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The effect of swine raising wastewater in the development of millet (*Pennisetum glaucum* L.), soil and leachate

Vanessa Aline Egewarth[1]*, Jonas Francisco Egewarth[1], Maritane Prior[2], Edmar Soares de Vasconcelos[1], Marcos Vinícius Mansano Sarto[3], Kaian Albino Corazza Kaefer[1], Gustavo Moratelli[1], Hugo Franciscon[1], Andressa Strenske[1] and Caroline Thais Eckert[2]

[1]State University of West Paraná, Marechal Cândido Rondon – Paraná – Brazil, street Pernambuco, Number 1777, Zip Code: 85960-000, Box: 91, Center, Brazil.
[2]State University of West Paraná, Cascavel – Paraná – Brazil, street Universitária, Number 2069, Zip Code: 85819-110, Jardim Universitário, Brazil.
[3]State University Paulista Júlio Mesquita Filho, Botucatu – São Paulo – Brazil, street José Barbosa de Barros, number: 1780, Zip Code: 18610-307, Box: 237, Brazil.

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The experiment was conducted in a protected cultivation in the Marechal Cândido Rondon, PR, Brazil. The experimental design was constituted of randomized blocks with six piggery wastewater doses (0, 25, 50, 100, 200 and 400 m³ ha^{-1}) in four repetitions. The variables evaluated were: number of tillers, plant height, dry matter, leaf area, leaf number, potassium content, phosphorus content and crude protein in the culture, leachate and soil analysis. The number of tillers increased linearly with the addition of SRW doses. At the beginning of the development of millet culture, swine raising wastewater (SRW) application causes a decrease in plant height; however, over the course of time, this management increases those values. There was an increase in the number of leaves at the beginning, and leaf area at the end of the development of millet crop. The SRW doses applied did not cause increase in phosphorus and potassium contents in plants, raising only the crude protein. The dry mass is highly influenced by the increase in SRW doses, with their highest levels in a dose of 319.75 m³ ha^{-1}. The SRW doses cause reduction in soil pH and its constituents are not leached.

Key words: Fertilization, swine dejects, nutrient leaching.

INTRODUCTION

In the southern region of Brazil, pig farming is one of the most important activities, and it represents almost 50% of all national production (SEAB / DERAL, 2013). As a result of the increased production, a large volume of waste is generated. Given its pollution potential, these wastes require specific treatments established by environmental protection laws that, in some situations, and given the inappropriate training of producers for the

*Corresponding author. E-mail: vanessaaline_egewarth@hotmail.com, Tel: +55(45) 32847878. Fax: +55(45) 32847879.

management of such wastes, they are simply treated as pollutants (Cabral et al., 2011).

The use of swine raising wastewater (SRW) will be effective as a biofertilizer if performed properly, due to the fact that it contains macro and micro nutrients such as nitrogen, phosphorus (Hountin et al., 2000; Ceretta et al., 2010), potassium, calcium, sodium, magnesium (Queiroz et al., 2004; Ceretta et al., 2005), iron, zinc, copper (Girotto et al., 2006; Mattias et al., 2010) and others that can contribute to reduce the use of chemical fertilizers on crops, easing production costs, and thus, increasing the income of rural properties (Berwanger, 2006; Vielmo, 2008; Dal Bosco et al., 2008).

Pearl millet (*Pennisetum glaucum* (L.) R. Brown) is a grass of tropical origin, annual summer, easy deployment and management, which stands out for its adaptation to a wide range of environments and to different conditions of climate and soil, being characterized by its precocity, its high potential of production and its nutritional quality (Tabosa et al., 1999).

Among the species used as cover crops and green manure, millet (*P. glaucum* (L.) R. Brown), is characterized by the production of straw in large quantities and with characteristics of greater persistence of the soil (Silva et al., 2010), for its high capacity of soil nutrient extraction, with large advantages of recycling, especially N and K, reducing leaching risks (Leite et al., 2010).

The composition of the SRW varies according to the production system used in each farm, by setting the degree of dilution of waste and its physico-chemical characterization (Castamann, 2005). Thus, to meet the nutritional needs of a particular culture, there is a concern about the possibility of contamination of groundwater by the movement of ions (Melo et al., 2006). Another problem is the possibility of soil and water contamination due to the high concentration of heavy metals, such as Zn and Cu, which the pig slurry has (Gräber et al., 2005; Mattias, 2006).

According to Prior (2008), inadequate application without a previous assessment of possible impacts that may be generated by SRW, is one of the problems found in many properties in the western region of Paraná - which concentrates 40% of swine raising of the State. This happens due to the lack of technology enhanced to use this material, and it may possibly contaminate groundwater, rivers and soils.

The above work has been prepared on the assumption that the application of high doses of swine raising wastewater contributes in the development of millet, but at the same time, can cause contamination of soil and groundwater. In this context, this study was aimed to evaluate possible effects of the application of SRW rates, for the concentrations of macro and micronutrients in the soil, potassium, calcium, magnesium, manganese, iron, copper and zinc in the leachate, and growth parameters in culture millet, sown in Polyvinyl chloride (PVC) pipes.

