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ASSOCIATION OF SWINE WASTEWATER AND MINERAL FERTILIZATION ON BLACK OAT PRODUCTION

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ABSTRACT: Swine wastewater (SW) has high organic load, becoming an important source of macro and micronutrients to plants, promoting the improvement of soil quality and development in various cultures. However, when done without agronomic and environmental criteria, it can cause soil problems, nutrient leaching, water resource damage and plant toxicity. The objective of this study was to evaluate the soil chemical properties and the leachate in face of the association of swine wastewater and mineral fertilization (MF) in oat cultivation. An experiment in drainage lysimeter was carried out, using SW applications associated to MF or not, where treatments consisted of doses of 0, 100, 200 and 300 m^3 ha^{-1} with the absence or presence of MF, under field conditions. We concluded that swine wastewater provided significant increases in sodium, copper, zinc, and nitrite + nitrate as well as pH and calcium reductions in the soil; and in the leachate, significant increase in sodium. Moreover, the use of mineral fertilizer comprising nitrogen, phosphorus and potassium induced a significant increase in phosphorus, potassium and electrical conductivity and a significant reduction in magnesium in the soil; however, in the leachate, electrical conductivity was increased.

KEYWORDS: soil fertility, nutrient leaching, drainage lysimeters.

INTRODUCTION

Pig farming is a key activity in rural areas of southern Brazil. In 2012, the national slaughter was over 36 million heads. Southern Brazil accounted for 64.0% of the national pig slaughtering, followed by Southeastern (17.8%), Center-Western (16.1%), Northeastern (1.2%) and Northern (0.1%) (IBGE, 2013).

Organic fertilization, or even its association with mineral fertilization, are economically viable alternatives for most farmers. In addition to promoting the improvement of soil quality, they are important sources of macro and micronutrients to plants (STEINER et al., 2011).

With the expressive pollutant charge in swine wastewater (SW), there is the concern that it will be carefully managed so as not to cause negative environmental impacts, such as eutrophication of water sources and contamination by metals which are often added to the pigs' diets (FEY et al., 2010).

However, despite the polluting potential, SW can contribute to reducing the use of commercial fertilizers (chemical or mineral) in crops. The use of SW might be effective as biofertilizer if performed properly (CABRAL et al., 2011).

There are difficulties to recommend an optimal dose of SW for each type of crop, due to the large variability in nutrient concentration in this type of wastewater, due to the different types of managements, both on the farm and in the waste treatment (FEY et al., 2010). Thus, when applied successively, swine wastewater can cause disproportionate increases in the availability of mineral nutrients in the soil (CELA et al., 2010; SCHERER et al., 2010; CASSOL et al., 2011.).

When available in the soil, ions found in SW can be absorbed by plants or leached from the surface to deeper layers. When leached, nutrients are incorporated into groundwater by internal

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drainage process and are thus transported over large distances, contaminating groundwater and drinking water sources (SAMPAIO et al., 2010).

This context shows the importance of obtaining data on the quality and quantity of nutrients present in the soil and leachate, observing the swine wastewater application rates in the soil, in order to verify the most consistent with the replacement of nutrients removed by the plant, considering soil type, SW characteristics, region climate conditions and cultivated crop.

Thus, the aim of this study was to evaluate the effects of swine wastewater associated with the presence or absence of mineral fertilization on soil chemical properties and the leachate, in the cultivation of black oats in drainage lysimeter.

MATERIAL AND METHODS

The experiment was conducted at an Experimental Center under the coordinates 24°54'02" S and 53°32'00" W, with average altitude of 760 meters. The climate is super humid mesothermal subtropical, with average annual rainfall of 1800 mm, average temperature of 20° C and relative average air humidity of 75% (CAVIGLIONE et al., 2000). The average rainfall, temperatures and relative air humidity in 2012 can be seen in Figure 1, and the months for the experiment are August, September and October. The soil of the experimental area is classified as typical dystroferric Red Latosol (EMBRAPA, 2006).

