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Influence of the Application of Filter Cake on Soil Chemical Characteristics

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The agricultural and agroindustrial sector are great waste generator, among them the filter cake, derived from the processing of sugarcane biomass. The inappropriate disposal of this residue can cause large impacts to the environment, however using it as an additional source of nutrients for the soil and consequently for the agricultural crops presents itself as a sustainable alternative. Therefore, the purpose of this work was to analyze the influence of the application of the filter cake, associated or not with mineral fertilization, on the chemical characteristics of the soil. The experimental design was a randomized complete block design with 4 treatments and 4 repetitions: T1 - filter cake (25 ton.ha^{-1}), T2 - filter cake (25 ton.ha^{-1}) plus mineral fertilization (139 kg.ha^{-1} of formulation 04 %, 30 % and 10 % of NPK), T3 - mineral fertilization (257 kg.ha^{-1} of formulation 04 %, 30 % and 10 % of NPK) and T4 - control. After 90 days of treatments application the soil chemical characteristics were evaluated: V% (base saturation), CEC (cation exchange capacity), sum of bases, organic matter, carbon, macronutrients (P, K, Ca, Mg, Ca + Mg) and micronutrients (Cu, Zn, Fe, Mn and Na). Data haS been submitted to analysis of variance and the results have been compared by the Scott-Knott test at 5% level of significance. The chemical characteristics of the soil, the parameters that presented significant difference were CEC, sum of bases and Ca + Mg, with emphasis on treatments T2 and T3 for the first two parameters and T1, T2 and T3 for Ca + Mg. In this way, it was observed that the use of the filter cake in the soil, under the conditions of this experiment, presents itself as a sustainable practice. Since the disposal of this residue in soil did not cause negative changes in the evaluated parameters, as the results showed, it can be used as a source of nutrients, reducing the dependence of producers on mineral fertilizers, and consequently a more sustainable agriculture.
Keywords: sugarcane; sustainable production; residue.

1. Introduction

Brazil is the world's largest producer of sugar cane (*Saccharum officinarum* L.), occupying the first place in production and export of sugar, and is also characterized as the largest consumer and exporter of sugarcane ethanol.

During the processing of sugarcane in ethanol or sugar, high amounts of residues are generated such as sugarcane bagasse, vinasse, filter cake, yeast, boiler ash, molasses and fusel oil (Pádua, 2014).

Among them, the filter cake stands out, therefore, it is estimated that for each ton of ground cane, 30 to 40 kg of filter cake are produced (Santos et al., 2010; González et al., 2014).

Processes that generate large amounts of waste need a sustainable approach to their reuse, through proposals and implementations to reduce pollution considering economic, health and environmental factors (Wu et al., 2014). The inadequate disposal of waste from the sugar-energy sector as well as being an environmental problem represents an additional cost in the production process.

In addition, waste reuse processes could save natural resources and reduce environmental impacts by re-entering production cycles when compared to processes using virgin feedstock (Schneider, 2013). In this

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sense, the concern with environmental protection linked to the high cost of fertilizers led to research on the recycling of organic waste, such as the by-products of the sugar-energy sector (González et al., 2014). Some of these studies have been focused on the use of fortified organic fertilizers, that is, the integration of organic and inorganic fertilizers aiming the improvement of the macro and micronutrients contents, adapting the crop requirements (Chonga et al., 2017).

The use of filter cake as an organic fertilizer in plant production has become an increasingly common practice because, in addition to increasing nutrients, it also benefits the physical and biological characteristics of the soil, such as the improvement of porosity (Santana et al. 2012).

The objective of the present work was to analyze the influence of filter cake, associated or not with mineral fertilization on soil chemical characteristics, as well as to evaluate the effect of filter cake application on the germination of soybean seeds (*Glycine max*).

2. Material and methods

2.1 Location of the experiment and soil characteristics

The experiment was conducted in a farm, located in the city of Maringá, state of Paraná, Brazil, between coordinates 23° 25' 31" S and 51° 56' 19" W. The soil of the experimental area was classified as Red Latosol Eutrophic.

Before the implantation of the treatments, soil samples were collected at 20 cm depth for analysis of soil chemical characteristics (Table 1).

