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Assessment of filter cake and biochar usage on soil attributes

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Avaliação do uso da torta de filtro e *biochar* nos atributos do solo

RESUMO
O objetivo do presente trabalho foi avaliar o efeito de diferentes doses de torta de filtro e *biochar* nos atributos químicos e biológicos do solo. Foi instalado 2 experimentos, ambos em delineamento inteiramente casualizado, com 7 tratamentos e três repetições, compostos por: Experimento (SC) - solo sem calcário + 1%, 2% e 3% de torta de filtro (tratamentos SCTF1, SCTF2 e SCTF3, respectivamente) e, solo sem calcário + 1%, 2% e 3% de *biochar* de torta de filtro (tratamentos SCBTF1, SCBTF2 e SCBTF3, respectivamente) mais o tratamento controle (TC); Experimento (CC) - solo com calcário + 1%, 2% e 3% de torta de filtro (tratamentos CCTF1, CCTF2 e CCTF3, respectivamente) e, solo com calcário + 1%, 2% e 3% de *biochar* de torta de filtro (tratamentos CCBTF1, CCBTF2 e CCBTF3, respectivamente) mais o tratamento controle (TC). Posteriormente, foram realizadas análises de caráter químico (pH, MO, COT, NT, P, K, Mg, Ca, Al e H+Al) e biológico (respiração do solo, CBM, NBM e atividade da enzima desidrogenase). Foram feitas análises de variância e regressão linear simples (teste t a 5% de probabilidade) por meio do software R. Para comparação das médias, foi utilizado o teste de Scott-Knott a 5% de probabilidade. Os atributos químicos do solo sofreram influência dos níveis de TF e BTF, SC e CC, apresentando maiores valores no nível de 3%. Para os atributos biológicos, o SCTF3 destacou-se.

PALAVRAS-CHAVE: Resíduo Industrial. Cana-de-açúcar. Pirólise. Fertilidade do Solo.

Assessment of filter cake and biochar usage on soil attributes

ABSTRACT
The aim of the present study was to evaluate the effect of different doses of filter cake and biochar on the chemical and biological attributes of the soil. Two experiments were set up, both in a completely randomized design, with 7 treatments and three replications, composed of: Experiment (SC) - soil without limestone + 1%, 2%, and 3% of filter cake (treatments SCTF1, SCTF2, and SCTF3, respectively) and, soil without limestone + 1%, 2%, and 3% of filter cake biochar (treatments SCBTF1, SCBTF2, and SCBTF3, respectively) plus the control treatment (TC); Experiment (CC) - soil with limestone + 1%, 2%, and 3% of filter cake (treatments CCTF1, CCTF2, and CCTF3, respectively) and, soil with limestone + 1%, 2%, and 3% of filter cake biochar (treatments CCBTF1, CCBTF2, and CCBTF3, respectively) plus the control treatment (TC). Subsequently, chemical (pH, OM, TOC, TN, P, K, Mg, Ca, Al, and H+Al) and biological (soil respiration, MBN, MBC, and dehydrogenase enzyme activity) analyses were performed. Variance and simple linear regression analyses (t-test at 5% probability) were conducted using the R software. For the comparison of means, the Scott-Knott test at 5% probability was used. The soil chemical attributes were influenced by the levels of TF and BTF, SC, and CC, showing higher values at the 3% level. For the biological attributes, SCTF3 was the most notable.

KEYWORDS: Industrial Residue. Sugarcane. Pyrolysis. Soil Fertility.