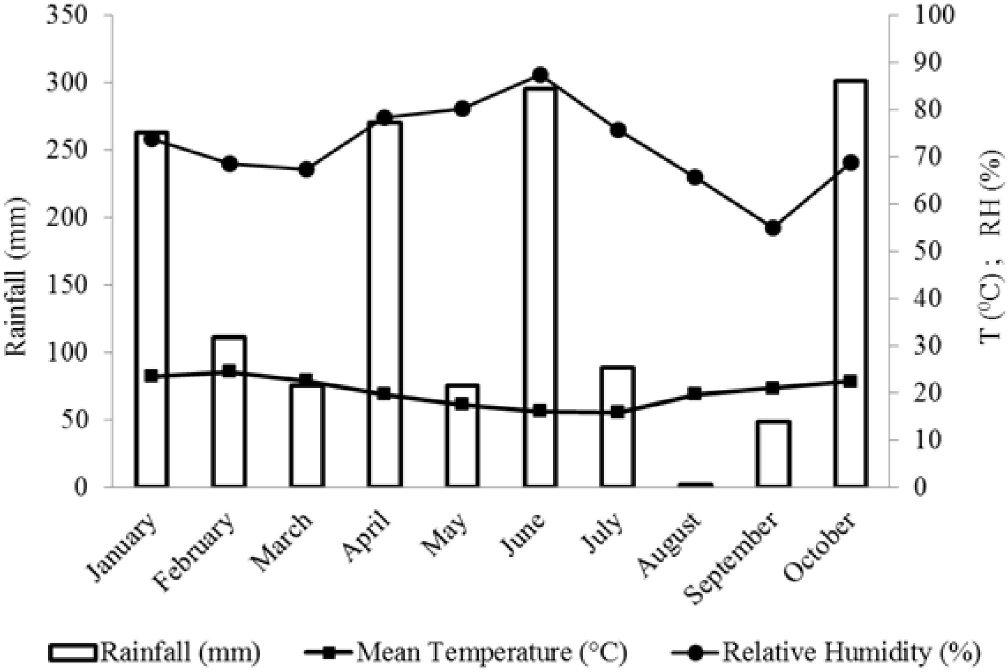

FIGURE 1. Monthly rainfall distribution, average temperature and relative air humidity in the period from January to October 2012. Source: SIMEPAR (2012).

The experimental area consists of 24 drainage lysimeters installed since 2005 (PRIOR et al., 2009). Each lysimeter is an experimental plot of 1.0 m^3 of volume and 1.60 m^2 of surface area, with a depth of 0.91 m and diameter of 1.43 m. Lysimeters are distributed in three rows with eight lysimeters each, spaced 0.4 m vertically and 0.5 m horizontally.

The first experiment conducted in the field was in 2006 with corn crops (*Zea mays* L.) (1st) and soybeans (*Glycine max* (L.) Merrill) (2nd), in 2007 black oat (*Avena strigosa Schreb.*) (3rd) and soybeans (4th); in 2008 with black oat (5th) and baby corn (6th); in 2009 with corn (7th), black oat (8th) and soybean (9th); in 2010 corn (10th) and black oat (11th); in 2011 soybeans (12th) and corn (13th). This paper discusses the black oat crop (14th) in 2012. Treatments are presented in Table 1 and history of nutrients is shown in Table 2.

TABLE 1. Treatment with swine wastewater (SW) associated with mineral fertilization (MF) applied in the lysimeters for black oat cultivation.

Mineral Fertilization	SW Doses			
	$0\ m^3\ ha^{-1}$	$100\ m^3\ ha^{-1}$	$200\ m^3\ ha^{-1}$	$300\ m^3\ ha^{-1}$
Absent	T1	T3	T5	T7
Present	T2	T4	T6	T8

TABLE 2. History of nutrients applied for (kg ha^{-1}) with MF and SW in the experimental area in six consecutive years, per treatment.

Treatment	N	P	K^+	N	P	K^+
	Total nutrients from MF in previous crops			Total nutrients from SW in previous crops		
(T1) 0 ARS-Absent	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
(T2) 0 ARS-Present	597 (20)	610 (50)	555 (50)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
(T3) 100 ARS-Absent	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	1013 (98)	156.42 (9.49)	476.15 (35.53)
(T4) 100 ARS-Present	597 (20)	610 (50)	555 (50)	1005 (98)	156.42 (9.49)	476.15 (35.53)
(T5) 200 ARS-Absent	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	2037 (196)	312.84 (18.98)	953.32 (71.06)
(T6) 200 ARS-Present	597 (20)	610 (50)	555 (50)	2030 (196)	312.84 (18.98)	953.32 (71.06)
(T7) 300 ARS-Absent	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	2570 (396)	471.68 (37.96)	2.445.64 (142.12)
(T8) 300 ARS-Present	597 (20)	610 (50)	555 (50)	2764 (396)	471.68 (37.96)	2.445.64(142.12)

MF: Mineral Fertilization; SW: Swine Wastewater; N: Nitrogen, P: Phosphorous, K: Potassium; Values in parentheses represent: Total nutrients through MF in the current crop and total nutrients through SW in the current crop.

