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Effect of biofertilization with cattle urine on the chemical properties of an Oxisol from the Amazon savanna[1]

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ABSTRACT

Soil correctives and mineral fertilizers are important for a sustainable production; however, they are ineffective in the long run, showing the need to apply alternative products. This research aimed to analyze the effect of cattle urine concentrations on the chemical properties of an Oxisol from the Amazon savanna. The experimental design was completely randomized, in a split-plot scheme over time, with five replications. Six cow urine concentrations (0, 10, 20, 40, 80 and 100 %) were randomized in the plots, and five soil collection times for evaluation (0, 7, 14, 21 and 28 days after application) were designated as subplots. At each collection time, the soil chemical properties were determined. The applied cow urine increases the soil pH up to the neutral range. The application of increasing concentrations of cattle urine positively influences the potassium content, sum of bases, base saturation and cation exchange capacity of the soil. The levels of organic matter decrease linearly over the evaluation periods, independently of the applied cattle urine concentrations. Among the studied concentrations, that of 80 % is the most recommended to improve the soil chemical attributes.

KEYWORDS: Liquid biofertilizer, soil fertility, soils of the Roraima state savanna.

RESUMO

Efeito de biofertilização com urina bovina nas propriedades químicas de um Latossolo Amarelo da savana amazônica

Corretivos de solo e fertilizantes minerais são importantes para uma produção sustentável, porém, pouco eficientes a longo prazo, revelando a necessidade da aplicação de produtos alternativos. Objetivou-se analisar o efeito de concentrações de urina bovina nas propriedades químicas de um Latossolo Amarelo Distrófico da savana Amazônica. O delineamento experimental foi inteiramente casualizado, em esquema de parcelas subdivididas no tempo, com cinco repetições. Seis concentrações de urina de vaca (0; 10; 20; 40; 80; e 100 %) foram aleatorizadas nas parcelas e cinco épocas de coleta do solo para avaliação (0; 7; 14; 21; e 28 dias após a aplicação) foram designadas subparcelas. Em cada época de coleta foram determinadas as propriedades químicas do solo. A urina de vaca aplicada aumenta o pH do solo até a faixa de neutralidade. A aplicação de concentrações crescentes de urina bovina influencia positivamente no nível de potássio, soma de bases, saturação por bases e capacidade de troca de cátions do solo. Os teores de matéria orgânica decrescem linearmente com o passar das épocas de avaliação, independentemente das concentrações de urina bovina aplicadas. Dentre as concentrações estudadas, a de 80 % é a mais recomendada para melhorar os atributos químicos do solo.

PALAVRAS-CHAVE: Biofetilizante líquido, fertilidade do solo, solos da savana de Roraima.

INTRODUCTION

For centuries intensive agriculture has reduced the fertility status of the soil to a level where even the application of fertilizers at higher rates cannot sustain soil productivity. Allied with this, the intensive use of chemicals is known to cause an immediate effect on agricultural production for a short period, but create long-term harmful effects on the ecosystem and soil health, leading to environmental problems and increased production costs (Pradhan et al. 2018).

Savanna soils usually have low fertility due to their characteristics, such as base saturation of less than 50 %, low cation exchange capacity, and, in some regions, toxicity due to the high rate of aluminum saturation (Gonçalves et al. 2021). These soils are deficient in calcium, magnesium and potassium. Phosphorus, on the other hand, has a low availability under natural circumstances (Sousa et al. 2016).

Against this background, the integrated use of inorganic and organic nutrient sources in agricultural

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production is becoming increasingly important to ensure food security on a sustainable basis, improving soil fertility and reducing the expenses with inorganic fertilizers. Different types of organic materials, such as animal manure, crop residues and animal urine, among others, have been used in crops; however, the amount and availability of nutrients in the organic material vary greatly, what can affect the results and the value of the supplied nutrient (Martins et al. 2015, Choudhary et al. 2017).

Regarding the use of cattle manure and urine as biofertilizer, it is worth noting that, although part of the cattle manure is used as fertilizer, after decomposition, the urine is usually drained as residual material from the farm, which can be considered wasteful, since this source of nutrients is available to farmers for free in their property. Thus, animal manure- and urine-based biofertilizers can be employed to enhance the conversion of unavailable nutrients in the soil into an available form to be taken up by plants (Verma et al. 2017).

