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ANALYSIS OF THE NUTRIENT CONTENTS OF SWINE BIOFERTILIZER IN THE SOIL

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ABSTRACT

The objective of this work was to verify through statistical analysis, analysis of variance by the F test, regression analysis, and multivariate analysis the behavior of the nutrient contents of the biofertilizer in the soil. For this, different levels of doses of liquid swine biofertilizer were used to identify which variables had relevant statistical significance, among the variables, pH, organic matter, phosphorus, potassium, calcium, magnesium, hydrogen + aluminum, aluminum, base saturation, boron, copper, iron, manganese, and zinc. The soil used was of the Red Latosol type. The option to use swine biofertilizer in this experiment is because in Brazil, the pig activity generates large amounts of manure that must be used in agricultural production. The experiment was carried out with 30 plots (pots of 500 grams each) conditioned and treated in an air-conditioned oven at a temperature between 28ºC and 31ºC, in the microbiology laboratory of the Prof. Edson Antônio Velano University - Unifenas, Alfenas Campus, in a completely randomized design - DIC, with 5 treatments and 6 replications. The period of liming and maintenance of field humidity was 70 days. The treatments were conducted with swine biofertilizer collected at the Unifenas Retiro School Farm in Alfenas, MG. The proportion of soil used was 40 m3, 80 m3, 160 m3, 320 m3 and 640 m3 per ha-1 corresponding to 10 ml, 20 ml, 40 ml, 80 ml, and 160 ml of

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biofertilizer respectively, plus the control plot that did not have the addition of biofertilizer and was named as 0ml. The amounts of biofertilizer were adopted after the first chemical analysis of the soil, and the swine biofertilizer was carried out. For data collection and verification, statistical analysis, analysis of variance by the F test, regression analysis, determination of the coefficient (R2), and others, the Sisvar 19 software was used. The results of the analysis of variance showed that there was a significant effect on some nutrients as the progressive increase in biofertilizer doses, thus, as the dose increase, the soil nutritional load levels also increased. Therefore, the use of swine biofertilizer improved the structure and physical and chemical characteristics of the soil. Thus, several types of plants could be cultivated after the incorporation of swine biofertilizer into the soil, especially legumes, vegetables and perennial crops, especially fruit trees.

Keywords: Sustainable agriculture. Innovation. Natural fertilizer. Soil treatment.

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INTRODUCTION

The productive capacity of a soil can be improved by using swine biofertilizer in liquid form, which is a natural and sustainable fertilizer produced from pig manure. This type of fertilizer has nutrients that are more easily accessible to seedlings, forming and formed plants, compared to undigested organic materials (Silva *et al*., 2012).

Fertilizing the soil with animal waste is an old practice, however, it can be dangerous if it is done without the necessary care to avoid soil contamination. However, the incorporation of biofertilizer in a sustainable way into the soil can bring several benefits, promote increased fertility and improve the conditions for the cultivation of different types of plants (Santos, 2012).

Porcine biofertilizer is rich in nutrients such as nitrogen, phosphorus, potassium, as well as essential micronutrients for plants. These nutrients are easily absorbed by plant roots, promoting healthy and vigorous growth. In addition, porcine biofertilizer is also a source of organic matter, which can improve soil structure by increasing its ability to retain water and nutrients and benefit sustainable agricultural production (Villela; Souza; Silva, 2004).

In some types of soils, such as those with little possibility of agricultural production, by incorporating biofertilizer and irrigation, plants adapted to the reality of this soil can be grown. The option of cultivation is for plants with minimal conditions of environmental damage and that have a slow possibility of replacing nutrients removed from that soil by the plants (Seganfredo, 1999).

Soil and plant nutrition seeks sustainable agricultural practices and this has been a widely discussed topic in recent years. The need is to be as natural as possible and with less possibility of polluting or contaminating the environment, so the excessive use of chemical, organic, biofertilizer fertilizers and inadequate agricultural practices can cause irreversible environmental problems and compromise the future of agriculture, flora, fauna, water resources, animals and people. As a rule, the most appropriate is the use of up to 5% diluted biofertilizer for plant development and up to 2% for seedling production, adjusted to the irrigation or fertigation system used on the property (Embrapa, 2017).

Thus, the objective of this work was to analyze the behavior of the nutrient contents of the biofertilizer in the soil through statistical analysis, analysis of variance by the F test, regression analysis, multivariate analysis and Pearson's correlation.

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METHODOLOGY

The experiment was conducted partly in the plant nursery, which is an area intended for the production of seedlings, and partly in the microbiology laboratory of the Prof. Edson Antônio Velano University, Alfenas – MG. The climate of the Alfenas region is of the tropical mesothermic type, alternating between hot and moderate, with an average annual temperature between 19.6 °C and 21.0 °C. The average annual rainfall is 1,261mm.

DESIGN

For the development of the experiment, the Completely Randomized Design (DIC) was adopted, with five treatments and six replications (5 x 6) in a total of thirty soil plots, which formed five groups, each containing six pots of five hundred grams each, and each group received six different doses of biofertilizer.

To determine the amounts of water, limestone, biofertilizer and temperature, the simple and compound rule of three was used for the calculations.

FIELD HUMIDITY

The need for humidification to maintain field humidity was determined at 130ml of water for each pot, and the same amount of water served as a base for incorporating porcine biofertilizer into the soil.

Each pot was filled with 500 grams of soil and watered with 130 ml of water. The theoretical weight of soil and water was approximately 635 grams. If at the reweighing a certain pot with an initial weight of 635 grams, weighed 590 grams, the water replacement would be 45 ml, so, if there was incorporation of 10 ml biofertilizer, it would be 35 ml of water and 10 ml of biofertilizer.

The field humidity began on June 15, 2023 and extended until August 25, with water replacement carried out every five or seven days.

NEED FOR LIMING – NC

Soil liming was carried out based on the result of the analysis carried out by the Cooxupé laboratory, therefore, 0.05 grams of dolomitic limestone were added to the soil in each pot potted with five hundred (500) grams of soil each and were placed at external room temperature for 30 days.