Table1. Results of the soil chemical analysis of the experimental area before the implementation of the experiment with filter cake.

Characteristics	Index
Phosphorus (mg / dm³)	11.21
Organic Carbon (g / dm³)	14.34
pH in calcium chloride	4.85
Aluminum (cmolc / dm³)	0.05
Potential acidity (cmolc / dm³)	6.04
Calcium + Magnesium (cmolc / dm³)	12.57
Calcium (cmolc / dm³)	9.75
Magnesium (cmolc / dm 3)	2.82
Potassium (cmolc / dm³)	0.46
Sum of Bases (cmolc / dm³)	13.03
Cation exchange capacity (cmolc / dm³)	17.70
Base Saturation (%)	68.30
Aluminum saturation (%)	0.0
Copper (mg / dm³)	43.70
Iron (mg / dm³)	46.53
Manganese (mg / dm³)	109.50
Zinc (mg / dm³)	34.28

2.2 Physico-chemical characteristics of the filter cake

The filter cake was obtained from a sugarcane plant located in the city of Maringá. After the samples collection, the samples were sent to the Laboratory of Agrochemistry of the State University of Maringá, where the physical-chemical characterization was carried out.

In the present study, the following composition was observed: humidity (71%), organic matter (69.7%), nitrogen (14.3 g.Kg^{-1}), phosphorus (16.90 g.Kg^{-1}), potassium (1.5 g.Kg^{-1}), calcium (23 g.Kg $^{-1}$), magnesium (3.4 g.Kg $^{-1}$), carbon (405.6 g.Kg^{-1}), carbon / nitrogen ratio (28.3 g.kg $^{-1}$) and pH (6.6).

2.3 Experimental design and treatments

The experimental design was a randomized block consisting of 4 treatments and 4 replicates, pre-established as: T1 - filter cake (25 ton.ha^{-1}); T2 - filter cake (5 ton.ha^{-1}) plus mineral fertilization (257 kg.ha^{-1} of formulated nitrogen 04 %, phosphorus 30 % and potassium 10 %); T3 - mineral fertilization (139 kg.ha^{-1} of the formulated nitrogen 04 %, phosphorus 30 % and potassium 10 %) and T4 control (no application). The plots consisted of an area of 20 m², being of size 4m x 5m, with a corridor of 1 meter between each block.

The determination of the applied dose of soil filter cake was based on the work of Fravet et al. (2010) in the sugarcane crop, because no information was found for the soybean crop.
However, the mineral fertilizer dose was determined based on the results of the soil analysis (Table 1) and according to the nutritional requirements of the soybean crop.
The cultivar used was Coodetec 2644 IPRO. The space between the planting lines was 0.40 m, representing a population of 255 thousand plants per hectare and 11 plants per linear meter of each plot were distributed.
The mineral fertilization was carried out in the subsoil at the time of sowing of the soybean with a sowing machine, while the application of the organic residues was done manually.

2.4 Chemical characterization of soil

The chemical characteristics of the soil were evaluated 120 days after the application of the treatments in samples collected from 0-20 cm depth in each plot. Subsequently these samples were sent to the laboratory for the chemical analysis of macronutrients and micronutrients.

2.5 Evaluation of seed germination

In the evaluation of the germination of soybean seeds, all the plants that emerged from each plot 15 days after sowing were computed, and the proportion between the seeds distributed in the soil and the emerged plants was estimated, measuring the percentage of germination of each plot.

2.6 Data analysis

The data were submitted to analysis of variance in the SASM-Agri software (Canteri et al., 2001). A comparison of means was performed by the Scott Knott test at the 5% probability level.