The use of cattle urine is considered a favorable agricultural practice for farmers because, among the different organic sources, it can provide the soil and plants with a good amount of nitrogen, as well as containing sulfur, phosphorus, potassium, sodium, manganese, iron, silicon, chlorine, enzymes and hormones (Pathak & Ram 2013). From an agroecological point of view, urine is, therefore, in many ways, suitable for use as a liquid soil biofertilizer, since it is not costly for the farmer, and, when the input is not available on the farm, it is low cost, does not pose health risks to farmers and consumers and is easy to apply, being practically ready for use simply by adding water (Nápoles et al. 2016). There are already reports of the favorable effects of cow urine application on some soils (Silva et al. 2011, Pradhan et al. 2018, Maciel et al. 2019, Coelho et al. 2021, Freire & Lima 2022), but there are no studies regarding its addition to Amazon savanna soils.

In this context, the idea that the cattle urine-based liquid biofertilizer can improve the soil chemical attributes, whether by improving the efficiency of the use of macro and micronutrients or by increasing the base saturation and cation exchange capacity, improving the quality and quantity of organic matter, among other benefits, motivated this study.

Thus, this study aimed to analyze the effect of cattle urine concentrations on the chemical properties of an Oxisol of the Amazon savanna.

MATERIAL AND METHODS

The experiment was conducted in pots arranged on benches at the Universidade Federal de Roraima (2º52'20.7"N, 60º42'44.2"W and altitude of 90 m), in Boa Vista, Roraima state, Brazil, between August 2020 and April 2021.

The collection of the soil used to fill the pots was delimited from an area of 100 m^2. The area has a Latossolo Amarelo Distrófico típico (LAdx) (Benedetti et al. 2011), equivalent to an Oxisol (USDA 1999), located in the geographic coordinates in UTM N 0754038; E 0317779.

The area for soil collection was carefully cleaned, removing all vegetation and impurities. The 0-0.20 m soil layer was excavated, crushed, piled and transferred to fiber bags using a bucket to establish the volume of 12 L of soil in each bag. In this layer, a sample of approximately 1 kg was taken for the chemical analyses. This analysis served as a control of the initial soil composition. There was no correction of soil acidity, so all field attributes were maintained until the application of the treatments.

The 5 L pots were filled, maintaining the humidity according to the field capacity, which was determined by weighing randomly chosen pots and replenishing the water needed to maintain the desired soil moisture.

To determine the amount of water applied, four pots were saturated by capillarity and weighed daily until a constant mass was obtained when they reached the field capacity. The volume of water applied to each pot was obtained by the difference between the average mass of the four pots at field capacity and the daily mass of four randomly chosen pots. The irrigation shifts were adjusted according to the amount of water needed to maintain 80 % of the field capacity, monitoring the amount of water reaching the surface of the bench with three rain gauges positioned next to the pots.

Cow urine was uniformly and homogeneously collected in the municipality of Boa Vista, from a dairy herd belonging to a local producer (Sítio São Judas Tadeu; 2º54'12.9"N and 60º43'58.9"W). After collection, the urine was put into plastic containers, properly disinfected, stored and kept sealed for up to five days before the first application for microbiological fermentation.

A sample of cattle urine was collected and stored in disinfected and closed plastic bottles to avoid ammonia loss. It was kept in a protected environment until its chemical composition was analyzed, such as pH, macro and micronutrient contents (Embrapa 2009). The sample was sent to be analyzed in a laboratory.

The experimental design was entirely randomized, with seven replications. Six concentrations of cattle urine were randomized in the plots (0 % - 5 L of water without cow urine; 10 % - dilution of 0.5 L of cow urine in 4.5 L of water; 20 % - dilution of 1 L of cow urine in 4 L of water; 40 % - dilution of 2 L of cow urine in 3 L of water; 80 % - dilution of 4 L of cow urine in 1 L of water; 100 % - 5 L of cow urine) and the soil sampling times for evaluation (0, 7, 14, 21 and 28 days after the application of cattle urine) were designated as subplots. Each experimental unit consisted of one plastic pot with 5 L capacity.