The SW (Table 3) came from pig farms of the full cycle type, located in Toledo - PR. The gross SW applied in the experiment was collected in the collection box prior to the outlet for the biodigester. After SW application (2 days), we proceeded to fertilization and seeding in direct planting system with spacing of 20 cm between rows, a total of 5 lines per lysimeter. MF applied was NPK: 8:20:20 in the dose 400 kg ha^{-1}. The black oat used was cultivar IAPAR 61 with a density of 155 kg ha^{-1}.

Because the experiment was long-term, systematic soil collection was carried out before and after experiment implementation. However, only the soil collection after crop cultivation was used in statistical analysis to evaluate the effects of treatments. Therefore, soil collection was carried out 60 days after sowing (DAS), when the oats had already been harvested, with one sample per lysimeter, totaling 48 samples. With the help of a Dutch auger, samples were collected at a depth of 0-20 cm, stored in plastic bags, identified, and sent for chemical characterization at the Agrilab Laboratory (Botucatu-SP). The parameters analyzed were hydrogenionic potential (pH), organic matter (OM), aluminum (Al^+), hydrogen and aluminum (H^++Al^+), calcium (Ca^{2+}) magnesium (Mg^{2+}), phosphorus (P), potassium (K^+), sodium (Na^+), total bases (TB), cation exchange capacity (CEC), base saturation (V), aluminum saturation (m), copper (Cu^{2+}), zinc (Zn^{2+}), total nitrogen (total N), ammonia nitrogen (NH_4^+), nitrite + nitrate (NO_3^- + NO_2^+), and electrical conductivity (EC) according to the protocol of RAIJ et al. (2001).

TABLE 3. Characterization of the swine wastewater used in the experiment.

Parameter	Values
pH ($CaCl_2$)	6.89
EC (µS m^{-1})	4,470.00
TOC (mg L^{-1})	29,916.30
N (mg L^{-1})	707.00
NORG (mg L^{-1})	266.70
NINORG (mg L^{-1})	440.30
NH4+ (mg L^{-1})	419.30
NO_3^- + NO_2^- (mg L^{-1})	21.00
P (g L^{-1})	33.01
K+ (mg L^{-1})	26,005
Na+ (mg L^{-1})	16.80
Ca_2^+ (mg L^{-1})	236.00
Mg_2^+ (mg L^{-1})	67.00
Cu^{+2} (mg L^{-1})	8.30
Zn^{+2} (mg L^{-1})	39.00
Fe^{+2} (mg L^{-1})	27.40
Mn^{+2} (mg L^{-1})	7.10
B (mg L^{-1})	1.27
S (mg L^{-1})	37.11
Turbidity (UNT)	3,140.00
DQO-F (mg L^{-1})	3,200.00
DQO (mg L^{-1})	10,320.00
TS (mg L^{-1})	20,000.00
FS (mg L^{-1})	2,300.00
VS (mg L^{-1})	17,700.00
TDS (mg L^{-1})	2,500.00
SFD (mg L^{-1})	1,500.00
VSD (mg L^{-1})	1,000.00

Protocol APHA AWWA and WEF (1998). pH: potential of hydrogen; EC: Electric conductivity (μS cm^{-1}); TOC: Total organic carbon; N: total nitrogen; NORG: organic nitrogen; NINORG: inorganic nitrogen; NH_{4+}: ammonium; NO_2 + NO_3: Nitrite + Nitrate; P: phosphorus; K^+: potassium; Na^+: sodium; Ca^{2+}: calcium; Mg^{2+}: magnesium; Cu^{+2}: copper; Zn^{+2}: zinc; Fe^{+2}: Iron Mn^{+2}: manganese; B: boron; S: sulfur; COD: chemical oxygen demand; TS: total solids; FS: fixed solids; VS: volatile solids; TDS: total dissolved solids; FDS: fixed dissolved solids; VSD: volatile solids dissolved.