MATERIALS AND METHODS

The experiment was conducted in a protected cultivation in the Horticulture Station and Protected Cultivation "Prof. Dr. Mario César Lopes to the Experimental Stations Center of Universidade Estadual do Oeste do Paraná - UNIOESTE, Campus Marechal Cândido Rondon, PR (coordinates 54° 22'W longitude and 24° 46'S latitude and an altitude of 420 m). The climate, according to Köppen (Critchfield, 1960) is the subtropical humid mesothermal Cfa dry winter, with rainfall well distributed throughout the year and hot summers. The average temperature of the coldest quarter varies between 17 and 18°C and in the hotter quarter between 28 and 29°C (IAPAR, 2007).

The treatments applied to the plots consisted of six SRW application rates (0, 25, 50, 100, 200 and 400 m^3 ha^{-1}), and 24 soil columns made of PVC pipe cross-section of 0.20 m in diameter and 0.70 m long were used, with a capacity of 19 L of soil, considering each column as an experimental unit.

At the bottom of the tube, a 20 mesh plastic screen was attached. A 5 cm layer of crushed stone No. 1 was used to help in the leachate filtering. The tubes were coupled in 18 L plastic pots (with closed bottom) to store the leachate and the spaces between the tube and the pots were sealed with a plastic foil, to avoid the mixture of the irrigation water along with the leachate. The sections were filled with soil, close to the surface.

The soil used in the experiment classified as eutrophyc red latosol (Oxisol) was collected from agricultural land at 0 to 20 cm and after being dried in shade and sieved on a 0.4 mm sieve, we carried out sampling for chemical caracterization (EMBRAPA, 2009), whose analysis showed the following characteristics: pH 4.44; Mo (mg dm^{-3}): 20.51; P ($cmol_c$ dm^{-3}): 16.91; H + Al ($cmol_c$ dm^{-3}): 4.85; Al +3 ($cmol_c$ dm^{-3}): 0.2; K ($cmol_c$ dm^{-3}): 0.46; Ca ($cmol_c$ dm^{-3}): 5.26; Mg ($cmol_c$ dm^{-3}): 1.15; SB: 6.87% and V: 58.67. Liming was done according to the methodology of Gianello et al. (1995), getting set the amount of 1.77 t ha^{-1} dolomitic limestone with PRNT 75% to 415 g in all the work for soil acidity correction.

The millet sowing (cv. BRS 1501) was manually held on October 26, 2012 leaving only one plant per section. We added about 30 g of straw (composed of Tifton grass hay) around the plants to protect the soil, by preventing the surface compaction caused by irrigation. The irrigation was manual and daily, with the help of sprinklers in accordance with the needs of the crop during its development.

The SRW was collected in a rural property located in the district of Novo Três Passos, in the city of Marechal Cândido Rondon – PR, in a pig farm in the finishing phase, which had already gone through the anaerobic process in an indian digester. Two samples of the residue were collected. One sample was sent to the laboratory for evaluation of total N (Methods of Analyses of the Association of Official Analytical Chemistist). The other sample was stored in a plastic bottle and frozen for a period of 15 days. After thawing, the sample was subjected to perchloric nitro digestion, according to the methodology described by Lana et al. (2010), for analysis of other chemical elements. The analysis showed the following composition: N (mg L^{-1}): 2240; P (g kg^{-1}): 0.4; K: (g kg^{-1}): 9.79; Ca (g kg^{-1}): 0.89; Mg (g kg^{-1}): 0.5; Cu (mg kg^{-1}): 36; Fe (mg kg^{-1}): 77.25; Mn (mg kg^{-1}): 12.75; Zn (mg kg^{-1}): 26.5.

The application of SRW was held on November 15, 2012, at the beginning of the vegetative cycle, before the culture starts its tillering (20 days after sowing - DAS). SRW was manually applied with the aid of a pipette, which was also used to dose the amount applied per plot, taking great care of the residue to be deposited uniformly over the entire area of the PVC pipe. The prescribed doses were based on an average of swine manure applied per hectare with manure spreader, about 150 m^3 ha^{-1}, commonly used by producers in the region as a means of material waste and grazing fertilization. The doses were applied following the randomized complete block design with four replications.