Evaluación del uso de torta de filtro y biochar en los atributos del suelo

RESUMEN
El objetivo del presente trabajo fue evaluar el efecto de diferentes dosis de torta de filtro y biochar en los atributos químicos y biológicos del suelo. Se instalaron dos experimentos, ambos con un diseño completamente al azar, con 7 tratamientos y tres repeticiones, compuestos por: Experimento (SC) - suelo sin cal + 1%, 2% y 3% de torta de filtro (tratamientos SCTF1, SCTF2 y SCTF3, respectivamente) y suelo sin cal + 1%, 2% y 3% de biochar de torta de filtro (tratamientos SCBTF1, SCBTF2 y SCBTF3, respectivamente), además del tratamiento control (TC); Experimento (CC) - suelo con cal + 1%, 2% y 3% de torta de filtro (tratamientos CCTF1, CCTF2 y CCTF3, respectivamente) y suelo con cal + 1%, 2% y 3% de biochar de torta de filtro (tratamientos CCBTF1, CCBTF2 y CCBTF3, respectivamente), además del tratamiento control (TC). Posteriormente, se realizaron análisis de carácter químico (pH, MO, COT, NT, P, K, Mg, Ca, Al y H+Al) y biológico (respiración del suelo, CBM, NBM y actividad de la enzima deshidrogenasa). Se llevaron a cabo análisis de varianza y regresión lineal simple (prueba t al 5% de probabilidad) mediante el software R. Para la comparación de las medias, se utilizó la prueba de Scott-Knott al 5% de probabilidad. Los atributos químicos del suelo

fueron influenciados por los niveles de TF y BTF, SC y CC, presentando mayores valores en el nivel de 3%. En cuanto a los atributos biológicos, destacó el tratamiento SCTF3.

PALABRAS CLAVE: Residuo Industrial. Caña de azúcar. Pirólisis. Fertilidad del Suelo.

1 INTRODUCTION

Sugarcane is a semi-perennial grass native to Southeast Asia, belonging to the Saccharum genus of the Poaceae family. It enjoys significant economic value both in Brazil and globally, being widely used in the production of sugar, electric power, and alcohol (SILVA et al., 2014; SOBRINHO et al., 2019).

Brazil stands out as the world's largest sugarcane producer. Data from the 2020/2021 harvest indicate a production of 658.8 million tons, with an area of approximately 8,616.1 thousand hectares dedicated to the crop (CONAB, 2020; SILVA et al., 2021).

Annually, there is growth in sugarcane cultivation, resulting in the expansion of areas and, consequently, an increase in waste associated with this sector. A notable example is filter cake (TF), a residue composed of a mixture of ground bagasse and sludge from the decantation process, originating in the treatment and clarification process of sugarcane juice. The production of this residue varies from 30 to 40 kg per ton of crushed cane (FRAVET et al., 2010; JUNIOR et al., 2011). With a high organic matter content, approximately 85.1%, filter cake can be a valuable option for degraded soils and/or soils with low fertility. Its chemical composition includes significant levels of phosphorus, nitrogen, calcium, potassium, magnesium, and micronutrients (CERRI et al., 1998; NUNES JUNIOR, 2005; FRAVET et al., 2010).

Besides its direct application, filter cake can be used as a by-product in the production of biochars, through thermochemical conversion. This practice has aroused increasing interest in the scientific community worldwide.

Filter cake derived biochars (BTF) show increases in the levels of nitrogen, phosphorus, potassium, calcium, and magnesium, and are free from toxic metals. The transformation of filter cake into biochar emerges as a promising option for agricultural use, contributing to the reduction of carbon loss through decomposition and the alkalinization of sandy acidic soils (EYKELBOSH et al., 2013; BERNADINO et al., 2018; FRANCO, 2019).

The application of this management technique in sandy soils in the Western Paulista region has the potential to provide benefits to the soil, while possibly resulting in cost reductions associated with liming and fertilizers. Thus, the present work aims to assess the effects of different doses of filter cake and biochar on the chemical and biological attributes of the soil, seeking to determine if biochar acts as a corrective agent in the soil.

2 MATERIALS AND METHODS

2.1 Study area

The experiments were conducted in a greenhouse, at the experimental area of the Universidade do Oeste Paulista, Campus II, Presidente Prudente - SP. They lasted for 12 months, starting in December 2018 and ending in December 2019.