Within each evaluation day, single soil samples were collected from each pot, which formed a composite sample of each treatment. The samples were mixed, homogenized, sieved and exposed to air under a clean bench in a ventilated area for drying. Subsequently, they were conditioned and stored, so all samples from all evaluation times were analyzed in the same period.

The following variables were studied (Embrapa 2009): soil pH (H_2O); sum of bases ($cmol_c\ dm^{-3}$); cation exchange capacity ($cmol_c\ dm^{-3}$); exchangeable base saturation; hydrogen + aluminum ($cmol_c\ dm^{-3}$); macronutrients ($g\ kg^{-1}$); and organic matter ($g\ kg^{-1}$).

The data set used for the construction of the graphs presented in this study was processed using the R software to perform the analysis of variance ($p \leq 0.05$) and regression analysis, and the best model to express the behavior of the cattle urine concentrations and the soil collection times on the evaluated attributes was selected. To test the homogeneity of variance of the residues, the Breusch & Pagan (1979) test was used. To verify the normality of the errors, the Shapiro-Wilk test was applied.

The graphs were constructed using the GGPLOT2 package from the R language, and the choice of the model selected for each variable was based on the significance of the parameter coefficients and the biological response of the soil. The "t" test was used to test the regression coefficients ($p \leq 0.05$). The maximum technical efficiency dose of cow urine obtained for a quadratic model was calculated based on the first derivative of the regression equation, equaling zero.

RESULTS AND DISCUSSION

Table 1 describes the results found in the chemical analysis of the cow urine used in the experiment during the evaluation period. Urine is an aqueous solution formed by eliminating unnecessary water, inorganic salts and other organic products of metabolism which cannot be accumulated in the blood (Araújo et al. 2009).

The urine pH, as can be observed by the analysis, was considered alkaline, but within the normal range for dairy cattle, what can be proven by the values of other elements studied, such as calcium, because the more acidic the pH, the lower the calcium concentration (Araújo et al. 2009). The urine pH can also be affected by the type of feed given to the animal, microbiological infection and the period during which urine was retained in the animal bladder. The normal pH range in adult cattle is between 7.0 and 9.0 (Church & Pond 1977), what shows that the urine pH of the cows used in this study remained within the physiological parameter.

According to the results obtained by Pathak & Kumar (2003), cattle urine contains nitrogen, sulfur, ammonia, copper, phosphate, sodium, potassium, manganese, carbolic acid, iron, uric acid, urea, silica, silicon, chlorine, magnesium, calcium, lactose, enzymes, creatinine and hydroxides, in greater or lesser amounts, depending on the animal husbandry system and feed. The cattle urine used in this experiment showed higher contents of K (11.3 $g\ kg^{-1}$) and N (6.2 $g\ kg^{-1}$) among the macronutrients, while, among the micronutrients, Fe (4.7 $mg\ kg^{-1}$) and Zn (4.3 $mg\ kg^{-1}$) are the ones that appear in higher concentrations.

Table 1. Chemical attributes of the cattle urine sample used in the experiment as liquid biofertilizer.

Sample	pH	N	P	K^+	Ca^{2+}	Mg^{2+}	Na^+	Fe^{3+}	Cu^{2+}	Mn^{2+}	Zn^{2+}
		$g\ kg^{-1}$						$mg\ kg^{-1}$			
Cattle urine	8.1	6.2	0.12	11.3	0.25	0.51	2.33	4.7	0.9	1.5	4.3

In research aimed at evaluating the effect of phosphorus sources in a pasture on nutrient concentrations in animal excretion, Rodrigues et al. (2008) concluded that nitrogen and potassium are the macronutrients excreted in the highest concentrations by cattle urine, and that calcium and phosphorus concentrations in urine contribute little to soil nutrient recycling. In addition, the authors concluded that nitrogen and potassium from animal excretions return to the ecosystem mainly through urine, while phosphorus and calcium return more through feces, what was proven in this research because, among the macronutrients present in the urine, P and Ca appeared in smaller quantities.