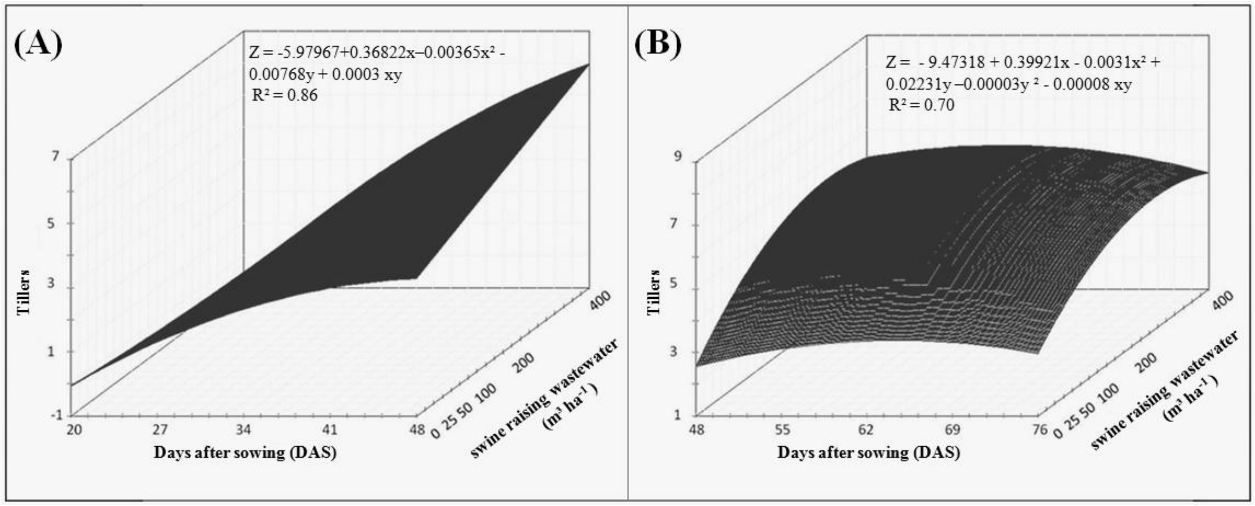

Figure 1. (a) Surface plot representing of number of tillers under the effect on doses of swine wastewater, from 20 to 48 days after sowing. (b) Surface plot representing of number of tillers under the effect on doses of swine wastewater, from 48 to 76 days after sowing.

During the experiment at 20, 27, 34, 41, 48, 55, 62, 69 and 76 days after sowing (DAS), the tiller number and plant height were evaluated. In the count of the tillers, all those which started tillering process were considered. For the plant height measurement, a measuring tape graduated in cm was used, and the distance between the ground surface and the maximum height reached by the leaves were measured, considering the point at which they are bent.

At 48 and 76 DAS, an evaluation was made of the dry mass of stem + sheath, dry mass of leaves, leaf area, leaf number, nitrogen content, potassium and phosphorus in plants, concentrations of potassium, calcium, magnesium, manganese, iron, copper and zinc in the leachate, dry weight of roots and waste, as well as macro and micronutrient concentrations in the soil. To obtain the dry weight values, the plants were cut at a height of 0.20 m above the ground, separated into leaves and stems plus sheath, and packaged in paper bags. Later, they were taken to a forced air circulation oven at 65°C for 72 h to determine the dry weight, which, when are added, represent the total dry matter according to the methodology described by Benincasa (2003).

To determine the dry mass of the root system, the pots were broken and the roots washed under running water to remove the excess of soil with subsequent drying in a forced air circulation oven. For leaf area determination, the authors used the destructive method of area known in cm^2, considering the dry mass of leaves (DML) and dry mass of the known area of sample (sample DM) according to the methodology described by Silva and Queiroz (2002).

After drying the fraction of the aerial part of the plant, the stems + sheath and the leaves, as well as the root system and the residual of the stems, they were ground separately in Wille type mill and weighed samples of 0.20 grams for further realization of sulfuric digestion. The digestion product ammonium sulfate [(NH4) 2SO4] was treated with excess of strong base (sodium hydroxide - NaOH - 10 mol L^{-1}) and subjected to distillation. With the values of the volume spent in the titration, the nitrogen (N) calculations were done in g kg^{-1} and the protein ones by multiplying the value of N by 6.25. After dilution of the digested material, the reading was carried out in a flame photometer previously calibrated and using the equation, the concentrations of potassium (K) in g kg^{-1} were obtained. By reading absorbance performed in a spectrophotometer at 725 nm, the phosphorus concentration values in kg^{-1} g were obtained, according to the methodology described by Lana et al. (2010).

At 76 DAS, the pots were broken, soil samples from each pot in depth 0 to 20 cm were packed in plastic bags, taken to the Physics Laboratory and Soil Classification from UNIOESTE, where they were transferred to paper bags and taken to the oven at 105°C until the obtainment of constant weight. Later they were sent to the Environmental Chemistry Laboratory and Instrumental from UNIOESTE and subjected to analysis for the determination of macro and micronutrients according to the methodologies described in Raij et al. (2001).

The leachate samples were stored in plastic bottles and frozen until the time of reading. Twenty-four hours prior to the readings, the samples were removed, thawed and sent to the Environmental Chemistry Laboratory and Instrumental from UNIOESTE, where readings were performed to determine the composition of its nutrients: K, Ca, Mg, Cu, Zn , Mn and Fe.

After being tabulated, the data were submitted to analysis of variance to verify its significance. When there was a significant effect, the average of the variables assessed over the time was studied by response surface with the aid of computer application GENES (Cruz, 2013). On the other hand, the averages of the variables assessed only at 48 and 76 DAS were studied by regression analysis, using the software Sisvar (Ferreira, 2011).