The results of the soil analysis are presented below in table 1.

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Table 1 Soil analysis results

Determinations			Findings
ph	pH (CaCl2 0.01 mol/L-1)	-	4,7
M.O.	Organic matter	g/dm3	6
P	Phosphorus (Resin)	mg/dm3	6
K	Potassium (NH4Cl)	mmolc/dm3	0,5
Ca	Calcium (NH4Cl)	mmolc/dm3	6
Mg	Magnesium (NH4Cl)	mmolc/dm3	1
H+Al	Hydrogen + Aluminum	mmolc/dm3	23
Al	Aluminum (NH4Cl)	mmolc/dm3	0
V%	Base Saturation	%	25
B	Boron (Hot Water)	mg/dm3	0,46
Ass	Copper (DTPA)	mg/dm3	0,4
Fe	Iron (DTPA)	mg/dm3	2
Mn	Manganese (DTPA)	mg/dm3	0,7
Zn	Zinc (DTPA)	mg/dm3	0,9

Source: Authors 2023

BIOFERTILIZER DOSAGE – DB

The thirty plots (five-hundred-gram pots) of the experiment were divided into five groups of six plots each. The biofertilizer dosages of the treatments were defined in ascending order, i.e., 0ml, 10ml, 20ml, 40ml, 80ml and 160ml, calculated according to the cubic footage of each treatment, and for 0ml six random plots (six jars of five hundred grams) were used.

For 10ml of biofertilizer, the simulation was 40m3 of soil and so on up to 160ml of biofertilizer and 640m3 of soil.

Biofertilizer dosages up to 40ml were added at once. The 80ml dosage was added to the soil in two times. However, the dosage of 160ml was added to the soil in 4 times, according to the need for water.

TEMPERATURE DURING THE EXPERIMENT

The experiment was at room temperature during the initial phase and liming until the date of incorporation of the biofertilizer into the soil pots. After the incorporation of the biofertilizer, until the date prior to sending it for laboratory analysis, the experiment remained in a controlled oven with variable temperature between 28 °C and 31 °C centigrade.

SOIL SAMPLES

The soil samples used in this research were collected in the Agronomy sector of the Prof. Edson Antônio Velano University (plant nursery), from a pile of soil reserved for

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academic experiments. The soil in question was extracted from an uncultivated region in the municipality of Alfenas – MG, extracted at a profile depth between 0 and 20 cm.

In all, 16.30 kg of soil were harvested. Of these, a soil sample of 1,300 grams was sent to the laboratory of the company Cooxupé in Guaxupé – MG, for analysis code 6024 to quantify the basic nutrients and micronutrients in the soil. The remaining 15 kg were sieved and dried at room temperature. After 15 days, the 15 kg of soil were potted in 30 units of plastic pots of 500 grams each.

BIOFERTILIZER COLLECTION

The amount of biofertilizer used in the experiment was five liters, harvested on the farm of the Retiro School Farm owned by the Prof. Edson Antônio Velano University, municipality of Alfenas, in June 2023. One liter (1000 ml) was sent for analysis code 5884 to verify the chemical composition. The remainder was reserved for the experiment, packed in a five-liter gallon, arranged in a cool place and away from light, until the incorporation of the last dose into the soil.

CHARACTERIZATION OF BIOFERTILIZER

Biofertilizer is a by-product obtained after anaerobic or aerobic fermentation from crop residues, garbage or animal waste, which contains nutrients, hormones, alcohols, phenols and microorganisms necessary for plant development, and can be used as fertilizer or agricultural defensive. However, biofertilizer increases the multiplication of microorganisms that favor soil health (Embrapa, 2017).

Biofertilizer can be used in the cultivation of cereals, fruit trees, native forests, pastures and vegetables. However, it is important to remember that the use of fertilizer from animal waste in the cultivation of vegetables that are ingested raw is prohibited in Brazil (Barros, 2021; Oliveira, 2021).

In this work, the biofertilizer used was of swine origin, because this important activity of Brazilian agribusiness produces a huge amount of waste, which needs to be used rationally to benefit other sectors and also to mitigate the high polluting power and the negative impacts that waste has, thus creating value for waste and giving it the right destination in search of sustainability and environmental well-being.

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VARIABLES ANALYZED

A total of 14 variables were analyzed, namely, pH, organic matter (OM), phosphorus (P), potassium (k), calcium (Ca), magnesium (Mg), hydrogen + aluminum (H+Al), aluminum (Al), base saturation (V%), boron (B), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn).

Despite all the links between macronutrients and micronutrients, this work analyzed and discussed only those nutrients that presented statistical significance, i.e., macronutrients such as pH, organic matter (OM), base saturation, potassium (K) and magnesium (Mg) and micronutrients, manganese and boron (Br).

Macronutrients and micronutrients

When an element is classified as essential for plant development, its lack often prevents the plant from completing its cycle. Another relevant factor is to know if this element should be contained in the soil or if it is supplied via correction. However, it is also important to know if an element is part of the molecule of an essential constituent of the plant, such as magnesium that is part of the chlorophyll molecule (Epstein, 1975).

Essential elements for plants such as water molecules (H2O) and any organic molecule composed mainly of carbon and hydrogen (CO, H) are absorbed by plants from the water extracted by the roots and from the CO2 absorbed via photosynthesis. Other macronutrients such as nitrogen (N), phosphorus (P), sulfur (S), potassium (K), calcium (Ca) and magnesium (Mg) are absorbed and required in higher quantities than the others. On the other hand, micronutrients such as iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), boron (B), molybdenum (Mo) and chlorine (Cl) are required in lower amounts than macronutrients. However, they are no less important than the former for plant development (Mendes, 2007).