The tested cow urine concentrations and the days after application did not show a significant interaction ($p < 0.05$) by the t-test for any of the attributes studied in the experimental soil of this research. However, analyzing the factors separately, there was a significant difference in urine concentration for pH (H_2O and $CaCl_2$), potential acidity (Al + H), potassium (K), sum of bases, base saturation and cation exchange capacity. For the days after the application of the treatments, only the soil organic matter content was influenced, while the values for phosphorus, calcium and magnesium were not significantly affected by the factors under study.

For the pH values, there were quadratic responses to the concentrations of cattle urine added to the soil, with maximum technical efficiency dose values of 82.14 % (pH 6.8) and 79.32 % (pH 6.5), respectively (Figure 1), moving from a range considered acidic to a range close to neutral.

Soils with a pH between 5.8 and 7.5 tend to show no problems with plant growth and development. Soils with pH below 5 may show deficiency of Ca, Mg, P, Mo, B or toxicity of Al, Mn and Zn, for example (Kiehl 1979).

According to Manzatto et al. (2002), about 84 % of Brazilian soils have acidity problems, what is considered a factor limiting the yield of most crops. Such correction is mostly carried out by adding calculated amounts of lime, what raises costs for the producer; thus, with more interest in developing research on biofertilizers, animal urine can become an alternative to lime.

Silva et al. (2011), working with cattle biofertilizer as a soil acidity corrective applied previously to yam cultivation, obtained an increase in pH in the last evaluation after harvest. In the study by Bellini et al. (2012), soil pH levels were maintained when using biofertilizers.

The values for potential acidity ($Al^{3+} + H^+$) varied from 1.85 g kg^{-1} in the treatment without urine addition to 0.21 g kg^{-1} in the maximum technical efficiency dose (75.43 %) (Figure 2). These results reflect the pH increase obtained with the addition of increasing doses of cattle urine (Figure 1), showing a good response of the soil to the treatments. On the other hand, not all biofertilizers show favorable responses to decrease the soil potential acidity, as can be seen in the study with doses of sewage sludge performed by Tranin et al. (2005), where they

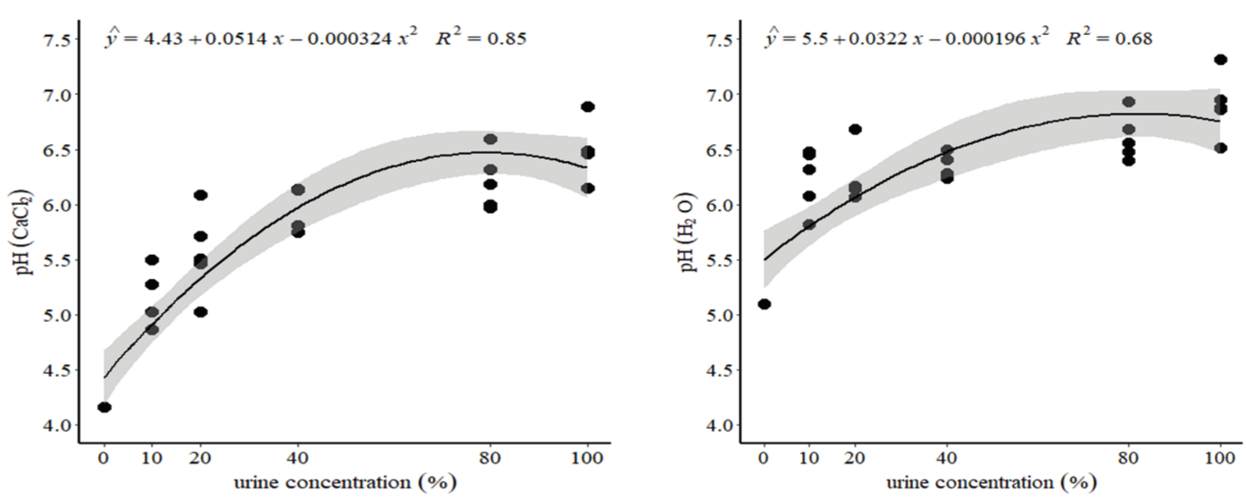


Figure 1. Soil pH (H_2O and $CaCl_2$) according to the cattle urine concentrations: 0 % - no application of cattle urine to the soil, only water; 10, 20, 40 and 80 % of cattle urine diluted in water; 100 % - application of pure cattle urine to the soil.

detected a decrease in pH and an increase in potential acidity (H + Al).