RESULTS AND DISCUSSION

The response surface generated by the analysis of the variable number of tillers, evaluated in the first period of 20 to 48 DAS (Figure 1a), in relation to the applied doses of SRW, was squaring in time and increasing linear over time regarding the doses. Furthermore, it was observed that the increase in doses slows the maximum production of tillers, showing that this variable takes more time to stabilize with higher doses. The equation found is from $Z = -5.97967 + 0.36822x – 0.00365x^2 - 0.00768y + 0.0003xy$ with $R^2 = 0.86$, the value of X = 25.6; Y = -604.4 and the maximum point of 1.054698 tillers.

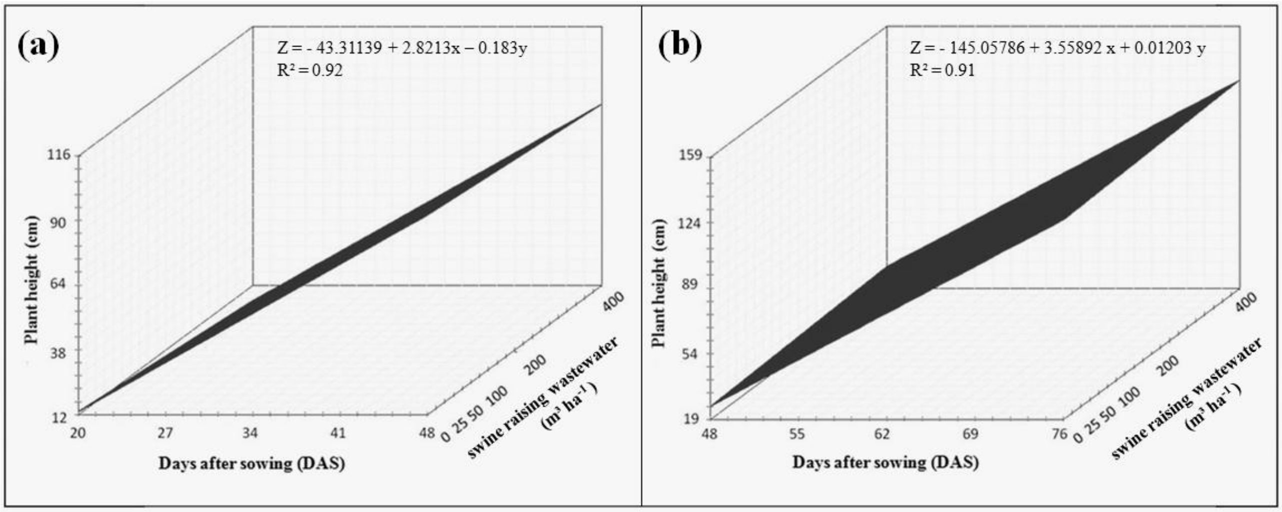

Figure 2. (a) Surface plot representing of plant height under the effect on doses of swine wastewater, from 20 to 48 days after sowing. (b) Surface plot representing of plant height under the effect on doses of swine wastewater, from 48 to 76 days after sowing.

In the second period (Figure 1 (b)), the effect was quadratic over the time and with an increase in the doses. The generated equation is $Z = -9.47318 + 0.39921x – 0.0031x^2 + 0.02231y – 0.00003y^2 - 0.00008xy$ with R^2 0.70. To 60.63 days after sowing and at a dose of 290.99 $m^3\ h^{-1}$, the maximum point found to the equation was 5.88 tillers.

The increase in tillering is associated with the higher availability of nutrients, which provides increased speed of formation of buds and initiation of the corresponding tillers. According to Freitas et al. (2005), appropriate fertilizer levels provide maximum tillering, while deficiencies increase as the number of dormant buds, reducing the number of tillers. Nevertheless, Mondardo et al. (2011) observed an increase in the number of tillers to the dose of 50 $m^3\ h^{-1}$, with subsequent reduction.

There was an increase in plant height in the first assessment period (Figure 2 (a)) increasing linearly over time. However, the increase of SRW doses caused a small decrease of this variable, the equation $Z = -43.31139 + 2.8213x – 0.183y$ with R^2 of 0.92. In the second period the behavior was also in a linear crescent way, despite the effect of the doses being small. The equation found for this variable was $Z = -145.05786 + 3.55892x\ 0.01203y$ with R^2 of 0.91. In both, the authors observed that the days after sowing had greater effects on plant growth than the doses applied. In other words, in every day that passed the plants increased 2.8213 and 3.55892 cm high respectively, and each m^2 of SRW applied per hectare increased 0.183 and 0.01203 cm high respectively.

Geraldo et al. (2000) when assessing the growth of four cultivars of millet (BN-2, IAPAR, HKP and Guerguera) observed that the average of plant height at 25, 30, 45 and 60 days after sowing was 6, 10, 56 and 170 cm, respectively. On the other hand, Sobrinho et al. (2008), in his work which were evaluated fertilizer sources in millet cultivation in the semi-arid, found no differences in plant height when compared the fertilization sources (legume - 95.61 cm, NPK - 111.30 cm, cattle manure - 113.61 cm and goat manure - 132.47 cm) but only the legume was like the control that had an average height of 36.04 cm.