Leachate samples were taken in two periods, at 40 DAS (days after sowing) when the first rain with enough intensity for collection occurred, and the second at 60 DAS when the last rain occurred before the black oat harvest. Both periods were used to determine the average behavior of ions in the leachate in each lysimeter during the experiment. The samples were analyzed chemically according to the concentrations of hydrogenionic potential (pH), calcium (Ca^{2+}), magnesium (Mg^{2+}), manganese (Mn^{2+}), potassium (K^+), sodium (Na^+), copper (Cu^{2+}), zinc (Zn^{2+}), nitrite (NO_3^-) and nitrite (NO_2^+), electrical conductivity (EC) according to the methodology of APHA, AWWA and WEF (1998).

The experiment was carried out in the field under randomized block design and factorial scheme with two factors (4x2) and three replications. The first factor relates to the use of ARS doses (0, 100, 200, 300 m^3 h^{-1} in the cycle) and the second factor was mineral fertilization. Prior to the analysis of variance was performed descriptive analysis and verification of normal errors. Parameters with no normal distribution were transformed. Initially the data for the soil and leachate extracts were subjected to variance analysis. When significant differences were detected for the treatments, polynomial regression was carried out using the computer software SAS 9.0 (SAS INSTITUTE, 2002). However, the Tukey test average at 5% was performed for the mineral fertilizer factor, when the interaction between factors was not significant.

RESULTS AND DISCUSSION

Table 4 shows the statistical analysis, in which it is possible to observe the effects of SW and MF factors on the soil chemical parameters. The interaction between the SW and MF factors was not significant. The parameters pH, Ca^{2+}, Na^{+}, Cu^{2+}, Zn^{2+} and NO_2^{-} + NO_3^{-} were significantly affected only by SW (Table 4). The FM factor, in isolation, influenced the Mg^{2+} parameters, P, K^{+} and CE. In addition, the other parameters were not affected by the SW and MF factors, being presented in Table 4.

In this experiment, the mineral fertilizer applied was composed of NPK, while in contact with the soil these salts are made available, which explains the presence of P, K, and CE in greater quantities when the MF was present and smaller when it was absent. As for Mg^{2+}, the effect was contrary; when the MF was present, this element was found to a lesser extent (Table 4).

It is observed in Figure 2 that the mean values of the soil pH decreased with the increase of SW doses applied, where the dose of SW 300 m^3 h^{-1} showed the lowest value (pH=6.59), and the dose of 0 m^3 ha^{-1} the highest value (pH=7.33). This reduction is explained due to the high amount of ammonia via the SW, which can be oxidized by the NO_3^{-} by microbial nitrification process, producing an acidifying effect of the medium (CASSOL et al. 2012). In near-neutral soils, there may be a reduction in pH due to the leaching of bases along the well-drained soil profile and placed in regions with frequent and significant precipitation (ADELI et al., 2008), such as the western region of Paraná.

TABLE 4. Mean values of pH, MO, Al^{+}, H+Al, Ca^{2+}, Mg^{2+}, P, K^{+}, Na^{+}, SB, CTC, V, m, Cu^{2+}, Zn^{2+}, N_{total}, NH_4, NO_2^{-}+NO_3^{-} and CE for different SW doses, presence or absence of MF in soil cultivated with black oat.

Treatments	pH in water	MO	Al	H+Al	Ca	Mg	P	K	Na	SB	CTC	V	M	Cu	Zn	N *total*	NH4	NO_3 + NO_2	CE
m^3 ha^{-1}		g dm^{-3}	mmolc dm^{-3}				mg dm^{-3}	mmolc dm^{-3}				%		mg dm^{-3}					µS.cm^{-1}
0	7.33*	28.58	0.00	3.25	60.92*	37.17	9.53	3.06	0.41*	101.50	106.17	96.08	0.00	7.24**	2.70**	1190.00	8.46	20.76*	76.62
100	7.24*	28.92	0.00	8.42	56.25*	35.33	15.28	2.87	0.65*	94.67	103.08	93.08	0.00	8.00**	6.75**	1248.33	9.63	21.93*	78.62
200	6.63*	30.00	2.46	28.83	46.25*	30.58	17.30	4.16	0.76*	89.20	104.33	76.00	8.69	8.98**	9.32**	1201.67	9.63	22.64*	77.21
300	6.59*	29.92	0.73	26.58	48.00*	31.25	16.97	5.41	0.79*	85.08	111.50	79.00	2.10	9.99**	13.13**	1318.33	9.04	25.43*	86.71
Presence	6.75	29.42	1.30	23.21	50.88	31.25b	20.80a	4.4a	0.68	91.09	106.63	81.33	4.65	8.73	8.35	1242.50	9.48	22.10	89.22a
Absence	7.14	29.29	0.29	10.33	54.83	35.92a	8.88b	3.28b	0.63	94.29	105.92	90.75	0.75	8.38	7.60	1236.67	8.90	23.27	70.36b
Mean	6.95	29.35	0.80	16.77	52.85	33.58	14.77	3.87	0.65	92.61	106.27	86.04	2.70	8.55	7.97	1239.58	9.19	22.69	79.79
CV (%)	10.38	16.66	54.46	58.13	22.27	22.12	34.09	25.95	33.82	20.97	21.99	26.93	26.79	13.44	35.03	14.39	26.93	17.26	26.93