Thus, this work will study only the macronutrients and micronutrients that presented statistical significance about the nutrient contents of the biofertilizer in the soil. Thus, we have the following macronutrients, pH, organic matter, base saturation, potassium and magnesium. The micronutrients that showed statistical significance were boron and manganese. The other macronutrients and micronutrients presented in the general analysis will not be considered because they do not present statistical significance in this analysis.

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STATISTICAL ANALYSIS

After obtaining the soil analysis for the proposed treatments, analysis of variance was performed by the F test and, presenting a significant effect, regression analysis was also performed, taking into account the use of several doses of biofertilizer. The data were obtained using the Sisvar 2019 software.

The main function of the F-test is to determine whether the results of an analysis of variance are meaningful by observing the P value associated with the calculated F-statistic. However, the F statistic is a ratio of between-group and within-group variances.

The significance level at 5% is the probability of rejection of the null hypothesis when it is true. For example, a significance level of 0.05 indicates a 5% risk of concluding that there is a difference when there is no real difference.

A result is only significant if it has been predicted as unlikely to occur due to sampling error alone, according to a threshold probability, in this case the level of significance.

METHODS OF ANALYSIS OF THE DEGREE OF FIT OF THE MODEL

The comparison of the results of adjustments was carried out through mathematical models with polynomial regression of grade 2 – R2, widely accepted in the agronomic area because it allows adjustments to the regression models.

COEFFICIENT OF DETERMINATION (R2)

The coefficient of determination or R2 is a form of adjustment of a statistical model such as simple or multiple linear regression, that is, they are the observable values of a random variable, where R2 varies between 0 and 1. To determine a reliable regression model fit, it is common to calculate the coefficient of determination R2, which represents the percentage value of the variable analyzed (Rousson; Gosoniu, 2007).

The calculation of the coefficient of determination is obtained by the following formula.

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2}{\sum_{i=1}^{n} (Y_i - \bar{Y}_i)^2}$$

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Where:

Ni : number of observations;

Yi : observed value;

Yi: estimated value of yi;

Y̅i : average of observations.

When R2 is equal to zero, it means that the coefficient of determination does not explain anything about the variation of the data and when it is equal to 1 it indicates that the coefficient explains all the variation of the data, thus, R2 represents the percentage of variation in the data (Góes, 2019).

RESULTS AND DISCUSSION

INTERPRETATION OF SOIL ANALYSIS

The first step for an interpretation of a safe soil analysis is to verify whether the interpretation criteria are by the analytical methods used in soil analysis (Mendes, 2007). The results were described according to data obtained through the statistical software Sisvar 19. The analysis of variance using the F test allowed us to verify that there was statistical significance in some variables. Thus, in the variables with significance, regression analysis was performed, which allowed us to conclude that there was an increase in nutrients in the soil, according to the increase in biofertilizer doses, as shown in table 2 below.

Table 2 Soil analysis results of the variables that were significant

Treatment	Repetition	ph	MO	K	Mg	B	Mn	V%
0 ml	1	6,7	7	1,2	12	0,09	0,3	84
0 ml	2	6,7	7	1	10	0,08	0,4	83
0 ml	3	6,8	7	0,2	10	0,13	0,5	82
0 ml	4	6,9	7	0,8	10	0,21	0,5	83
0 ml	5	6,9	7	1,1	11	0,23	0,6	84
10 ml	1	6,9	6	0,1	10	0,16	0,5	83
10 ml	2	6,9	7	1,2	12	0,13	0,6	85
10 ml	3	6,8	7	1,1	11	0,15	0,3	82
10 ml	4	6,9	7	0,5	11	0,16	0,5	84
10 ml	5	6,9	7	0,7	12	0,1	0,4	84
20 ml	1	6,9	6	0,3	11	0,12	0,5	83
20 ml	2	7	6	0,3	10	0,1	0,5	82
20 ml	3	7	7	0,7	10	0,15	0,3	82
20 ml	4	6,9	7	0,7	10	0,11	0,5	82
20 ml	5	7,1	7	1,1	11	0,16	0,1	84
40 ml	1	7,2	8	2,1	12	0,14	0,3	86
40 ml	2	7,2	7	1,2	12	0,1	0,4	84
40 ml	3	7,2	8	1,8	11	0,14	0,6	84
40 ml	4	7,2	8	1,8	12	0,14	0,4	85

40 ml	5	7,2	7	1,5	11	0,16	0,5	85
80 ml	1	7,2	7	2,2	11	0,1	0,4	83
80 ml	2	7,1	7	3,1	12	0,21	0,4	85
80 ml	3	7,2	8	2,6	12	0,19	0,4	84
80 ml	4	7,2	8	3,1	13	0,23	0,4	86
80 ml	5	7,2	7	3,6	13	0,24	0,4	86
160 ml	1	7,1	7	6,2	13	0,3	0,4	86
160 ml	2	7,1	7	5,9	12	0,26	0,3	86
160 ml	3	7	8	7,2	13	0,29	0,2	86
160 ml	4	7	7	7,3	14	0,23	0,1	87
160 ml	5	7	7	7,3	14	0,23	0,1	87

Source: Authors 2024

ANALYSIS OF THE INCORPORATION OF BIOFERTILIZER INTO THE SOIL

pH

pH is a measure that expresses the hydrogen potential of a solution, indicating the degree of acidity, neutrality or alkalinity of the substance that it may have in the soil or an aqueous substance. Here we will use the concepts of chemical classification for soil analysis. The pH scale ranges from 0 to 14, and values lower than 6.9 indicate acidic soils. A value equal to 7.0 indicates neutral acidity and values greater than 7.1 indicate alkaline soils (Mendes, 2007). The pH ratings are shown in Table 3.

Table 3 - Soil pH classification.