Regarding the leaf area, we observed that there was only a statistically significant difference of 5% of probability for the second cut (Figure 3 (a)), whereas in the number of leaves (Figure 3 (b)) there was difference in the first cut, both in a linear crescent way. The leaf area depends intimately on soil fertility, climatic conditions, the spacing and the genetic material efficiency in using the available nutrients. As photosynthesis depends on the leaf area, the crop yield will be greater the faster the plant achieves the maximum leaf area and the longer this variable remains active (Pereira and Machado, 1987).

Tomazella (2005) attributes that the increase in the leaf area is due to the larger number of photosynthetically active leaves, brought about by the expansion of leaf length. The number of leaves is a fairly stable genotypic characteristic; however, although it is genetically determined, it is also affected by environmental and handling factors (Mondardo, 2010). According to Costa et al. (2005), being the leaf the carbohydrate production center that will supply the vegetative and reproductive organs, its sanity and also its number are the essential factors to ensure the effective yield of the crop.

Gonçalves and Quadros (2003) had 4.2 leaves per tiller when evaluating a millet pasture under cattle grazing. On the other hand, Mondardo et al. (2011) found 6.32 leaves per tiller at a dose of 75 $m^3\ ha^{-1}$ of swine manure. Through analysis of variance, there was no significant

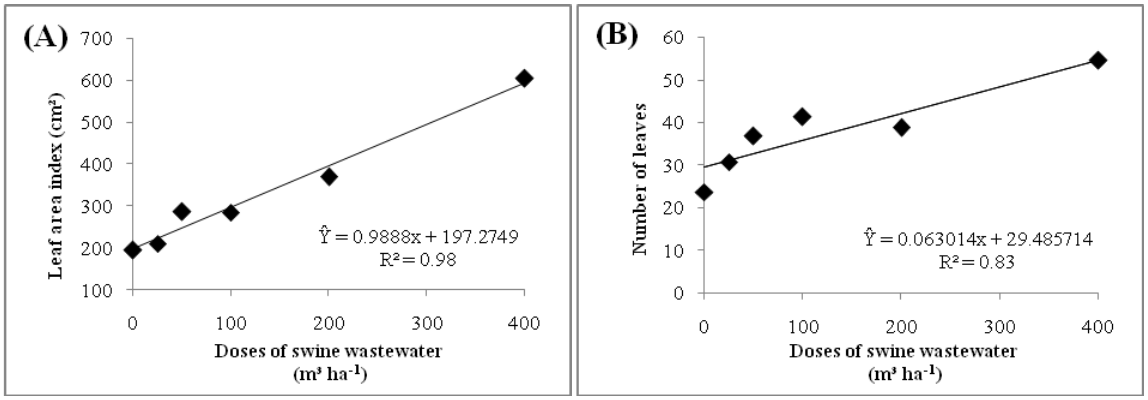

Figure 3. (A) Leaf area of second cut –76 DAS, (B) Number of leaves of first cut – 48 DAS.

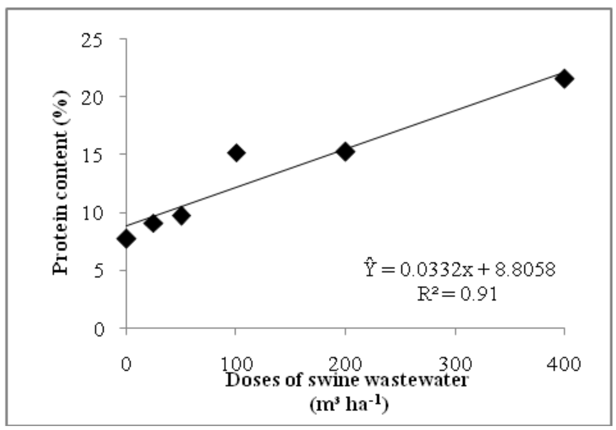

Figure 4. Crude protein content (%) of millet culture under the effect on doses of swine wastewater.

statistical difference at 5% probability for the potassium and phosphorus contents in the fractions of the evaluated plants, as to the content of protein in the plant; there were significant differences in the levels found in the first cut leaves.

This result is related to the nitrogen content that the culture absorbed during its development, since this nutrient is important for the development of the culture. According to EMBRAPA (2003), with the purpose of holding the fodder, silage or grazing, it is recommended to apply between 20 and 30 kg of N ha^{-1} at sowing and 60 to 80 kg N ha^{-1} in cover at the beginning of tillering. If planting is carried out in spring / summer in areas that have not suffered any previous fertilization, the soil must be corrected as if to planting a forage of average demand, with the nitrogen being used at the base, 50-100 kg ha^{-1} (EMBRAPA, 2003).