2.2 Acquisition of materials

The sugarcane filter cake biochar was produced and supplied by SPPT Ltd., located in Mogi Morim, in the state of São Paulo. The material was produced through a thermochemical conversion process - slow pyrolysis, at 400°C. Before the production process, the filter cake was ground and passed through a 2mm sieve.

2.3 Experimental design and pot preparation

The soil used to fill the plastic pots was a Red Latosol, collected from the 0-30 cm depth layer. Before the start of the pot experiment, a granulometric analysis was conducted. The analysis showed that the soil had a sand content of 875.7 g kg^{-1}, silt content of 30.3 g kg^{-1}, and clay content of 94.3 g kg^{-1}.

For both experiments, without limestone application (SC) and with limestone application (CC), a completely randomized design was used, consisting of 7 treatments with three repetitions (Table 1). The doses of TF and BTF were 1, 2, and 3% relative to the soil volume in the pot, PVC, of 15 L. A standard value of 10 kg (soil + TF or BTF in each pot) was used, i.e., 9.9 kg, 9.8 kg, and 9.7 kg of soil for 0.1 kg, 0.2 kg, and 0.3 kg of TF or BTF respectively, according to the treatments.

After filling the pots, in the CC experiment, 10 g of dolomitic limestone was applied and incorporated to raise the base saturation to 60%, following the previously mentioned experimental design (Table 1). Subsequently, the soils were moistened and remained incubated for 30 days, after which the respective doses of filter cake and filter cake biochar were incorporated and remained incubated for another 90 days. Applications of the equivalent to 30 kg ha^{-1} of N, 200 kg ha^{-1} of K_2O, and 180 kg ha^{-1} of P_2O_5, in the form of urea, potassium chloride, and single superphosphate, respectively, were also carried out. The fertilization recommendation was based on the guidelines of Technical Bulletin 100 (RAIJ et al., 1997) and applied directly into the plastic pots.

Table 1 – Treatment description

	Treatments	Levels of TF ou BTF Application
Experiment (SC)	Control Treatment – TC	-
	Soil without limestone insertion + Filter Cake – SCTF1	1 % - equivalent to 100 g or 0.1 kg
	Soil without limestone insertion + Filter Cake – SCTF2	2 % - equivalent to 200 g or 0.2 kg
	Soil without limestone insertion + Filter Cake – SCTF3	3 % - equivalent to 300 g or 0.3 kg
	Soil without limestone insertion + Filter Cake Biochar – SCBTF1	1 % - equivalent to 100 g or 0.1 kg
	Soil without limestone insertion + Filter Cake Biochar – SCBTF2	2 % - equivalent to 200 g or 0.2 kg
	Soil without limestone insertion + Filter Cake Biochar – SCBTF3	3 % - equivalent to 300 g or 0.3 kg
Experiment (CC)	Control Treatment – TC	-
	Soil with limestone insertion + Filter Cake – CCTF1	1 % - equivalent a 100 g or 0.1 kg
	Soil with limestone insertion + Filter Cake – CCTF2	2 % - equivalent a 200 g or 0.2 kg
	Soil with limestone insertion + Filter Cake – CCTF3	3 % - equivalent a 300 g or 0.3 kg
	Soil with limestone insertion + Filter Cake Biochar – CCBTF1	1 % - equivalent a 100 g or 0.1 kg
	Soil with limestone insertion + Filter Cake Biochar – CCBTF2	2 % - equivalent a 200 g or 0.2 kg
	Soil with limestone insertion + Filter Cake Biochar – CCBTF3	3 % - equivalent a 300 g or 0.3 kg

Source: The Authors, 2023.
Subtitle:TF refers to "Filter Cake," a byproduct from the sugar and ethanol production process, rich in organic matter and nutrients. BTF stands for "Filter Cake Biochar," produced through the pyrolysis of filter cake, resulting in a carbon-

rich material that can enhance soil quality and fertility. TC: Control treatment, where soil is used in its natural condition without any additions. SCTF1, SCTF2, SCTF3: Soil treatments without limestone insertion, filter cake added with different concentrations. SCBTF1, SCBTF2, SCBTF3: Soil treatments without limestone insertion, filter cake biochar added with different concentrations. CCTF1, CCTF2, CCTF3: Soil treatments with limestone insertion, filter cake added with different concentrations. CCBTF1, CCBTF2, CCBTF3: Soil treatments with limestone insertion, filter cake biochar added with different concentrations. The application levels (1%, 2%, 3%) represent the percentage of the weight of TF or BTF relative to the soil weight in the pot, equivalent to 100g (0.1 kg), 200g (0.2 kg), and 300g (0.3 kg), respectively.

