.4	3.1	2.4	3.1	2.7	2.7	0.68^{NS}	14.11
	0.20-0.40	1.0	0.9	1.1	0.9	1.3	1.8	1.3	1.2	1.81^{NS}	12.19

^{NS}Not significant by F test ($p > 0.05$); CV - Coefficient of variation

The organic matter content of the soil was not altered by the application of pig slurry biofertilizer (Table 3), due to the low dry matter content of this organic fertilizer, low C/N ratio and the presence of readily decomposable organic C in the swine waste, aside from the likely increase in soil microbial activity after effluent application (Ceretta et al., 2003; Sousa et al., 2014).

Similar results were reported by Caovilla et al. (2010), Medeiros et al. (2011) and Homem et al. (2014) in relation to the soil fertility properties. Caovilla et al. (2010) found no significant changes in pH, base saturation, and concentrations of P, K^+, Ca^{2+}, and Mg^{2+} in soil drip-irrigated with swine wastewater at different concentrations during soybean cultivation. Medeiros et al. (2011) found that the use of swine wastewater for cotton irrigation did not alter pH, soil organic matter, P, Ca, Cu, and Zn in the topsoil (0-0.2 m). Homem et al. (2014) observed that successive applications of swine wastewater, which amounted to 150 m^3 ha^{-1}, did not increase pH and P, K^+, Na^+, Ca^{2+}, and Mg^{2+} concentrations in the 0-0.2 m soil layer in an area of *Brachiaria decumbens*.

In a pot experiment, Duarte et al. (2008) found that there was no change in pH and levels of P and K in soil irrigated with wastewater from a sewage treatment, in sweet pepper cultivation. According to these authors, the soil pH of the effluent-irrigated areas may increase due to the increase in the denitrification process, where one mole of H^+ is consumed for every denitrified mole of NO_3^-. Cabral et al. (2011), in an experiment under field conditions with elephant grass, observed that soil pH did not vary and that the P and Mg concentrations in the soil increased with the application of up to 750 m^3 ha^{-1} of swine wastewater.

There are several reports in the literature of increased levels of soil nutrients after pig slurry application under field conditions (Ceretta et al., 2003; Scherer et al., 2010; Girotto et al., 2010; Veiga et al., 2012). However, these studies used organic fertilizers with a higher dry matter content compared with the biofertilizer used in this experiment. In addition, these studies tested successive pig slurry applications.

Ceretta et al. (2003) applied 28 rates of up to 40 m^3 ha^{-1} of pig slurry to the surface of a pasture soil in 4 years, and observed increases in Ca, Mg, and especially soil P, which reached extremely high values in the 0-0.1 m layer. According to these authors, there was no increase in soil pH, and K and organic C after applying the organic fertilizer. Scherer et al. (2010) found that in areas treated with swine waste in the long term (around 15 years, and between 20 and 25 years), the P, K, Cu and Zn concentrations increased markedly in the soil surface layers, especially in 0-0.05 m.

Girotto et al. (2010) found linear increases in available Cu and Zn concentrations in soil layers of a no-tillage area treated with 17 applications of up to 80 m^3 ha^{-1} of pig slurry over 78 months. According to the authors, the levels of available Cu and Zn in the 0-0.10 m soil layer of the treatment with the highest rate of organic fertilizer were, on average, 12 and 24 times higher, respectively, than in the control. Veiga et al. (2012) found that continuous application of high pig slurry rates, up to 200 m^3 ha^{-1} yr^{-1} on the soil surface, resulted in sharp increases in P, Cu and Zn concentrations to a depth of 0.2 m. These authors also reported a reduction in soil pH with the application of organic fertilizer, and attributed it to the acidification process of nitrification.

The concentrations of N, P, K, Ca, Mg, Cu and Zn in corn leaves were not affected ($p > 0.05$) by the application of pig slurry biofertilizer to the soil surface (Table 5). The means of these leaf nutrient levels were, respectively, 34; 3.0; 25; 4.1 and 2.0 g kg^{-1}; 12 and 25 mg kg^{-1}, and were within the range considered as suitable for maize (Cantarella et al., 1997), which expresses balanced nutritional level.

Nutrient concentrations, especially K and N, were expected to increase in the soil and corn leaf tissue with the application of pig slurry biofertilizer. This fact was not observed, probably due to the N and K leaching caused by the biofertilizer to a soil layer below those assessed in the experiment, which results in non-use of these nutrients effluent by corn. In biofertilizer, nutrients as N are more readily available to plants (Vilela Júnior et al., 2003). However, these forms are also more prone to leaching losses.

Similar results were obtained by Santos et al. (2012) and Sediyama et al. (2014), who detected no changes in foliar N, P and K concentrations in sweet pepper and pumpkin, with the application of pig slurry biofertilizer. In contrast, Sediyama et al. (2009) reported increases in foliar concentrations of N, Ca and Mg in okra with the use of up to 48 m^3 ha^{-1} of pig slurry biofertilizer.