3. Results and discussion

3.1 Chemical characterization of soil

Regarding the chemical characteristics of the soil, the analyzes performed prior to the implementation of the experiment showed that the values of macronutrients, micronutrients and CEC (cation exchange capacity) were classified as high, according to the established parameters of Ronquim (2010). However, the soil presented high acid value (Table 1), a fact that according to Raij et al. (2001), may lead to the unavailability of some nutrients for the soybean crop.
On the other hand, after applying the treatments, there was no significant variation in pH values, which were slightly lower for soybean cultivation, but did not present significant differences between treatments (Table 2). The ideal range of pH in calcium chloride varies between 5.4 and 5.9, where the best availability of nutrients occurs, avoiding the toxicity of some elements.
According to Vieira and Weber (2013) the filter cake has 9.1 $g.kg^{-1}$ of calcium (Ca), which can beneficially influence soil pH, leaving it in a range closer to the ideal for crops. However, even the filter cake used in this experiment presented 23.07 $g.kg^{-1}$ of Ca, the application did not lead to differences in pH in relation to the other treatments.
Base saturation (V%) is an excellent indication of general soil fertility conditions. Soils can be divided according to base saturation in eutrophic (fertile) soils (V% ≥ 50%). Based on these data, all the treatments presented values that fit them in eutrophic soils, suitable for a good conduction of the soybean crop, being that there were no statistical differences between treatments (Table 2).
Soils with V% between 50 and 80 are generally ideal for most crops to grow properly (Ronquim, 2010), AS V% values above 50% INDICATE a good availability of Ca^{2+} (calcium), Mg^{2+} (magnesium) and K^+ (potassium), a fact that is crucial for the good development of agricultural crop.
The parameters of the base sum and the CEC presented similar performance for the filter cake treatments + mineral fertilization (T2) and mineral fertilization (T3) (Table 2). This parallelism of results may be due to the fact that the sum of the bases is composed by the sum of the nutrients K, Ca and Mg, and the CEC is composed of the sum of these nutrients added to these H and Al.
The organic matter (OM) and the carbon factors did not present statistical difference (Table 2). According to the chemical analyzes of the residues used in this work, the filter cake presented a carbon / nitrogen (C / N) ratio of 28.3:1. According to the chemical analyzes of the residues used in this work, the filter cake presented a carbon / nitrogen ratio (C / N) of 28.3: 1. Moreira and Siqueira (2006) report that the C/N ratio of a material influence on its decomposition time, being that the larger the C / N ratio the longer the time for its decomposition.

Table 2. Results of pH, saturation by base (V%), CEC (cation exchange capacity), sum of bases, organic matter and carbon of soil samples submitted to different treatments.

Treatment[1]	pH (CaCl)	V%	CEC (cmolc/dm³)	Sum of bases (cmolc/dm³)	Organic matter (g/dm³)	Carbon (g/dm³)
T1	5.03 a*	71.04 a	19.16 b	13.65 b	26.69 a	15.48 a
T2	4.95 a	71.31 a	19.80 a	14.12 a	26.33 a	15.27 a
T3	4.95 a	71.71 a	20.29 a	14.55 a	26.69 a	15.48 a
T4	4.85 a	68.30 a	17.70 b	13.03 b	24.71 a	14.34 a
CV[2] (%)	6.21	4.64	4.18	8.43	6.21	7.39

[1] T1 - Filter cake; T2 - Filter cake + mineral fertilization; T3 - Mineral fertilization; T4 - control.
*Averages followed by the same letter do not differ by Scott Knott's test (5%). [2]CV = coefficient of variation.

This fact corroborates with the observed results, and the soil samples were collected 120 days after the application of the residues, thus, the filter cake presented a slower decomposition, resulting in a more efficient maintenance of the organic matter of the soil.

In relation to the macronutrients, Table 3 shows the results regarding the macronutrient values in the soil samples in each treatment, among the evaluated nutrients, a statistical difference was observed only for Ca + Mg (calcium + magnesium).

The phosphorus and potassium values did not present statistical difference. Similar results among these nutrients probably occurred as a function of the composition of the residue that presents between 1 and 2% of P and K (Santos et al., 2010).

Table 3. Concentration of phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and calcium magnesium (Ca + Mg) in soil samples under different treatments.

Treatments[1]	P (mg/dm³)	K^+ (cmolc/dm³)	Ca^{2+} (cmolc/dm³)	Mg^{2+} (cmolc/dm³)	Ca+Mg (cmolc/dm³)
T1	19.93 a*	0.60 a	9.96 a	3.08 a	13.05 a
T2	15.30 a	0.57 a	10.37 a	3.18 a	13.54 a
T3	18.88 a	0.55 a	10.90 a	3.10 a	14.00 a
T4	11.21 a	0.46 a	9.75 a	2.82 a	12.57 b
CV[2] (%)	11.32	11.75	7.92 a	6.08	6.68

[1] T1 - Filter cake; T2 - Filter cake + mineral fertilization; T3 - Mineral fertilization; T4 - control.
*Averages followed by the same letter do not differ by Scott Knott's test (5%). [2]CV = coefficient of variation.