The soil organic matter content decreased linearly over the evaluation times, regardless of the concentration of cattle urine applied, reaching the end of the experimental cycle with a value of 8.84 g kg^{-1} (Figure 3). This decreasing value of organic matter shows that the soil, regardless of the treatment, had an input of easily assimilated minerals, which favored the growth of the soil native microbiota, and, consequently, demanded more carbon from the added organic matter, leading to a fast decomposition. Overall, in this research, the increase in organic matter was small over the observed period in all treatments.

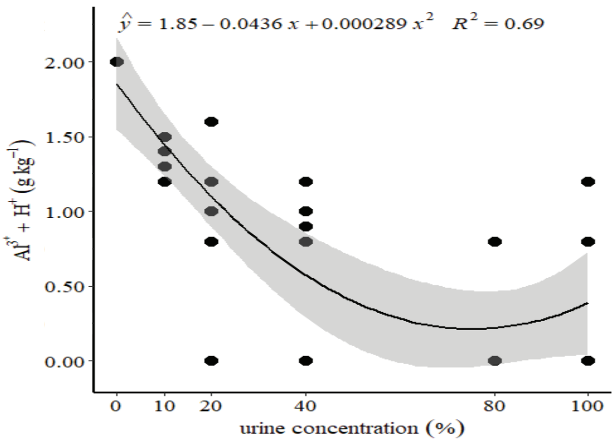


Figure 2. Potential acidity (Al^{3+} + H^+) according to the cattle urine concentrations: 0 % - no application of cattle urine to the soil, only water; 10, 20, 40 and 80 % of cattle urine diluted in water; 100 % - application of pure cattle urine to the soil.

As stated by Bowles et al. (2014), the microorganisms that are added to the soil along with the biofertilizer control key functions in the soil, such as the decomposition and accumulation of organic matter or transformations involving the mineral nutrients that are continuously assimilated during the growth cycles of the different organisms that make up the ecosystem.

The potassium values (Figure 4) increased linearly with increasing concentrations of cow urine, demonstrating the gradual enrichment of the soil with this essential macronutrient for plants. This result was already expected, since biofertilizers generally increase the biodiversity of useful microorganisms that act in the solubilization of various organic compounds that release nutrients to plants (Trani et al. 2013).

According to Freire & Lima (2022), cattle urine comprises practically all the nutrients that plants need, with K being its main constituent. However, the balance of the urine components, besides differing greatly with the nutritional, hydric and physiological state of the cattle, may not yet supply all the plants needs, requiring specific evaluations for each crop and the way this biofertilizer is applied.

The first study developed with cattle urine as a biofertilizer took place in New Zealand

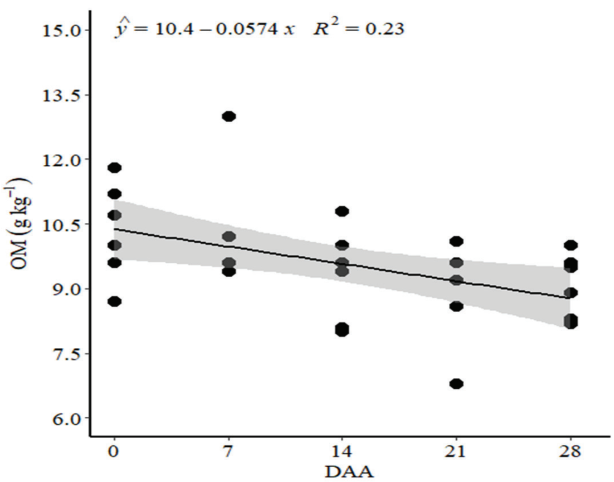


Figure 3. Soil organic matter (OM) according to the cattle urine concentrations: 0 % - no application of cattle urine to the soil, only water; 10, 20, 40 and 80 % of cattle urine diluted in water; 100 % - application of pure cattle urine to the soil. DAA: days after application.