2.4 Evaluated parameters

2.4.1 Analysis of soil chemical attributes

Soil samples were collected from each pot, at a depth of 0-10 cm, for the analysis of chemical attributes (determination of pH levels, organic matter content, phosphorus, potassium, magnesium, calcium, aluminum, and hydrogen plus aluminum), following the methodology of Raij et al. (2001). From these data, the values of the sum of bases (SB), cation exchange capacity (CEC), base saturation (V%), and aluminum saturation (m%) were obtained. Analyses of carbon (MENDONÇA; MATOS, 2017) and total soil nitrogen (CANTARELLA; TRIVELIN, 2001) were also conducted.

2.4.2 Analysis of soil biological attributes

For the biological analyses, the soil was first air-dried on a bench for 24 hours. After this process, the soil samples were passed through a 2.0 mm mesh sieve, and then the analyses of soil basal respiration (ALEF; NANIPIERI, 1995; RODELLA; SABOYA, 1999), microbial biomass carbon (FERREIRA; CAMARGO; VIDOR, 1999), microbial biomass nitrogen (TEDESCO et al., 1995), dehydrogenase enzyme activity (VAN OS; GINKEL, 2001), and the calculation of the metabolic quotient (ANDERSON; DOMSCH, 1993) were performed.

2.4.3 Data Analysis

The data were submitted to variance analysis through the R software. For the comparison of means, the Scott-Knott test at 5% probability was used. Linear regression analysis, t-test at 5% probability, was also performed.

3 RESULTS AND DISCUSSION

3.1 Analysis of soil chemical attributes

The incorporation of materials altered the soil's chemical attributes (Table 2). Regarding soil pH, it was found to be significantly different from the control treatment (TC). Treatments with the addition of TF and BTF (SC) showed a pH in the neutral/alkaline range.

For soil organic matter (SOM), the treatment that received SCTF3 insertion showed a higher value (average content) and significance compared to TC, SCTF1, and SCBTF1. In total organic carbon (TOC), the treatment that showed the highest value compared to TC was the one

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with SCBTF3 insertion. Biochar is a carbon-rich material and, when applied to the soil, tends to have a longer persistence time compared to biomass (PETTER; MADARI, 2012), which can contribute to a greater carbon input in the soil and assist in reducing carbon loss through decomposition (EYKELBOSH et al., 2013; BERNADINO et al., 2018; FRANCO, 2019).

Total nitrogen (TN) showed, except for the treatment with SCBTF1 insertion, significant differences when compared to TC. And phosphorus (P) showed elevated values compared to TC, especially in the SCTF3 and SCBTF3 treatments.

The highest values for calcium (Ca), magnesium (Mg), sum of bases (BS), cation exchange capacity (CEC), and base saturation (V) were obtained in the treatment with SCBTF3 insertion. The application of biochar to the soil can increase pH, cation exchange capacity, and organic carbon, and increase nutrient availability (TRAZZI et al., 2018).

TC showed the highest value only for potential acidity (H+Al) and potassium (K). For the other attributes, TF and BTF had a significant influence compared to TC, providing an increase in values. Franco (2019) and Barros et al. (2014) mention that the application of filter cake to the soil can influence the increase of some nutrients (nitrogen, phosphorus, calcium, magnesium) and CEC.