Sartor et al. (2012) treated a no-tillage cereal crop for 6 years with 10 applications of up to 60 m^3 of pig slurry ha^{-1}, and found

Table 5. Nutrient concentrations in corn leaf tissue as related to the application of pig slurry biofertilizer

Variables	Biofertilizer rates (m^3 ha^{-1})							Mean	F	CV (%)
	0	40	80	120	160	200	240			
N (g kg^{-1})	32.7	34.4	33.8	34.2	34.2	34.9	33.9	34.0	0.76 ^{NS}	4.49
P (g kg^{-1})	3.0	2.9	3.0	3.1	3.2	2.9	3.0	3.0	2.61 ^{NS}	3.78
K (g kg^{-1})	26.1	23.5	24.6	24.9	26.4	25.9	26.6	25.4	1.16 ^{NS}	8.14
Ca (g kg^{-1})	4.3	4.3	4.3	4.2	4.0	4.0	3.9	4.1	4.29 ^{NS}	4.43
Mg (g kg^{-1})	2.0	2.1	2.0	2.1	1.9	1.8	1.9	2.0	0.77 ^{NS}	13.91
Cu (mg kg^{-1})	11.0	11.5	11.4	11.6	11.6	12.2	12.2	11.6	3.85 ^{NS}	3.75
Zn (mg kg^{-1})	25.8	24.5	24.0	25.7	25.2	23.9	23.8	24.7	1.12 ^{NS}	6.69

^{NS} - Not significant by F test ($p > 0.05$); CV - Coefficient of variation

Table 6. Corn grain yield and yield components as related to the application of pig slurry biofertilizer

Variables	Biofertilizer rates (m^3 ha^{-1})							Mean	F	CV (%)
	0	40	80	120	160	200	240			
Grain yield (kg ha^{-1})	9.528	9.593	9.650	9.406	9.388	10.302	9.727	9.656	0.44 ^{NS}	9.69
Ear lenght (cm)	14.8	15.9	15.3	15.3	15.5	15.6	15.6	15.4	0.60 ^{NS}	6.13
Ear diameter (cm)	5.3	5.3	5.3	5.3	5.3	5.4	5.4	5.3	3.27 ^{NS}	1.19
N° of kernels per ear	542	561	542	561	549	562	558	554	0.85 ^{NS}	3.51
1.000 grain weight (g)	313	316	316	313	310	305	311	312	0.69 ^{NS}	3.06

^{NS} - Not significant by F test ($p > 0.05$); CV - Coefficient of variation

Table 7. Nutrient concentrations in the corn kernels as related to the application of pig slurry biofertilizer

Variables	Biofertilizer rates (m^3 ha^{-1})							Mean	F	CV (%)
	0	40	80	120	160	200	240			
N (g kg^{-1})	12.8	13.3	12.8	13.8	13.8	13.6	14.1	13.5	2.22 ^{NS}	4.97
P (g kg^{-1})	2.8	2.7	2.2	2.6	2.4	2.6	2.7	2.6	0.56 ^{NS}	9.45
K (g kg^{-1})	4.2	4.0	3.3	3.9	3.5	3.8	4.1	3.8	0.53 ^{NS}	11.38
Ca (g kg^{-1})	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.71 ^{NS}	15.25
Mg (g kg^{-1})	1.3	1.3	1.1	1.2	1.2	1.3	1.4	1.3	0.54 ^{NS}	10.62
Cu (mg kg^{-1})	1.9	1.8	1.6	2.0	2.1	1.9	2.0	1.9	0.50 ^{NS}	10.55
Zn (mg kg^{-1})	26.2	24.6	23.1	26.3	26.0	25.0	25.8	25.3	0.27 ^{NS}	8.76

^{NS}Not significant by F test ($p > 0.05$); CV - Coefficient of variation

that N, P and Zn concentrations in corn leaves increased up to an estimated rate of about 40 m^3 fertilizer ha^{-1}. The authors also found that K, Ca, Mg, and Cu concentrations in corn leaves remained unchanged with the application of organic fertilizer.

Pig slurry biofertilizer had no significant ($p > 0.05$) effect on corn grain yield and yield components (ear length, ear diameter, number of kernels per ear and 1.000 grain weight) (Table 6), because the digester effluent induced no improvements in soil fertility. The average grain yield in the experiment (9.656 kg ha^{-1}) was clearly above the center-south average of Brazil, in the 2013/2014 growing season, for maize in the main season (6.230 kg ha^{-1}) (CONAB, 2014). Grain yield was high due to the good soil fertility in the area and the favorable weather conditions (temperature and precipitation) during the course of this experiment.

Ceretta et al. (2005), Seidel et al. (2010) and Lourenzi et al. (2014) reported increases in corn grain yield under pig slurry application. In these experiments, the maximum grain yields were, respectively, 15, 10 and 11.6 t ha^{-1}, exceeding the yield of this study. The different performance in grain yield with organic fertilization in those experiments, compared to our study, is because pig slurry biofertilizer has a higher water content and consequently lower nutrient content compared with liquid swine manure.

Cabral et al. (2011) observed no increase in dry matter production of elephant grass with application of up to 750 m^3 ha^{-1} of swine wastewater. Freitas et al. (2004) found an increase in yield of silage corn using swine wastewater in irrigation. Orrico Júnior et al. (2012) found that the application of pig slurry biofertilizer at rates of up to 0.57 L pot^{-1}, equivalent to up to 300 kg N ha^{-1} linearly increased the dry matter production of *Brachiaria brizantha*.

The nutrient concentrations in maize kernels were not affected either ($p > 0.05$) by pig slurry biofertilization (Table 7). Thus, as the properties evaluated were not benefitted, the chief advantage of applying this effluent consisted in the water reuse.

Conclusions

1. Doses up to 240 m^3 ha^{-1} of pig slurry biofertilizer applied to soil with good fertility did not influence soil chemical properties and did not affect corn yield.

2. The use of pig slurry biofertilizer did not affect nutrient concentrations in corn leaves and kernels.

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