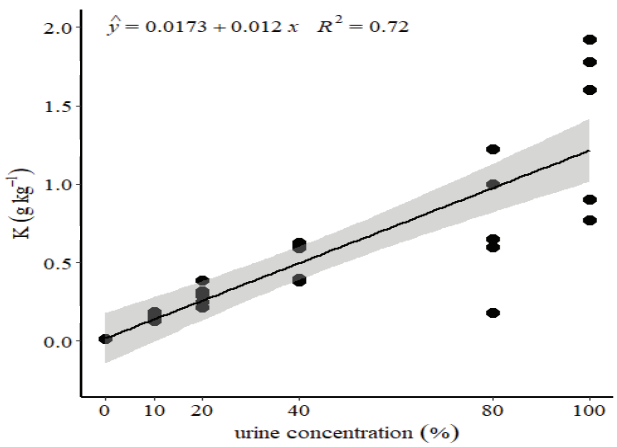
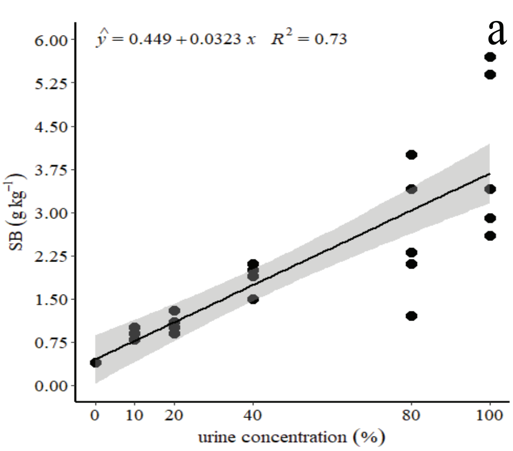


Figure 4. Potassium (K) in the soil according to the cattle urine concentrations: 0 % - no application of cattle urine to the soil, only water; 10, 20, 40 and 80 % of cattle urine diluted in water; 100 % - application of pure cattle urine to the soil.

(During & McNaught 1961), where the researchers made applications aiming at pasture nutrition, and positive effects were observed, mainly as a source of N and K. In the research in question, the application of 80,000 L ha^{-1} of cow urine to pasture resulted in a residual potassium effect and an increase in plant yield over two years, and the amount of K deposited by cow urine on the pasture for one year was found to be equivalent to an application of 1,000 kg ha^{-1} of K_2O.

A study conducted on an Alfisol by Maciel et al. (2019) revealed the efficiency of biofertilizers from dairy cattle waste, not only on physical aspects of the soil but also on its chemical attributes. After applying the biofertilizer, the macronutrients remained between good and very good grades, according to Ribeiro et al. (1999). The authors also mention that this fertilizing model had no involution concerning chemical fertilizers.

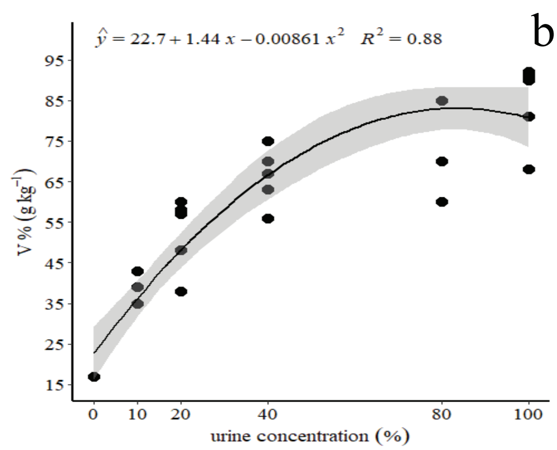


There was an increase in the exchangeable base contents (Figure 5a), attributed to the cycling of nutrients, due to the decomposition of organic matter (Figure 3), what has also been verified by Azevedo et al. (2007).