** Significant regression at 1% significance. * Significant regression at 5% significance. CV: coefficient of variation. Means followed by different letters in the column differ statistically by the Tukey's test at 5% significance.

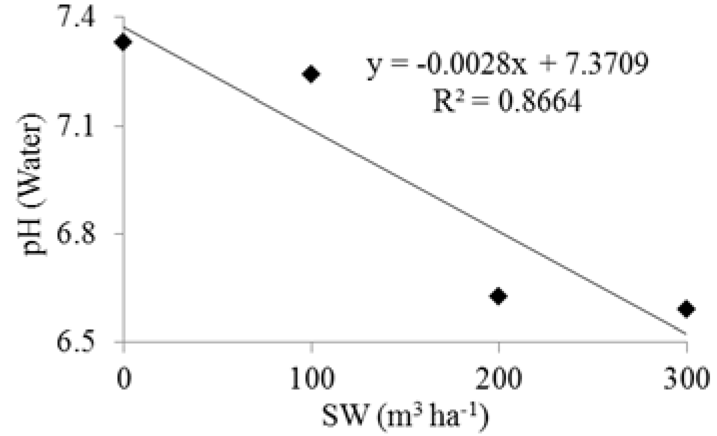

FIGURE 2. Water pH values in soil cultivated with black oat subjected to different SW doses.

CABRAL et al. (2011) did not observe a dependence relation of soil pH and SW doses. Yet SMANHOTTO et al. (2010), who conducted similar studies in the same experimental area, found average values of the aqueous soil extract pH, at 59 DAS, higher for the highest SW dose of 300 m^3 ha^{-1}, which differed significantly from the control (0 m^3 ha^{-1}) and the dose of 100 m^3ha^{-1}

The application of SW showed significant results for Ca levels, where the highest application rate corresponded to the smallest amount of Ca found (Figure 3).

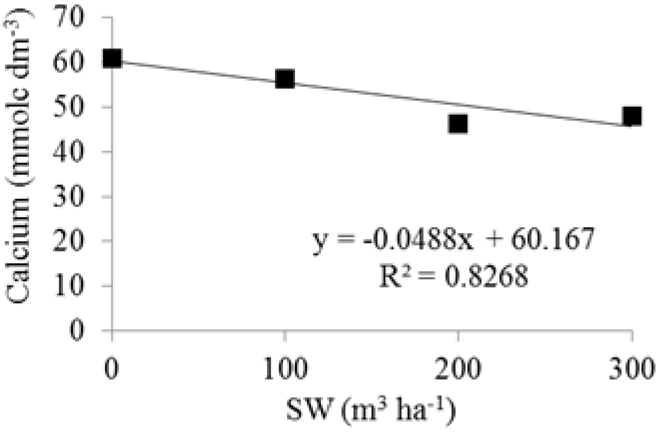

FIGURE 3. Calcium level in soil cultivated with black oat subjected to different SW doses.

CABRAL et al. (2011) also found such downward trend in the Ca concentration depending on SW. An opposite trend was found by DAL BOSCO et al. (2008), which found an increase in Ca levels, from 288 mg L^{-1} to 558 mg L^{-1}.