Table 2 – Chemical attributes of soil with the insertion of filter cake and biochar, without limestone addition

Treatment	pH	SOM	TN	TOC	P	H+Al	K	Ca	Mg	BS	CEC	V
		g dm^{-3}	mg kg^{-1}	g kg^{-1}	mg dm^{-3}	------mmol$_c$ dm^{-3}------						%
TC	5.3b	8.7c	74.1c	3.3c	4.5e	12.1a	1.8a	8.3c	6.7b	16.8c	28.9c	57.3c
SCTF1	7.6a	12.1b	126.6b	5.7b	69.1d	7.9b	0.9b	15.1c	12.0b	28.0c	35.93c	77.8b
SCTF2	7.4a	14.4a	183.5a	8.1a	211.0b	8.6b	0.7b	41.9b	27.1a	69.8b	78.4b	89.0a
SCTF3	7.6a	17.0a	209.8a	9.8a	262.2a	8.2b	0.8b	49.2b	34.4a	84.5b	92.7b	90.9a
SCBTF1	7.7a	12.5b	72.8c	5.9b	143.23c	7.6b	1.1b	47.5b	18.4b	67.0b	74.6b	89.6a
SCBTF2	7.6a	14.4a	140.3b	9.4a	208.8b	7.2b	1.3b	54.9b	29.0a	85.2b	92.4b	92.1a
SCBTF3	7.7a	14.9a	178.0a	11.1a	236.6a	7.2b	1.2b	88.8a	36.4a	126.4a	133.6a	94.5a
CV%	1.7	11.2	12.4	16.5	13.7	6.8	19.3	22.6	20.8	19.2	17.3	3.82

Source: The Authors, 2023.
Subtitle:TC (Control Treatment): Soil in its natural state, without any additions. SCTF1, SCTF2, SCTF3: Soil treatments without limestone insertion, with varying levels (1%, 2%, and 3% respectively) of filter cake. SCBTF1, SCBTF2, SCBTF3: Soil treatments without limestone insertion, with varying levels (1%, 2%, and 3% respectively) of filter cake biochar. pH: A measure of the soil's acidity or alkalinity; SOM (Soil organic matter in g dm^{-3}); TN (Total Nitrogen in mg kg^{-1}); P (Phosphorus in mg dm^{-3}); H+Al (Potential Acidity in mmolc dm^{-3}); K (Potassium in mmolc dm^{-3}); Ca (Calcium in mmolc dm^{-3}); Mg (Magnesium in mmolc dm^{-3}); BS (Sum of Bases in mmolc dm^{-3}); CEC (Cation Exchange Capacity in mmolc dm^{-3}); V (Base Saturation %); Means followed by the same letter do not differ significantly by the Scott-Knott test ($p<0.05$).

The experiment that incorporated a fixed dose of limestone along with TF or BTF also showed higher values compared to the control treatment (CT). This was observed for pH, SOM, TOC, TN, P, Ca, Mg, BS, CEC, and V (Table 3).

The treatment with the addition of CCBTF3 showed higher values for TN, TOC, P, Ca, Mg, BS, CEC, and V. This confirms the efficiency of biochar application as a soil amendment, as it is noted that where biochar was applied (CCBTF1, CCBTF2, and CCBTF3), there was a reduction in potential acidity, showing significance from the other treatments.

Another attribute that had a significant increase after the higher applications of biochar (CCBTF2 and CCBTF3) was TOC. This indicates that the application of this material can

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influence the increase in soil carbon stock, thus contributing to the reduction of loss of this element.

Tabela 3 – Chemical attributes of soil with the insertion of filter cake and biochar, with limestone addition