Together with the application of cow urine, the decomposition of organic matter in the soil also contributed to the increase in base saturation (V%) from a value of 22.7 % in the soil without urine application, reaching a saturation of 82.91 % in the 83.62 % cow urine concentration (Figure 5b). Base saturation is an excellent indicator of the general fertility conditions of a given soil, and is even used as a complement in the nomenclature of soils, since they can be classified according to the base saturation into eutrophic (V% ≥ 50) and dystrophic (V% < 50) soils, fertile and poorly fertile, respectively (Ronquim 2010).

A low value of base saturation, as observed in the soil without the application of cattle urine and in the lower concentrations of the biofertilizer, means that there are only a few cations, such as Ca^{2+}, Mg^{2+} and K^+, saturating the negative charges of the colloids, and, in this case, most of these charges may be neutralized by H^+ and/or Al^{3+}, what is reflected in the higher soil acidity, as can be observed in the treatment without the application of urine. This condition may be quite normal for large tropical areas, as is the case in the sandy and leached soils of Brazil. Most crops yield well when the soil base saturation is between 50 and 80 % (Ronquim 2010), what was achieved in this experiment by adding cow urine to the soil.

The organic matter decomposition is also associated with higher values of cation exchange



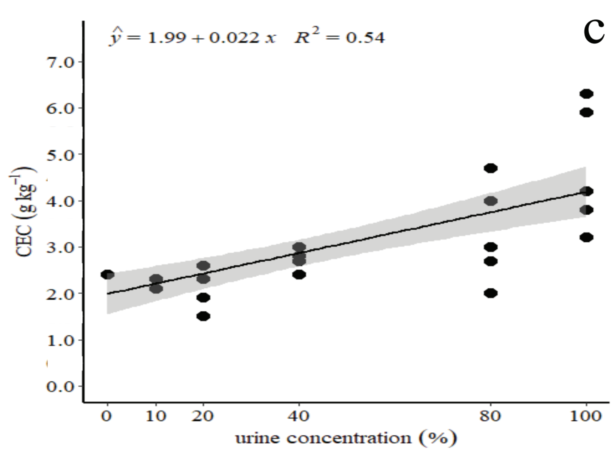


Figure 5. Sum of bases (SB; a), base saturation (V%; b) and cation exchange capacity (CEC; c) of the soil according to the cattle urine concentrations: 0 % - no application of cattle urine to the soil, only water; 10, 20, 40 and 80 % of cattle urine diluted in water; 100 % - application of pure cattle urine to the soil.

capacity (Figure 5c). It can be seen that the higher the concentration of cow urine, the higher the cation exchange capacity in the studied soil, probably due to the positive effect of the mineralization of the soil organic matter, which helps to increase the cation exchange capacity and sum of bases, thus causing a greater release of exchangeable cations and anions that are adsorbed in the soil colloids.

Thus, involving livestock in the production system is a great alternative for producers with this resource on their farms and can reduce production costs, what is important for small-scale agriculture (Pradhan et al. 2018). Many farmers are already revising old practices of applying cattle urine through fertilizers and pesticides (Choudhary et al. 2017).

Animal urine is an effective tool for improving the soil chemistry, what can result in higher plant yields sustainably without suppressing soil fertility, and it is possible to use cow urine in combination with mineral fertilizers. It is hoped that cattle urine can further open the doors of sustainable agricultural production, because, as already mentioned in this research, it is an environmentally friendly resource that is economically viable and easily available on farms. Thus, agroecological formulations with cattle urine can be a powerful source for improving soil fertility.

CONCLUSIONS

1. Cattle urine promotes an increase in the soil pH up to the neutral range;
2. Potassium, sum of bases, base saturation and cation exchange capacity of the soil are positively influenced by the application of increasing concentrations of cattle urine;
3. Phosphorus, calcium and magnesium are not affected by the concentrations of cattle urine nor by the days after the application of the treatments under the experimental conditions of this research;
4. The soil organic matter content decreased linearly over time, regardless of the concentration of cattle urine applied;
5. Among the cattle urine concentrations studied, that of 80 % is the most recommended for improving the soil chemical attributes.

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