MENDONÇA & ROWELL (1994) reported that small changes in Ca^{2+} levels in the soil can occur due to the low concentration of this element in the wastewater or its high retention by organic matter (CAOVILLA et al., 2010), since they did not observe such changes in the soil after application of SW in Dystroferric Red Latosol, grown with soybeans. These results also diverged from CASSOL et al. (2012), who observed an increase in the Ca^{2+} content in the layer of 0-2.5 cm when applied at a dose greater than or equal to 100 m^3 h^{-1}, SW and in the layer of 2.5-5 cm when the dose was of 200 m^3h^{-1}.

In Figure 4, there is a positive linear behavior in the content of Na^+ in the soil with the increase of SW doses. It is also noted that the same behavior was observed in the leachate analysis for this nutrient where the doses were increased in relation to the increase in SW application (Table 5). It is necessary to be cautious about Na^+ content, since high concentrations in the soil solution compared with Ca^{2+} and Mg^{2+} can cause deterioration of the soil structure by the dispersion of colloids and subsequent blockage of the macropores, causing decrease in permeability to water and gases (HOMEM et al. 2014).

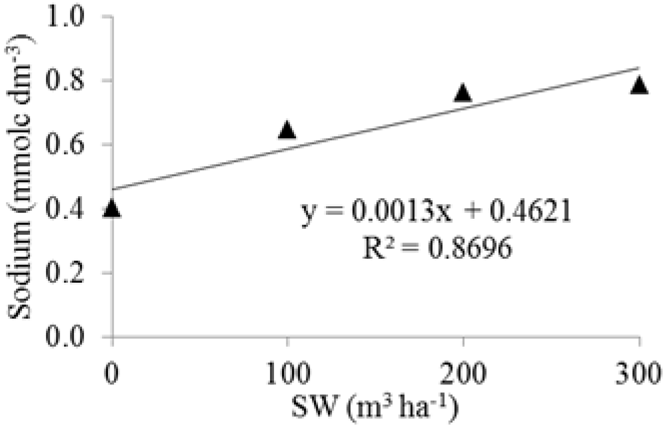

FIGURE 4. Content of sodium in soil cultivated with black oat subjected to different SW doses.

As can be seen in Table 4, the fertilization system with several SW dosages significantly increased the levels of Cu^{2+} and Zn^{2+} in soil, the average value found for the dosage of 0 m^3 h^{-1} was 7.24 mg dm^{-3} and for the dosage of 300 m^3 h^{-1} was of 9.99 mg dm^3 for copper. As for Zn^{2+} concentrations, they were 2.70 mg dm^{-3} and 13.3 mg dm^{-3} for SW dosages 0 m^3 h^{-1} and 300 m^3 h^{-1}, respectively. These differences in the availability of Cu^{2+} and Zn^{2+} in soil must be attributed to the addition of nutrients from the organic sources used in this study.

These metals are usually associated with organic compounds, mainly linked to humic substances. So after applying SW, it is necessary that the organic compounds are mineralized for the release of metals, favoring the accumulation in the soil surface layers and hence the transfer of such elements through surface runoff (GIROTTO et al., 2010; SCHERER et al.; 2010). However, metals when added to the soil via SW have little mobility, accumulating in larger quantities in the surface layer, without further environmental leaching risks (Table 5) (SCHERER et al., 2010).

In Figure 5, there is a positive linear behavior of Cu^{2+} and Zn^{2+} in relation to the SW doses applied, that is, the higher the dose applied, the higher the content of nutrients found in the soil. According to HEINRICHS et al (2001), the Cu^{2+} concentrations in the soil above 0.8 mg L^{-1}, are considered high levels for soil. Note that the average of values is above this threshold (Table 4).

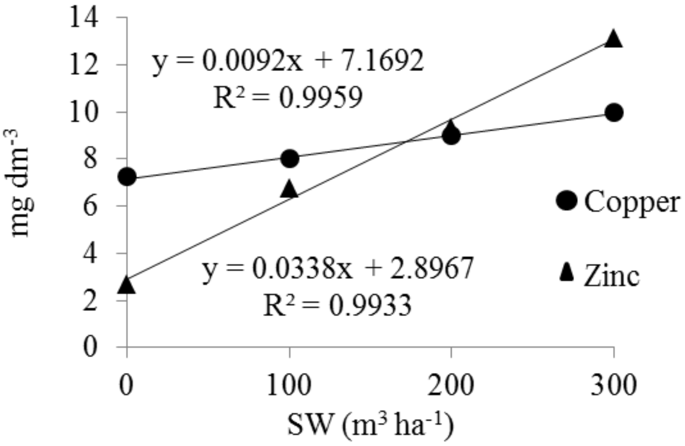

FIGURE 5. Copper and zinc content in soil cultivated with black oat subjected to different SW doses.