Treatment	pH	SOM	TN	TOC	P	H+Al	K	Ca	Mg	BS	CEC	V
		g dm^{-3}	mg kg^{-1}	g kg^{-1}	mg dm^{-3}	---------------------------------mmol$_c$ dm^{-3}------------------------------						%
TC	5.3b	8.7c	74.1c	3.3c	4.5d	12.1a	1.8a	8.3e	6.7d	16.8d	28.9d	57.3c
CCTF1	7.5a	12.6b	93.8c	5.1c	106.1c	8.2b	0.7b	26.3d	15.3d	42.4d	50.5d	83.6b
CCTF2	7.7a	16.7a	135.8b	7.2b	212.1b	7.7b	0.9b	77.8b	39.1b	117.8b	125.5b	93.8a
CCTF3	7.7a	18.1a	199.2a	7.7b	250.4a	7.7b	1.3b	73.6b	47.4b	122.3b	130.0b	94.1a
CCBTF1	7.6a	13.3b	104.7c	6.7b	137.8c	7.5c	1.2b	55.4c	25.2c	81.8c	89.3c	91.6a
CCBTF2	7.7a	14.4b	152.2b	10.3a	217.7b	7.1c	1.0b	58.6c	44.2b	103.9b	111.0b	93.5a
CCBTF3	7.7a	18.0a	234.0a	11.1a	283.7a	7.1c	1.1b	123.3a	62.1a	186.5a	193.6a	96.3a
CV%	1.5	13.7	22.2	14.7	15.6	4.6	23.3	12.4	17.0	17.4	15.9	3.5

Source: The Authors, 2023.

Subtitle:TC (Control Treatment): Soil in its natural state, without any additions. CCTF1, CCTF2, CCTF3: Soil treatments with limestone, with varying levels (1%, 2%, and 3% respectively) of filter cake. CCBTF1, CCBTF2, CCBTF3: Soil treatments with limestone, with varying levels (1%, 2%, and 3% respectively) of filter cake biochar. pH: A measure of the soil's acidity or alkalinity; SOM (Soil organic matter in g dm^{-3}); TN (Total Nitrogen in mg kg^{-1}); P (Phosphorus in mg dm^{-3}); H+Al (Potential Acidity in mmolc dm^{-3}); K (Potassium in mmolc dm^{-3}); Ca (Calcium in mmolc dm^{-3}); Mg (Magnesium in mmolc dm^{-3}); BS (Sum of Bases in mmolc dm^{-3}); CEC (Cation Exchange Capacity in mmolc dm^{-3}); V (Base Saturation %); Means followed by the same letter do not differ significantly by the Scott-Knott test ($p<0.05$).

In Figure 1, it is noted that total organic carbon, total nitrogen, phosphorus, sum of bases, and cation exchange capacity were influenced by the levels of filter cake and biochar application in treatments with and without limestone addition.

For TN, the treatments that showed higher values were SCTF and CCBTF at the 3% application level.

TOC showed greater linearity (R2 = 0.99) in treatments with SCTF insertion, but the treatments that showed higher values were those with the addition of biochar at the 3% level, SC and CC.

For P, BS, and CEC, comparing the treatments, SC and CC, CCBTF at the 3% level stood out, showing higher values. This confirms that the combined addition of biochar and limestone can bring benefits to the soil.