Through the study by regression analysis, we observed an increase of protein in the leaves in the first cut (48 DAS) in a linear crescent way, as the applied SRW doses were increased (Figure 4). Amaral et al. (2008) when studying three varieties of millet (BRS1501, BN 1 and Common) at 70 days of growth, found an average crude protein content (9.86%) similar to those obtained with the lowest doses studied by Mondardo et al. (2011), that in assessing the behavior of millet under doses of swine manure culture, observed quadratic effect on crude protein content, being the lowest content (8.77%) obtained with doses of 13 m³ ha^{-1}, from which the content rose to 13.82%, with a maximum dose of manure (115 m³ ha^{-1}) applied. Heringer and Moojen (2002) also observed an increase in crude protein in response to nitrogen application in millet. On the other hand, Kollet et al. (2006) found 15.42% values of protein for millet with 42 days of age. Mondardo et al. (2011) observed an increase in crude protein of oat in response to application of pig slurry doses up to 50 m³ ha^{-1}.

Guideli et al. (2000) when evaluating production and quality of millet fertilized with nitrogen, noted that crude protein showed differences between fractions, being greater in the leaf (22% on average) in relation to the stem (14% on average). Similar behavior was observed by Aita (1995), in millet common cultivar fertilized with300 kg ha^{-1} N, whose average protein content in the leaf

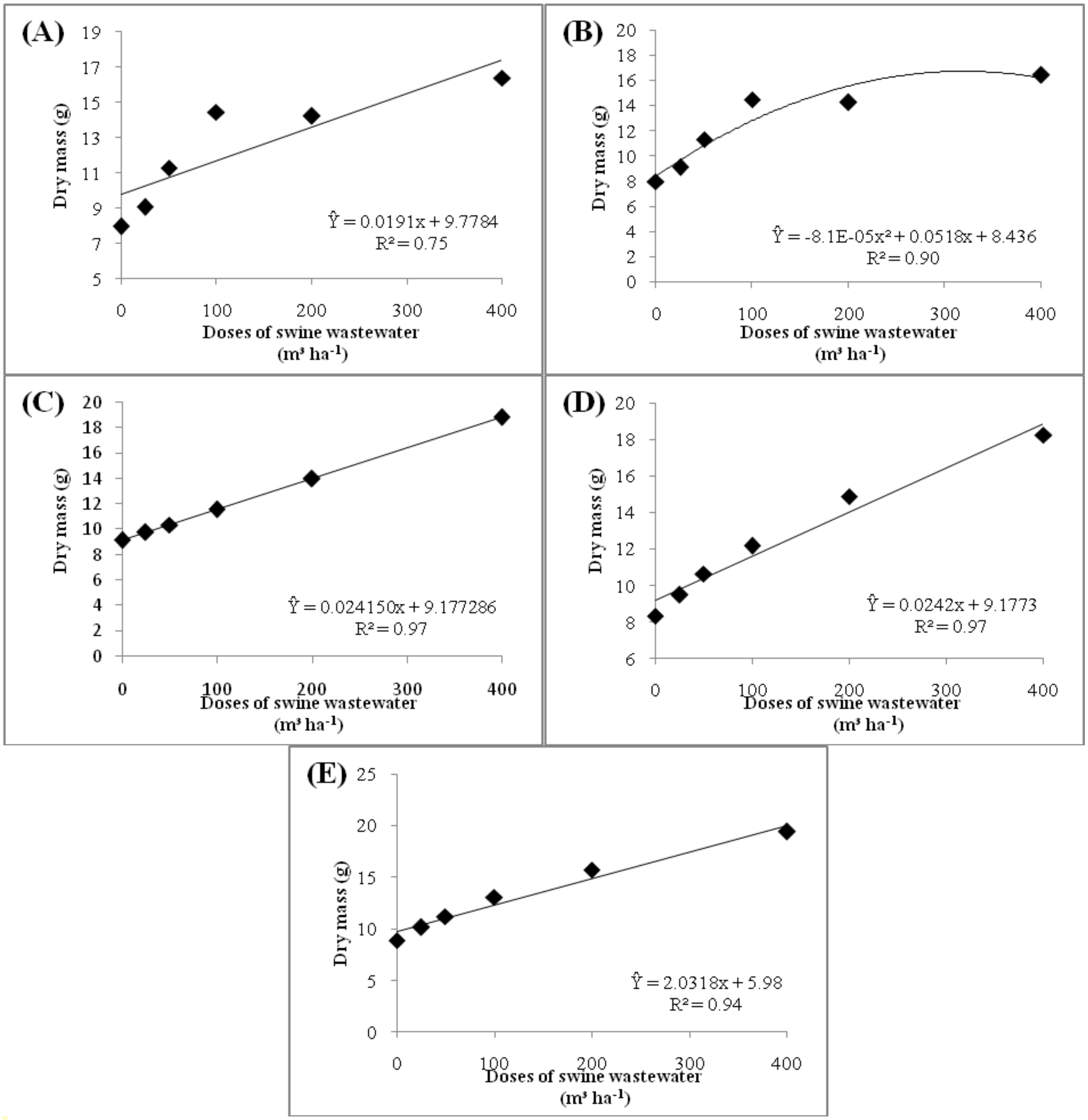

Figure 5. (A) Leaf dry mass of the first cut, (B) Leaf dry mass of the second cut, (C) Culm and sheath dry mass of the second cut, (D) Residual dry mass, (E) Total dry mass of millet culture under the effect on doses of swine wastewater.