Soil acidity interpretation classes							
Chemical classification							
Characteristic	Ac. very high	High acidity	Medium acidity	Weak acidity	Neutral acidity	Weak alkalinity	High alkalinity
ph	< 4.5	4,5 - 5,0	5,1 - 6,0	6,1 - 6,9	7,0	7,1 - 7,8	> 7.8
Agronomic classification							
ph	Very low		Low	Good	High	Very high	
	< 4.5		4,5 - 5,4	5,5 – 6,0	6,1 - 7,0	> 7.0	

Source: Adapted from Mendes (2007)

pH plays an important role in agriculture, directly affecting plant health and nutrient availability in the soil. In low-pH soils, nutrients such as phosphorus, potassium, and calcium may become less accessible to plants. On the other hand, in overly alkaline soils, micronutrients such as iron, zinc, and manganese can become scarce for plants because the high pH does not allow these micronutrients to be fully absorbed during plant development. Therefore, an inadequate pH can lead to toxicity or nutrient deficiency. In acidic soils, low pH, the aluminum in the soil can become toxic to plant roots. On the other

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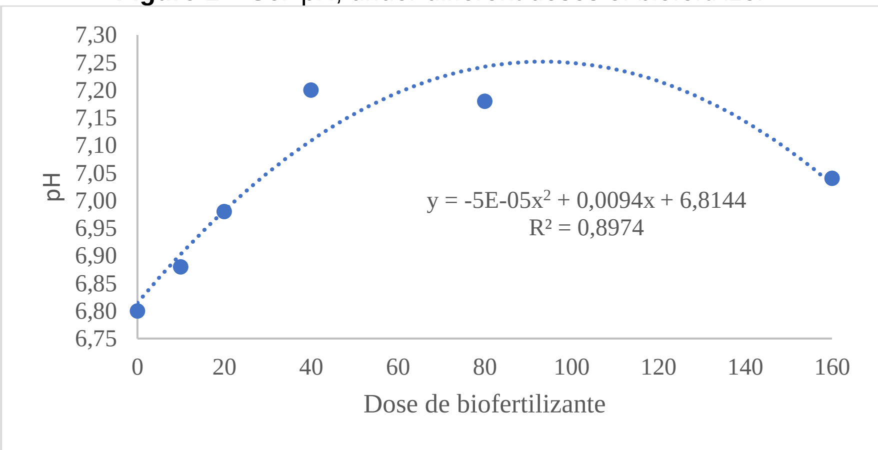
hand, alkaline soil, high pH, can cause iron deficiency in plants. The ideal for plants is the pH with neutral acidity at 7 (Lepsch, 2011).

The result of the pH analysis in the studied soil is shown in figure 1 below.

Figure 1 – Soil pH, under different doses of biofertilizer



Source: Authors 2024

When analyzing the pH scatter plot (Figure 1), it was observed that there was a quadratic polynomial distribution, presenting a dose of 94ml of biofertilizer ideal to improve soil acidity. However, above this value, biofertilizer provides a decrease in pH, making the soil acidic again. For this variable, the adjustment was $R^2 = 0.8974$, i.e., indicating that there is greater homogeneity between the values analyzed.

Organic matter

Soil organic matter plays a key role as a key indicator of soil quality and as a basis for agricultural sustainability. But this depends on the input of organic material, mineralization rate, texture, climate, rainfall, among other factors. It is worth noting that the form of soil management greatly influences the decrease, stagnation or increase of soil organic matter (Khorramdel *et al.*, 2013).

Soil organic residues can be of plant and animal origin and products of their transformations, however vegetation is the largest source of deposition of organic materials to the soil. The volume of soil organic matter is determined by the balance between the input of organic matter and the output of carbon dioxide – CO2 from the soil. The organic matter renewal cycle is according to the rates of deposition, decomposition and renewal of waste that occur dynamically (Costa; Silva; Ribeiro, 2013).

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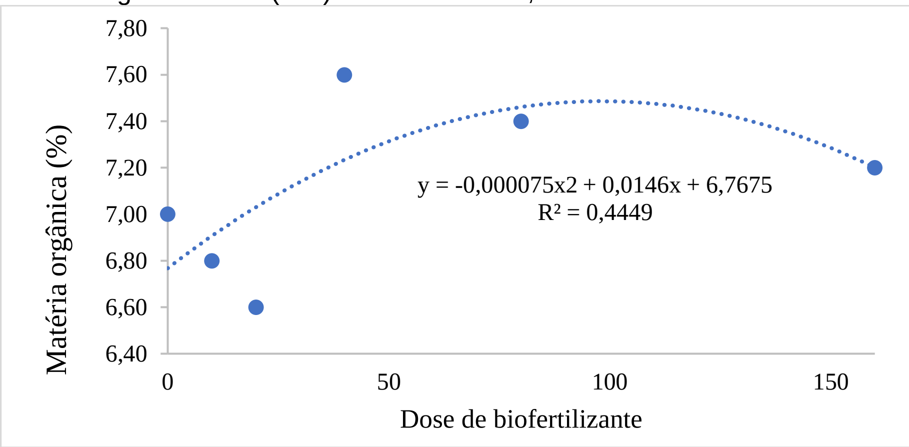
The result of the analysis of the Organic Matter in the studied soil is shown in figure 2 below.

Figure 2 – Organic Matter (OM) levels in the soil, under different doses of biofertilizer



Source: Authors 2024

The increase in the levels of organic matter in the soil as a function of the biofertilizer dosages (0, 10, 20, 40, 80, 160 ml $^{ha-1}$) is demonstrated through the analysis of the scatter plot, as identified in figure 2.

When analyzing the organic matter scatter plot (Figure 2), it can be seen that there was a quadratic polynomial distribution, presenting an ideal dose of 93.33 ml of biofertilizer, which is the maximum point of elevation, and then showing a decline in organic matter, adopting practically the same behavior compared to pH. For this variable, the adjustment was $R^2 = 0.4449$, which is not an ideal percentage, as it was below 70%, however, when it comes to organic matter, this is an important nutrient for soil and plants.

It is possible to observe that, according to the data from the soil analysis, after the application of the biofertilizer, there was an increase in the levels of organic matter in the soil analyzed.