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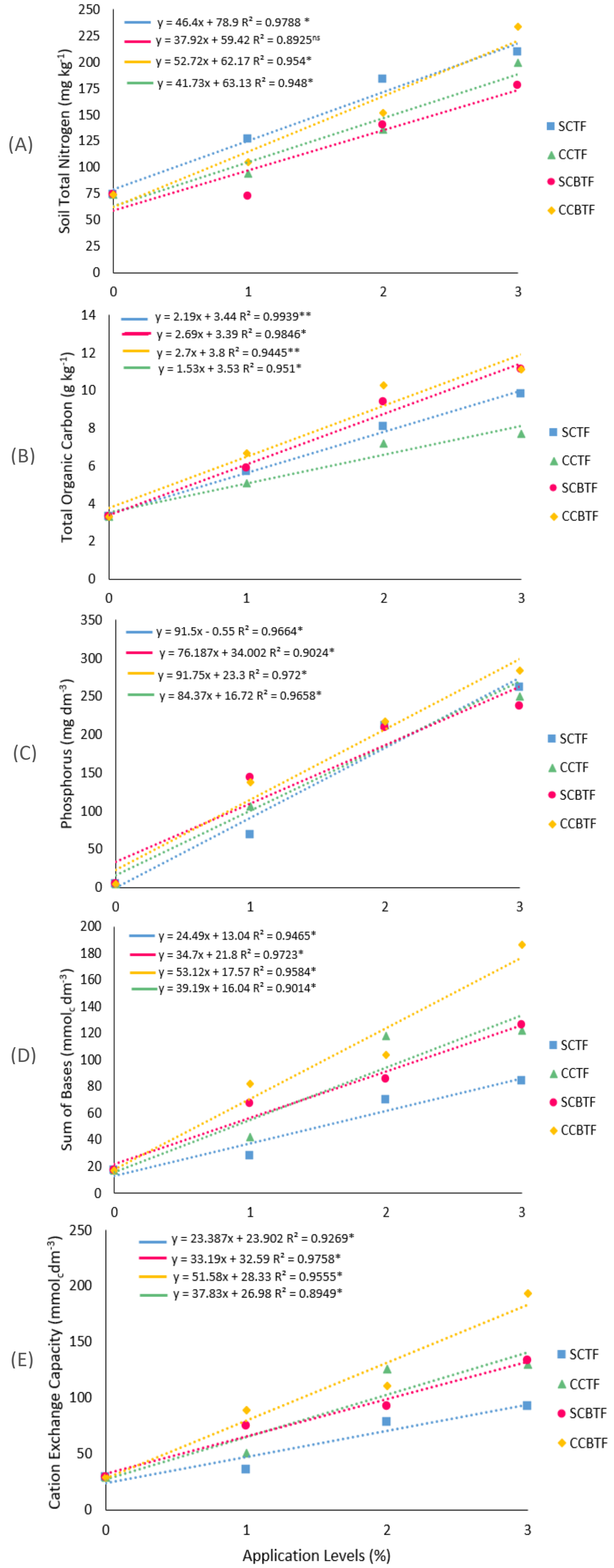
Figure 1 – Linear regression of chemical attributes as a function of TF and BTF levels in SC na CC tratments.



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Source: The Authors, 2023.
Subtitle: (A) Soil Total Nitrogen; (B) Total Organic Carbon; (C) Phosphorus; (D) Sum of Bases; (E) Cation Exchange Capacity. ** and * significant at 1% and 5% levels, respectively, by the t-test.

3.2 Analysis of Soil Biological Attributes

Treatments with addition of filter cake (TF) differed significantly from control treatment (TC), showing higher basal respiration values (Table 4). These values may be related to greater microbial activity, ecological disturbance, or a high level of ecosystem productivity (ISLAM & WEIL, 2000; TU, RISTAINO & HU, 2006; SOUZA, 2021).

The SCTF3 treatment showed a value of 425.32 mg kg^{-1} for microbial biomass carbon (MBC), which may indicate greater carbon immobilization in this treatment. And it differed significantly from the other treatments.

For microbial biomass nitrogen (MBN), the highest values were 29. 8 and 23.3 mg kg^{-1} for SCTF2 and SCTF3, which may indicate greater nitrogen immobilization, and they were significantly different from TC.

A significant difference was observed in activity of the dehydrogenase enzyme among the treatments. SCTF3 showed higher values for this enzyme. Dehydrogenase is related to metabolically active cells in microbial decomposition and in soil organic matter (BALOTA et al., 2013; GADJA, PRZEWLOKA & GAWRYJOLEK, 2013; SOUZA, 2021).