and stem was 11.3 and 7.4%, respectively. However, in this paper, the protein content only found in the first cut leaves increased 13.83% from the higher dose applied (400 m³ ha^{-1}), in relation to the low treatment (0 m³ ha^{-1}). Since this was a linear effect, it is believed that plants fertilized with doses above 400 m³ ha^{-1} of SRW in the studied conditions, have higher crude protein contents. When evaluating the leaves dry mass, stem + sheath, roots, residual, and total dry matter of the culture, by analysis of variance, we observed a significant statistic difference at 5% of probability for dry mass of leaves, both for the first and for the second cutting, dry matter of the stem + second cut sheath, for residual dry matter mass and, consequently, for total dry matter mass. Through a study using regression analysis (Figure 5), it can be seen that there is an increase in the dry matter mass of the first cut leaves, stem dry matter plus sheath of the second cut, residual dry matter and dry matter mass of the total plant, linearly. As for the second cut, the increase in dry matter mass in the leaves occurred in increasing quadratic response.

The dry matter mass of the second cut sheets had its

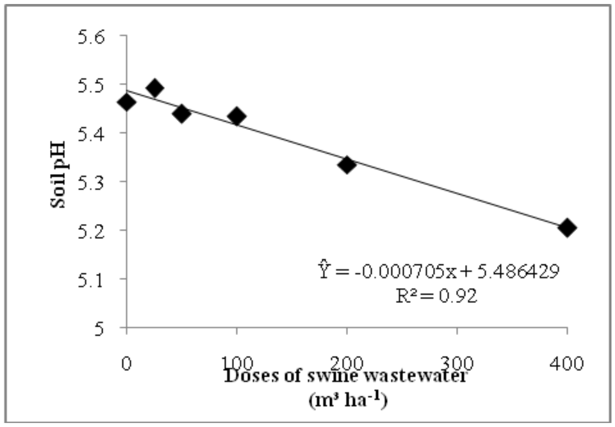

Figure 6. Soil pH after the cultivation of millet under the effect on doses of swine wastewater**.**

higher yield with the dose of 319.75 m³ ha^{-1} of SRW, with dry matter mass of 16.72 g per plant. Mondardo et al. (2011) also found a quadratic effect of the application of liquid swine manure on the dry matter mass production of leaves, stem and root system ($p > 0.05$). The dry matter mass of stems decreased to the dose of 43 m³ ha^{-1}, while the dry matter mass of the leaves and root system rose to the doses of 75 and 50 m³ ha^{-1}, respectively. The increase in stems' dry matter mass is a result reported in the literature for the application of nitrogen fertilization (Gomide, 1997; Patês et al., 2007), and this characteristic is essential in the development of tiller and consequently on grazing.

Due to the fact that pig waste has a high concentration of N in its composition, about 2.24 kg of N m^3, the dose of 400 m^3 h^{-1} achieved limits of 890 kg ha^{-1}, on its higher dose, much higher than the recommended, which may have favored this improvement in the development. Likewise, Bellon et al. (2009) found quadratic behavior of the variables in response to doses of swine manure. The minimum dry matter mass production of the stems was obtained with the dose of 45.5 m^3 ha^{-1} of swine manure. The maximum dry matter mass production of leaves, shoots and roots were obtained with doses of 67.9; 65.6 and 56 m^3 ha^{-1}, respectively, equivalent to N doses 89.3; 86.3 and 73.6 kg ha^{-1}.

Buso et al. (2012) when evaluating the dry matter mass production of millet cultivars subjected to various levels of nitrogen fertilization, observed quadratic effect in relation to the application of N and dry matter mass production. On the other hand, Nobrega (2010) and Silva (2010) observed linear effect according to an increase of N doses with the highest production achieved with 80 and 160 kg ha^{-1} of N, respectively, in work conducted with millet.

There was no significant difference between most of the nutrients and soil characteristics evaluated in terms of the SRW doses in millet cultivation. Only the pH was influenced by this source of variation. From the data that consisted significant effect of SRW doses, they were studied by means of regression analysis. There was a linear decrease in the soil pH, decreasing with the increase of applied dose (Figure 6).

In soil with a pH near neutrality, it is possible to find a decrease in pH with the use of the manure (Lourenzi, 2010). This has been observed in the United States by Adeli et al. (2008), who used pig slurry in a soil with an initial pH of 6.9 and, after applying the manure for 15 years, the soil pH decreased to 5.9 in the layer of 0 to 15 cm. According to Lopes (1989) and Guerra et al. (1999), the decrease of the soil pH values over time is due to leaching of bases along the soil profile. Medalie et al. (1994) emphasize that the greater the amount of nitrogen fertilizer, the greater the acidity of the soil due to the release of H + ion.