As for the Cu^{2+} and Zn^{2+} levels in the leachate, no significant differences between the means of the SW factor or MF factor were found (Table 5).

These results corroborate those obtained by SCHERER & NESI (2009), which showed that the addition of poultry manure and/or pork increased Cu^{2+} and Zn^{2+} content in the surface layer (0-20 cm) soil, especially in direct planting system. The authors emphasized the effect of manure in Cu^{2+} and Zn^{2+} soil contents, regardless of tillage system, restricted to the first 20 cm. DAL BOSCO et al. (2008), studying different application doses (0, 100, 150 and 200 m^3 h^{-1}), also obtained an increase in Cu^{2+} contents, but without any significant differences for Zn^{2+}. Different results were presented by OLIVEIRA et al. (2001), who showed greater Cu^{2+} content in the surface layer and innermost layer. According to the authors, these results show that the Cu^{2+} concentrated in the surface layer due to higher levels of organic matter and in the deepest layer due to the very origin of the soil. The intermediate layers, however, where the levels were much lower for Cu^{2+}, reflect the region which accounts for higher volumes of roots and from where larger concentrations of nutrients are absorbed by crops (STEINER et al., 2011).

It is observed in Table 4 that the Cu^{2+} value had a smaller variation compared to Zn^{2+}, but both elements increased with the increase in SW doses. According to OLIVEIRA & MATIAZZO (2001), the smaller mobility of Cu^{2+} is usually attributed to the formation of stable organometallic complexes and low solubility. Nevertheless, that, in addition to the complexation with organic substances, binding can occur with non-exchangeable soil fractions, such as, for example, iron oxides and manganese. The authors stated further that a greater or lesser mobility of heavy metals such as Cu^{2+} and Zn^{2+}, is determined by soil characteristics such as levels and types of clay, pH, CEC and MO which influence the reactions of adsorption/desorption, precipitation/dissolution, complexation and redox. COUTO et al. (2010) in property with successive applications of SW found significant differences for Cu^{2+} and Zn^{2+} compared to SW doses. This variation was from 0 to 18 mg dm^{-3} for Cu^{2+}, and from 6 to 42 mg dm^{-3} for Zn^{2+}. According to BERENGUER et al. (2008), high levels of these metals in the soil can cause plant phytotoxicity and enhance water contamination, when some of its forms are transferred by superficial runoff or leaching (GIROTTO et al., 2010).

Regression analysis demonstrates a positive linear effect of the application of SW doses on $NO_3^- + NO_2^+$ content in soil cultivated with black oats (Figure 6).

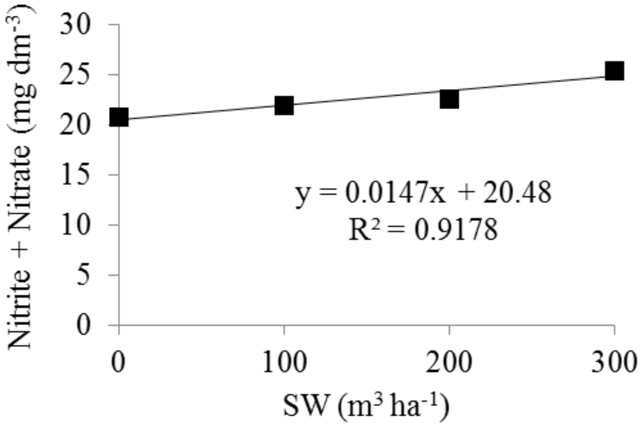

FIGURE 6. Nitrite + nitrate content in soil cultivated with black oat subjected to different SW doses.

According to SCHERER et al. (1996), nitrogen present in the SW is up to 70% in ammonium form (NH_4^+), susceptible to volatilization, which can vary from 5 to 75%, depending on climatic factors, such as rainfall. The pH is the most influential parameter in this process; however, in the range of values observed in this experiment pH effect is reduced.