Base saturation

Base saturation is a very relevant indicator within soil analysis, as it is related to soil fertility and nutrient availability for plants. Considered as a chemical characteristic of the soil, it helps us understand its nutritional status and helps us create strategies for agricultural sustainability. It is commonly related to the pH of the soil, being used to calculate the need for liming (Freire, 2006).

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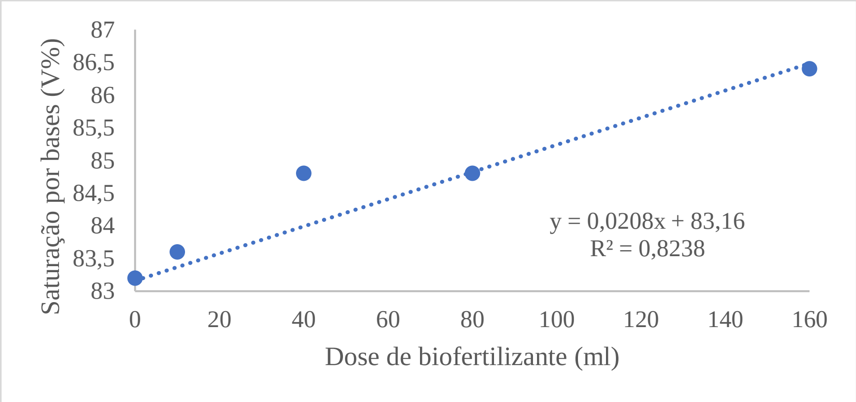
Base saturation refers to the ratio of exchangeable basic cations to the cation exchange capacity determined at pH 7.0 (neutral). Basic cations include calcium, magnesium, potassium, sodium, aluminum, and hydrogen (Ronquin, 2010).

Knowing base saturation is essential to evaluate soil fertility and understand that a soil with low V% can compromise plant development and water and nutrient absorption. Soils with V% greater than 50% are considered fertile soils, also known as eutrophic soils because they store more than half of the basic cations. Soils with V% less than 50% are called non-fertile soils, known as dystrophic soils. They are usually poor in exchangeable bases (Ca) and high saturation by aluminum (Al) (Richert; Gubiani, 2011).

The result of the analysis of base saturation in the soil studied is shown in figure 3 below.

Figure 3 – Base saturation in the soil, under different doses of biofertilizer



Source: Authors 2024

In the base saturation scatter plot (Figure 3), we can see that $R^2 = 0.8238$ represents that the fit of the values to the model was high, demonstrating greater precision in the results. It is possible to observe through the results that there is a linear growth in base saturation when the doses of biofertilizers increase, approximately 0.02% for each ml. This demonstrates that this fertilizer can favor the soil, as well as plant development.

Potassium

The behavior of potassium in the soil under the effect of the different doses of biofertilizer applied to the soil is an inverse quadratic behavior, with a decline of potassium in the first doses and then a linear growth of potassium contents in the soil as the biofertilizer doses increase. This indicates that the linear growth is proportional to the increase in doses.

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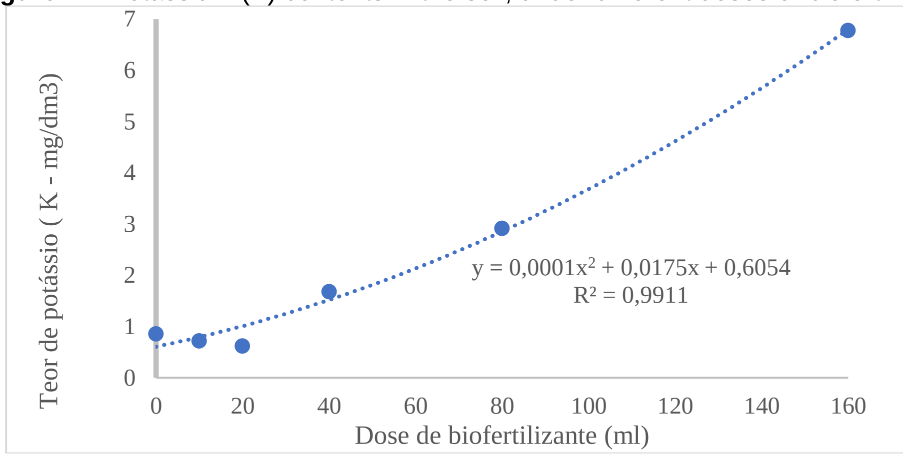
Potassium belongs to the group of primary macronutrients, and is generally absorbed in large quantities by plants. Involved in essential functions, it improves the quality of the agricultural product, promotes the healthy growth of cultivated plants (Costa *et al*., 2009).

Thus, the growth and significance of potassium contents in the soil are shown in figure 4 below.

Figure 4 – Potassium (K) contents in the soil, under different doses of biofertilizer



Source: Authors 2024

Potassium has no structural function in plants, although this element plays a fundamental role in participating and activating various physiological phenomena within the plant, it activates more than eighty enzymes. Potassium is an important element in osmotic regulation and acts in other fundamental physiological events for the plant, such as water absorption, maintenance of cell turgor, regulation of stomatal opening and closing, plant growth, transport, redistribution and storage of carbohydrates and nutrients inside the plant. Together with calcium and magnesium, it participates in the important function of maintaining ionic balance with anions (Embrapa, 2012).

By analyzing the scatter plot in figure 4 referring to potassium, we realize that the behavior of potassium is increasing as the doses of biofertilizer increase. This is because biofertilizer contains a large amount of potassium in its composition, so as it is to be expected that the increase in dosage certainly adds more potassium to the soil.