Table 4 – Biological attributes of soil with the insertion of filter cake and biochar, without limestone addition

Treatment	Soil Respiration	*q*CO_2	MBC	MBN	Dehydrogenase
	mg C-CO_2 kg^{-1} solo h^{-1}	mg C-CO_2 kg^{-1} BMS-C h^{-1}	mg kg^{-1}	mg kg^{-1}	µg TTF g^{-1} solo h^{-1}
TC	5.7b	0.044a	214.5b	11.5c	2.8c
SCTF1	13.4a	0.042a	214.5b	17.7c	4.4b
SCTF2	14.1a	0.032a	254.0b	29.8a	4.8b
SCTF3	14.1a	0.029a	425.3a	23.3b	6.0a
SCBTF1	11.3a	0.039a	260.5b	15.1c	2.9c
SCBTF2	14.1a	0.045a	204.9b	6.44d	2.8c
SCBTF3	15.9a	0.035a	177.8b	12.7c	2.6c
CV%	19.4	18.5	12.9	19.6	13.7

Source: The Authors, 2023.
Subtitle: TC (Control Treatment): Soil in its natural state, without any additions. SCTF1, SCTF2, SCTF3: Soil treatments without limestone insertion, with varying levels (1%, 2%, and 3% respectively) of filter cake. SCBTF1, SCBTF2, SCBTF3: Soil treatments without limestone insertion, with varying levels (1%, 2%, and 3% respectively) of filter cake biochar. qCO_2 (Metabolic Quotient); MBC (Microbial Biomass Carbon); MBN (Microbial Biomass Nitrogen). Means followed by the same letter do not differ significantly by the Scott-Knott test (p<0.05).

In the treatments with limestone addition (Table 5), CCTF2 and CCBTF1 showed higher values for microbial biomass carbon. In microbial biomass nitrogen, there was an increase compared to the control in the treatments with CCTF1, CCBTF1, and CCTF2. For the activity of the dehydrogenase enzyme, the treatments that had an application of filter cake showed significance from the others and higher values. The consistency of qCO_2 across treatments suggests that while microbial activity changes, the efficiency of microbial communities in utilizing carbon remains stable.

Tabela 5 – Biological attributes of soil with the insertion of filter cake and biochar, with limestone addition

Trat.	Soil Respiration	*q*CO_2	MBC	MBN	Dehydrogenase
	mg C-CO_2 kg^{-1} solo h^{-1}	mg C-CO_2 kg^{-1} BMS-C h^{-1}	mg kg^{-1}	mg kg^{-1}	µg TTF g^{-1} solo h^{-1}
TC	5.6c	0.044a	214.5b	11.5b	2.8b
CCTF1	10.3b	0.037a	158.1c	22.4a	4.5a
CCTF2	16.0a	0.037a	265.5a	16.3a	4.7a
CCTF3	17.2a	0.035a	168.9c	7.8b	5.1a
CCBTF1	17.0a	0.039a	261.9a	20.8a	2.6b
CCBTF2	12.3b	0.047a	223.6b	8.6b	2.4b
CCBTF3	15.3a	0.035a	173.4c	9.5b	2.0b
CV%	12.7	15.4	11.6	25.7	13.6

Source: The Authors, 2023.

Subtitle:TC (Control Treatment): Soil in its natural state, without any amendments. CCTF1, CCTF2, CCTF3: Soil treatments with limestone, with varying levels (1%, 2%, and 3% respectively) of filter cake. CCBTF1, CCBTF2, CCBTF3: Soil treatments with limestone, with varying levels (1%, 2%, and 3% respectively) of filter cake biochar. qCO_2 (Metabolic Quotient); MBC (Microbial Biomass Carbon); MBN (Microbial Biomass Nitrogen). Means followed by the same letter do not differ significantly by the Scott-Knott test ($p<0.05$).

4 CONCLUSION

The soil chemical attributes were influenced by the levels of filter cake and biochar application in treatments both without and with the addition of limestone, with SCTF3, CCTF3, and CCBTF3 showing higher values at the 3% level.

The microbial biomass and soil enzymatic activity showed changes with the insertion of filter cake and biochars in treatments without limestone addition, especially for the SCTF3 treatment. For treatments with limestone addition, CCTF2 and CCBTF1 stood out in terms of MBC, MBN, and respiration, which could indicate higher microbial biomass activity. And, for the dehydrogenase enzyme, the treatments with TF addition showed higher values.

Generally, it can be concluded that biochar can act as a soil amendment, as where BTF was inserted, for both SC and CC treatments, potential acidity was reduced.

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