Nunes (2005) reports that the organic matter of the filter cake reduces the fixation of the phosphorus by the oxides of iron and aluminum, making this element available to the roots. The same author also reports that the reaction of the organic matter of the pie, by allowing greater stability of aggregates, potentiates the absorption of other nutrients, optimizing the nutrition of the plants.

The Ca^{2+} and Mg^{2+} cations, when analyzed separately, did not present statistical differences (Table 3), but when combined, treatments of filter cake (T1), filter cake + mineral fertilization (T2) and mineral fertilization (T3) differed statistically of the control group (Table 3).

The results obtained from the macronutrients reinforce the environmental viability of the use of filter cake in the soil as a source of nutrients for agricultural crops, such as soybean, since they reduce the environmental impacts related to inappropriate waste disposal.

Table 4. Concentration of copper (Cu), zinc (Zn), iron (Fe), manganese (Mn) and sodium (Na) in different treatments.

Treatments[1]	Cu (mg/dm³)	Zn (mg/dm³)	Fe (mg/dm³)	Mn (mg/dm³)	Na (mg/dm³)
T1	43.44 a*	34.12 a	42.30 a	112.43 a	11.84 a
T2	41.98 a	33.20 a	40.21 a	110.20 a	10.83 a
T3	42.10 a	34.13 a	38.19 a	107.38 a	12.88 a
T4	43.70 a	34.28 a	46.53 a	109.50 a	12.95 a
CV[2] (%)	11.68	10.44	11.89	2.95	8.88

[1] T1 - Filter cake; T2 - Filter cake + mineral fertilization; T3 - Mineral fertilization; T4 - control.
*Averages followed by the same letter do not differ by Scott Knott's test (5%). [2]CV = coefficient of variation.

Regarding micronutrients, their concentration was not influenced by the treatments, and there were no statistical differences (Table 4). Results obtained by Moura Filho (2014) showed that the use of filter cake in high doses can provide the total amount of macronutrients nitrogen, phosphorus, calcium, magnesium and sulfur and of the micronutrients manganese, zinc, iron, copper and boron necessary for the plant development of the applied culture.

3.1 Analysis of soybean seed germination

Germination was evaluated 15 days after sowing and it was verified that between the treatments there was no significant difference (p> 0.05) (Table 5), that is, the application and maintenance of organic residues did not change the percentage of germination of seeds of soybean.
It should be noted that none of the treatments integrated with the organic residues influenced negatively the germination. Thus, the application of organic waste can lead to an improvement in soil quality, as verified by Santana et al. (2012) in which the authors observed that the application of the filter cake to the soil, besides promoting the increase of nutrients, improved the physical and biological structure of the same. These results confirm that when well managed the use of these residues in the soil can play an important role in providing nutrients and maintaining soil integrity, contributing to a more sustainable agriculture.

Table 5. Percentage of germination of soybean seeds submitted to different treatments.

Treatments	Germination (%)
T1- Filter cake	82.76 a*
T2- Filter cake + mineral fertilizer	84.47 a
T3- Mineral fertilization	76.14 a
T4-Control	77.46 a
CV (%)	3.66

*Averages followed by the same letter do not differ by Scott Knott's test (5%). CV = coefficient of variation.

It should be noticed that when organic sources are used for fertilization, the advantages are not only limited to the harvest season, since there is a residual effect in subsequent years, favoring the chemical, physical and biological characteristics of the soil (Ghosh et al., 2009). SO, the development of effective practices, especially with the manipulation of the quantity and type of organic waste, can improve the sustainability of the ecosystems in the long term (Liu et al., 2009).

4. Conclusion

In this study, the application of the filter cake influenced the parameters CTC, sum of bases and Ca + Mg.
The use of filter cake in the soybean crop proved to be feasible for the sustainable management of this crop, since it did not negatively influence the germination.

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