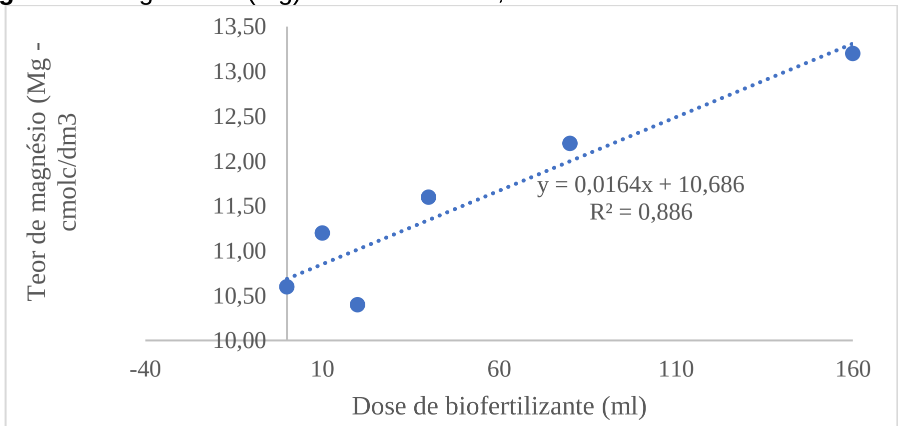
When performing a polynomial regression analysis to evaluate the relationship between potassium concentration in the soil and the possibility of plant growth, the indicator $R^2 = 0.9911$ suggests that there is a strong correlation between the variables studied, indicating that the variation in potassium concentration in the soil largely explains the variation in plant growth, that is, that there is a 99.11% chance that plants will grow healthily (Nachtigall; Rau, 2005).

Magnesium

Magnesium is considered an important macronutrient for plants because it actively participates in several metabolic processes. It is essential for the growth and productivity of agricultural crops. Magnesium makes up about 2% of the Earth's crust and has its origin in primary silicate minerals such as biotite, chlorite, talc, etc. (Castro *et al*., 2018).

It is possible to observe that the behavior of magnesium is similar to organic matter because it presents a constant linear growth, as can be seen in the scatter plot in Figure 5.

Figure 5 - Magnesium (Mg) levels in the soil, under different doses of biofertilizer



Source: Authors 2024

According to the scatter plot in figure 5, the magnesium content in the soil increases linearly proportionally to the biofertilizer doses. For each ml, an increase of 0.016 cmolc/dm3 of the nutrient is observed. Magnesium's main function is to be the central atom of the chlorophyll molecule that gives plants their green color, so about 20% of the plant's magnesium is part of the green pigment. Another role of magnesium is to be an activator of enzymes related to energy metabolism. It also binds the pyrophosphate structures of ATP and ADP and interacts with calcium and potassium (Embrapa, 2020).

When we analyze the linear regression plot, we realize that there is a strong relationship between the concentration of magnesium in the soil and that this is beneficial for plant growth with an $R^2 = 0.886$. This means that almost 89% of the variation in plant growth can be explained by variation in magnesium levels, which is an essential macronutrient for photosynthesis and other vital processes for plants (Saraiva *et al*., 2023).

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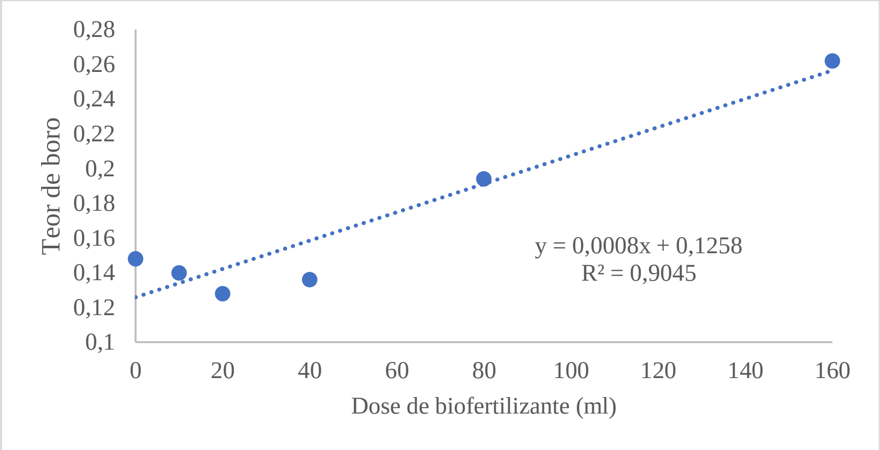
Boron

Boron is a crucial micronutrient for plant growth, playing a vital role in carbohydrate regulation and the formation of plant cell walls (Soares; Alleoni; Casagrande, 2005).

Boron and manganese were the only micronutrients that had statistical significance in relation to soil contents.

The behavior of boron in the soil under the effect of the different doses of biofertilizer (0, 10, 20, 40, 80, 160 ml ha-1) maintains the same performance of magnesium and potassium, as can be seen in the scatter plot, shown in figure 6.

Figure 6 – Boron (B) levels in the soil, under different doses of biofertilizer



Source: Authors 2024

Like all micronutrients, boron is required by plants in much smaller amounts, however, this micronutrient is relevant in plant growth as long as the dose is adequate. Little boron in the soil will cause deficiency and there will be no synergism with potassium. In excess in the soil, it can cause toxicity. It is worth mentioning that the low phosphorus content in the soil can interfere with boron metabolism, aggravating the symptoms of deficiency or toxicity (Sinha; Dube; Chatterjee, 2003).

Boron is associated with growth, cell development and helps maintain the integrity of membranes, so, like calcium and magnesium, it is part of the cell walls of plants like pectins. Boron also participates in the synthesis of the nitrogenous base uracil which is important in protein formation and aluminum tolerance. In soil, the main source of boron is organic matter, while in soil, boron can be immediately absorbed by plants. In Brazilian soils, total boron levels can vary from 31 to 54 mg $^{kg-1}$ and be available from 0.06 to 0.32mg dm-3. However, high concentrations of calcium in the plant may provide a higher requirement for boron (Mendes, 2007; Batista *et al.*, 2018).