Conversely, Assmann et al. (2007) working on an eutrophyc red latosol (Oxisol) with an initial pH of 4.52, in the layer of 0 to 20 cm, and applying twice the dose of 80 m^3 ha^{-1} of swine manure, in a period of 156 days observed that the pH rose to 4.79. For Hue and Licudine (1999), the addition of organic residues in acid soils can cause increased pH values in soil water by the adsorption of H + ions in the decaying crop residues, which are part of the non humic fraction of soil organic matter.

Chantigny et al. (2004) reported that increments in soil pH values can be due to the alkaline characteristic of swine manure and also by the dissociation of the manure derived carbonates.

Cassol et al. (2012), when assessing the availability of macronutrients and corn yield fertilized with swine manure applied superficially in dystroferric red latosol, whose pH in the layer 0 to 20 cm was 6.1, cultivated with oats-corn succession in direct planting system in annual doses of up to 200 m^3 ha^{-1}, for nine years, realized that no changes were found in the soil pH. These results agree with assessments of other works, which also found no effect of this kind of animal waste in soil pH Ceretta et al. (2003), Scherer et al. (2010) and Cassol et al. (2011). According to Lourenzi (2010), there is a soil pH balance trend when it receives successive manure application, in a range of approximately 5.0 to 6.0.

The values resulting from the analysis of variance of K, Ca, Mg, Cu, Zn and Fe found in the leachate, collected in the two seasons respectively, were not significant. Prior (2008) when assessing the SRW effect in soil and corn, also did not find potassium in the leachate. However, Maggi et al. (2011), when evaluating the leaching of nutrients in soil cultivated with the application of SRW found concentrations of 84.94 mg L^{-1} K in the leachate. Maggi et al. (2011) also found higher Ca concentrations in the leachate as the increase in rates of SRW, and by regression analysis, the authors observed that this increase was in a linear way, since when comparing the leaching of this mineral, over the time the Ca contents leached were decreasing.

As the calcium in the soil has a stronger absorption when compared with Ammonium, Potassium and Magnesium, its leaching is not so intense and actually not enough to cause concern in terms of loss. This may explain the fact that this mineral does not have significant values when compared to the control. Nevertheless, authors with Furtini Neto et al. (2001) confirmed that the application of the organic waste in the soil increases the leaching of calcium due to the fact that SRW causes the increase of pH, promoting mineralization by increasing the release of CO_2 and consequently the leaching of Ca $(HCO_3)_2$ with water.

Although the absence of copper in the leachate was observed, especially when considered the treatments that received higher doses of SRW, the results corroborate Santos (2010), who also did not find the presence of this element in the leachate. Low Cu mobility in the soil was also commented on by Miyazawa et al. (1996), since Cu is a transition metal, has high affinity (high constant of stability) with organic compounds such as humic acid, fulvic acid, and organic acids soil.

Although pig manure has low concentrations of Cu and Zn, their application in excessive doses can result in accumulation of these elements in the soil, which can cause poisoning not only to plants, but also in other levels of the food chain (Scherer et al., 1996).

Mancuso and Santos (2003), in general, also state that the heavy metals may be toxic to plants and animals. However, there are no case reports of chronic toxicity to plants and animals, due to the disposal of wastewater in the soil as a result of the low concentrations of these elements in the soil in wastewater. As for the infiltration and percolation, heavy metals are retained by the majority of soils, especially when high in organic matter and pH > 7.0. Another factor that contributes to the low mobility of heavy metals is the high clay content in the soil (Kabala and Singh, 2001).

The availability of Mn in the soil depends mainly on the pH, redox potential, the organic matter and the balance with other cations (Santos, 2010). When the pH of soil decreases the H + and Al^3 + Mn compete with the exchange sites, increasing the solubility of Mn in solution (Santos, 2010). Lamy (1983) suggests that although the amount of leached trace elements is less than 1% of the total added, there may be considerable increase when considering the sandy soils with low organic matter content and subject to heavy rains. This may explain the fact that Mn in the assessed leachate was not found, because clay was used as a substrate.

Conclusion

The number of tillers increases linearly with increments in SRW doses. The SRW application causes an increase in plant height from DAS 48 and 28 days after the first cut. The leaf area, dry matter mass of stem + sheath, residual dry matter mass and total dry matter mass, evaluated at 76 DAS and the number of sheets, crude protein content, dry matter mass of leaves assessed at 48 DAS showed linear crescent response to the increase in SRW doses.

The dry matter mass of leaves at 76 DAS had its highest yield with the dose of 319.75 m^3 ha^{-1} of SRW, with a dry matter mass of 16.72 g per plant. The K and P contents in the millet crop, K, Ca, Mg, Cu, Zn, Mn and Fe in the leachate were not affected by doses of SRW. Furthermore, in the soil before, only the pH had changed in relation to the applied doses, decreasing linearly. Finally, before the use of high doses of SRW causes changes in soil pH.

Conflict of Interest

The authors have not declared any conflict of interest.

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