AITA & GIACOMINI (2008) in an experiment with SW application in soil cultivated with maize noted that in the three years of the experiment, the amount of NO_3^- increased rapidly in the soil surface layers. This rapid onset of NO_3^- in the soil occurred because of high nitrification of ammonia nitrogen from manure, as evidenced by AITA et al. (2007) in a field experiment. Where the ammonia nitrogen applied with liquid waste in no-tillage was completely nitrified between 15 and 20 days after the application of manure.

No significant differences were observed for any form of NO^{3+} NO^{2+} in the leachate, both for SW and MF (Table 5). DAUDÉN & QUÍLEZ (2004), MAGGI et al. (2011) and SMANHOTTO (2008) in their experiments with SW found no significant differences in the concentrations of these elements in the leachate either.

The leachate electrical conductivity was higher with mineral fertilizer (Table 5). This result was expected because the used mineral fertilizer was NPK.

The analysis of the leachate (Table 5) revealed that the Na^+ content increased according to the SW doses applied (Figure 7). The increase in the Na^+ content in the leachate is worrying because some of this ion is leached normally because of its strong adsorption to colloids, which can lead to soil sodification. However, such problem is not observed in all treatments, because the highest concentration observed (PST = 0.71%) was lower than the threshold for classification of sodic soils (PST>7%).

TABLE 5. Mean values for pH, Ca, Mg, Mn, K, Na, Cu, Zn, EC, nitrite and nitrate for different SW doses, presence or absence of MF in the leachate from the soil cultivated with black oat.

Treatments	pH	Ca	Mg	Mn	K	Na	Cu	Zn	CE	NO_2^-	NO_3^-
SW											
0	6.93	66.59	0.40	0.01	3.69	5.21*	0.03	0.07	159.18	0.14	0.02
100	6.82	60.98	0.39	0.01	3.73	5.93*	0.03	0.06	154.77	0.15	0.06
200	7.05	65.32	0.39	0.01	3.82	6.92*	0.03	0.06	144.51	0.14	0.84
300	7.02	60.68	0.37	0.01	4.00	8.81*	0.03	0.07	181.71	0.11	1.70
Mineral Fertilization											
Present	6.84	64.97	0.38	0.01	4.16	6.39	0.03	0.07	176.75a	0.14	0.57
Absent	7.05	61.99	0.39	0.01	3.50	6.95	0.03	0.06	144.68b	0.13	0.67
Mean	6.95	63.39	0.39	0.01	3.81	6.72	0.03	0.07	160.04	0.13	0.65
CV (%)	5.43	62.33	32.28	0.37	57.92	26.86	0.64	31.37	21.72	52.24	95.80

* Significant regression at 5% significance level. CV: coefficient of variation. Levels in mg L^{-1}.

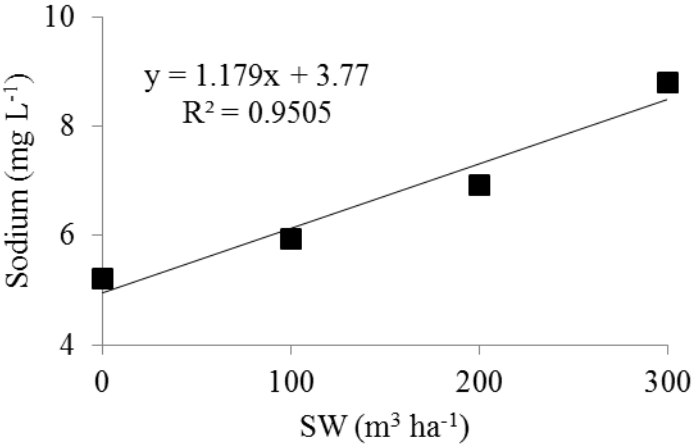

FIGURE 7. Sodium content in leachate cultivated with black oat subjected to different SW doses.

CONCLUSIONS

Considering the experimental results, it can be concluded that:

- The swine wastewater and mineral fertilization factors did not provide significant effects when combined; but induced significant differences in isolation.

- The application of swine wastewater favored: the soil, with significant increase in the concentrations of sodium, copper, zinc, nitrite + nitrate and significant reduction in pH and calcium; in the leachate, significant increase in sodium.

- The use of mineral fertilizer comprising nitrogen, phosphorus and potassium, induced: in the soil, a significant increase in phosphorus, potassium and electrical conductivity and a significant reduction in magnesium; in the leachate, significant increase in electrical conductivity.

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