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Boron adsorption increases with increased pH and concentration of the nutrient, which can reduce leaching losses (Catani *et al*., 1971). With an $R^2 = 0.9045$ in a linear regression analysis, as shown in figure 6, it indicates that approximately 90.45% of the variability of the boron data in the soil can be explained by the regression model used, meaning that the model is quite adequate to predict the boron values in the soil. This confirms that there is a strong correlation between the independent variables of the model and the concentration of boron in the soil.

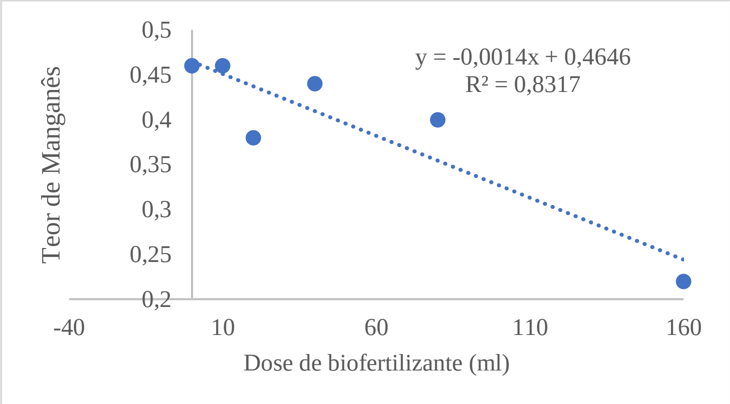
Manganese

Manganese in soil has a complex role and is an essential micronutrient for plants, however, it must be administered with caution, because it can become toxic in high concentrations (Borkert, 1991).

For manganese, a negative linear effect can be observed in Figure 7, i.e., contrary to organic matter, magnesium and boron. From the increase in biofertilizer doses, there is a linear decrease in the manganese content in the soil, for each ml there is a decrease of 0.0014 cmolc/dm3 of the nutrient. This fact may have to do with the increase in pH, as this can influence the decrease of some micronutrients and, depending on it, can be toxic to crops. This micronutrient should be administered with caution due to its ease of toxicity.

The result of the analysis of manganese in the studied soil is shown in figure 7 below.

Figure 7 – Manganese contents in the soil, under different doses of biofertilizer



Source: Authors 2024

Good agricultural practices such as liming can be used to adjust the pH of the soil and, consequently, the availability of manganese. Proper soil pH management is crucial to maintain manganese balance and avoid both deficiency and toxicity. However, in acidic

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soils (low pH), the availability of manganese increases, which can lead to toxicity and cause brown spots on leaves and reduce the absorption of other essential nutrients. On the other hand, in alkaline soils (high pH), the availability of manganese decreases, which can cause nutritional deficiency in plants and yellowing in leaves (Malavolta *et al*., 1989).

As pH can directly influence the availability of manganese to plants, in soil with pH 7 as shown in the scatter plot, which can be considered neutral, it was expected that the availability of manganese would be moderate, however, the value of $R^2 = 0.8317$ indicates a strong correlation between the dependent and independent variable, suggesting that manganese has a significant impact on the soil studied, as shown in Figure 7.

Therefore, it can be inferred that the manganese content has a considerable impact on the soil characteristic studied, be it fertility, structure or other relevant property. It is important to remember that correlation does not imply causation, although it seems to have a significant impact, more research is needed to establish a definitive causal relationship, because other factors can influence the soil.

CONCLUSION

From the global political perspective in search of sustainability, it is perceived that this work addresses sustainable agriculture, health and well-being, technological innovation, sustainable communities, responsible consumption and production, through research and studies on pig farming, manure, biodigester, anaerobic biodigestion, biogas, bioenergy and biofertilizer.

From an economic and social point of view, pig farming is an important activity for small and medium-sized agricultural properties, because it fixes the man in the field, generating direct and indirect jobs in food production to meet world demand.

However, the increase in pig production causes very serious environmental problems, due to the large volume of waste produced and most of this waste does not receive adequate treatment to be disposed of. In addition, the best way to treat manure is through an anaerobic biodigester, which through anaerobic digestion transforms pig manure into biogas and biofertilizer, being an alternative that must be seriously evaluated, because the biodigester, by virtue of its final products, offers solutions to rural properties, related to the problems of deficit of electricity supply and the nutritional deficiency of the soil. Therefore, it can be said that the equipment can be used to treat pig waste efficiently in the production of clean energy (biogas) and biofertilizer.

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Because biogas can be used for heating or electricity production through a power converter, it is a self-sustaining and inexpensive energy source that can be used to generate other by-products. In addition, the use of biogas considerably reduces the emission of greenhouse gases, the pollution of natural resources and the air, improving people's health and well-being.

Biofertilizer, in turn, helps agriculture and producers by making them more accessible and sustainable economically and socially, through responsible consumption and production. Thus, biofertilizer when incorporated into the soil is able to increase the levels of macronutrients and micronutrients essential to improve the physicochemical structure of the soil, invigorating plants and stimulating increased productivity.

The types of plants that can benefit from nutrition with swine biofertilizers include legumes such as beans, soybeans, oats and peas, which are able to fix atmospheric nitrogen and enrich the soil with other nutrients and favor irrigation.

Vegetables such as spinach, lettuce and carrots can be grown using biofertilizer, for this, it is recommended that the soil be analyzed and corrected and then use porcine biofertilizer. Perennial crops such as fruit trees and shrubs can also benefit from increasing the nutrient levels of porcine biofertilizer in the soil such as apple, guava, passion fruit, cashew and others.

From the point of view of future research on biogas, electricity, biofertilizer, agricultural production, sustainability and social welfare, this work aims to contribute to future researchers because it facilitates the understanding of the benefits of biofertilizer application in the soil.

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REFERENCES

1. Barros, T. D. (2021). *Biofertilizante*. Embrapa. https://www.embrapa.br/agencia-de-informacao-tecnologica/tematicas/agroenergia/residuos/biogas/biofertilizante

2. Batista, M. A., et al. (2018). *Principles of soil fertility, fertilization and mineral nutrition*. https://backoffice.books.scielo.org/id/bv3jx/pdf/brandao-9786586383010-06.pdf

3. Borkert, C. M. (1991). Manganese. In M. E. Ferreira & M. C. P. Cruz (Eds.), *Micronutrients in agriculture* (pp. 173–189). Potafos/CNPq.

4. Castro, C. de, et al. (2018). *Magnesium: management for the nutritional balance of soybean*. [S.l.: s.n.].

5. Catani, R. A., Alcarde, J. C., & Kroll, F. M. (1971). The adsorption of boron by soil. *An. Esc. Sup. Agric. Luiz de Queiroz*, 28, 189–198.

6. Costa, E. M., Silva, H. F., & Ribeiro, P. R. A. (2013). Soil organic matter and its role in the maintenance and productivity of agricultural systems. *Encyclopedia Biosphere, Centro Científico Conhecer*, 9(17), 1842.

7. Costa, J. P. V., Barros, N. F., Bastos, A. L., & Albuquerque, A. W. (2009). Potassium diffusive flux in soils under different levels of moisture and compaction. *Brazilian Journal of Agricultural and Environmental Engineering*, 13(1), 56–62.

8. Embrapa. (2017). *Hortbio biofertilizer: agronomic properties and instructions for use* (Technical Circular No. 162). https://ainfo.cnptia.embrapa.br/CT-162.pdf

9. Embrapa. (2012). *Potassium contents in the soil, nutritional status and dry matter production of alfalfa as a function of doses and frequency of potassium fertilization after two years of cultivation* (Boletim de Pesquisa e Desenvolvimento, 33), 25.

10. Embrapa. (2020, June). Trichoderma fungus is an ally in the biological control of diseases in agricultural crops. https://www.embrapa.br/busca-de-noticias/-/noticia/53541439/fungo-trichoderma-e-aliado-no-controle-biologico-de-doencas-em-culturas-agricolas

11. Epstein, E. (1975). *Mineral nutrition of plants: principles and perspectives* (E. Malavolta, Trans.). Livros Técnicos e Científicos.

12. Freire, O. (2006). *Soil of tropical regions*. FEPAF.

13. Goes, R. J. (2019). *Fuzzy modeling of dry matter accumulation and nutritional variables of tillage cover crops for no-tillage system in response to different nitrogen doses* (Master’s dissertation). São Paulo State University Júlio de Mesquita Filho, Tupã – SP.

14. Khorramdel, S., Koocheki, A., Mahallati, M. N., Khorasani, R., & Ghorbani, R. (2013). Evaluation of carbon sequestration potential in corn fields with different management systems. *Soil & Tillage Research*, 133, 25–28.

15. Lepsch, I. F. (2011). *19 lessons in Pedology*. Oficina de Textos.

16. Malavolta, E., Malavolta, M. L., Cabral, C. P., & Matsunaga, E. (1989). Note on manganese deficiency in cassava (*Manihot esculenta* Crantz). *Revista de Agricultura*, 64(2), 107–117.

17. Mendes, A. M. S. (2007). Class given in the Course of Management and Conservation of Soil and Water. Federal Superintendence of Agriculture, Livestock and Supply of the State of Bahia – SFA -BA/SDC/MAPA. https://ainfo.cnptia.embrapa.br/digital/bitstream/CPATSA/35800/1/OPB1291.pdf

18. Nachtigall, G. R., & Raij, B. van. (2005). Analysis and interpretation of potassium in soil. In *Symposium on Potassium in Brazilian Agriculture* (2nd ed., pp. 93–118). Brazilian Association for Potash and Phosphate Research.

19. Oliveira, R. (2021, December 30). Opportunities for the use of physiological and alternatives for fertilizer shortages. *Agroinsight*. https://agroinsight.com.br/oportunidades-para-uso-de-fisiologicos-e-alternativas-para-escassez-de-fertilizantes/

20. Richert, J. M., & Gubiani, P. I. (2011). *Chemical properties of soil*. http://www.fisicadosolo.ccr.ufsm.quoos.com.br/downloads/Disciplinas/FundCiSolo/FCS_5aProps_quimicas.pdf

21. Ronquin, C. C. (2010). *Concepts of soil fertility and appropriate management for tropical regions*. Embrapa Satellite Monitoring.

22. Rousson, V., & Goşoniu, N. F. (2007). An -Square Coefficient Based on Final Prediction Error. *Statistical Methodology*, 4(3), 331–340.

23. Santos, M. R. (2012). Yield, quality and nutrient absorption by pumpkin fruits as a function of biofertilizer doses. *Horticultura Brasileira*, 30(1), 160–167.

24. Saraiva, J. R., Faquin, V., Toledo Neto, S. de, & Castro, G. de. (2023, May 11). Magnesium Dynamics in the Soil-Plant-Environment System. *Agromove*. https://blog.agromove.com.br/magnesio-solo-planta-ambiente

25. Seganfredo, M. A. (1999). *Cadernos de Ciência & Tecnologia*, 16(3), 129–141.

26. Silva, W. T. L., et al. (2012). Physicochemical evaluation of effluent generated in anaerobic biodigester for efficiency evaluation and application as agricultural fertilizer. *New Chemistry*, 35(1), 35–40.

27. Sinha, P., Dube, B. K., & Chatterjee, C. (2003). Phosphorus stress alters boron metabolism of mustard. *Communication in Soil Science and Plant Analysis*, 34, 315–326.

28. Soares, M. R., Alleoni, L. R. F., & Casagrande, J. C. (2005). Thermodynamic parameters of the boron adsorption reaction in highly weathered tropical soils. *Química Nova*, 28(6), 1014–1022.

ISSN: 2358-2472

29. Vilela, L., Sousa, D. M. G. de, & Silva, J. E. (2004). Potassium fertilization. In D. M. G. de Sousa & E. Lobato (Eds.), *Cerrado: soil correction and fertilization* (pp. 169–182). Embrapa Technological Information.