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Influência da borra de café nos atributos microbiológico do solo e na cultura de milho

Influence of spent coffee grounds on soil microbiological attributes and maize crop

Influencia de la borra de café en los atributos microbiologicos del suelo y cultivo de maíz

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Resumo

O objetivo do trabalho foi avaliar a influência de diferentes doses de borra de café sobre os microrganismos do solo responsável pela ciclagem de nutriente e o desenvolvimento da cultura do milho em plantio direto. O ensaio foi conduzido a campo no Centro Estadual de Educação Profissional Agrícola Fernando Costa, em bloco ao acaso com 4 tratamento, com as seguintes doses, 0, 3, 6 e 9 t ha^{-1} de borra de café. Foram avaliados carbono da biomassa microbiana (CBM), respiração basal (RBS), quociente microbiano e metabólico (*q*MIC e *q*CO_2), desenvolvimento da planta e a produtividade do milho. Na dose de 9 t ha^{-1} de borra houve incremento da matéria orgânica e aumento significativo da biomassa microbiana (219,01) e *q*MIC (1,5). Com aumento da atividade microbiana, o desenvolvimento da planta foi 20% superior comparado ao controle, altura da planta (2,21) e diâmetro do colmo (2,99). Consequentemente a produtividade foi superior em 42 sacas ha^{-1} em relação a testemunha. Assim, podemos concluir que a borra de café pode ser uma alternativa muito viável no uso como adubo orgânico na agricultura.

Palavras-chave: Adubo orgânico; Biomassa microbiana; *Zea mays*; Resíduo orgânico.

Abstract

The objective of this work was to evaluate the influence of different doses of spent coffee grounds on soil microorganisms responsible for nutrient cycling and the development of corn crop under no-tillage. The trial was conducted in a field at the State Center for Agricultural Professional Education Fernando Costa, in a randomized block with 4 treatments, with increasing doses, 0, 3, 6 and 9 t ha^{-1} of coffee grounds. Microbial biomass carbon (CBM), baseline respiration (RBS), microbial and metabolic quotient (*q*MIC and *q*CO_2), plant development (corn) and productivity were evaluated. At the dose of 9 t ha^{-1} of spent coffee grounds, there was an increase in organic matter and microbial biomass (219.01) and *q*MIC (1.5). With increased microbial activity, the development of the plant was 20% higher compared to the control, plant height (2.21) and stem diameter (2.99). Consequently, the productivity was 42 bags ha^{-1} higher than the control. Thus, we can conclude that spent coffee grounds can be a viable alternative for use as organic fertilizer in agriculture.

Keywords: Organic fertilizer; Microbial biomass; *Zea mays*; Organic waste.

Resumen

El objetivo del trabajo fue evaluar la influencia de diferentes dosis de borra de café en los microorganismos en el suelo responsables del ciclo de nutrientes y el desarrollo del cultivo de maíz sin labranza. La prueba se realizó en el campo en el Centro Estatal de Educación Profesional Agrícola Fernando Costa, en un bloque aleatorio con 4 tratamientos, con las siguientes dosis, 0, 3, 6 y 9 t ha^{-1} de café molido. Se evaluaron el carbono de la biomasa microbiana (CBM), la respiración basal (RBS), el cociente microbiano y metabólico (*q*MIC y *q*CO_2), el desarrollo de las plantas (maíz) y la productividad. A la dosis de 9 t ha^{-1} de borra, hubo un aumento en la materia orgánica y un aumento significativo en la biomasa microbiana (219.01) y *q*MIC (1.5). Con una mayor actividad microbiana, el desarrollo de la planta fue un

20% mayor en comparación con el control, la altura de la planta (2.21) y el diámetro del tallo (2.99). En consecuencia, la productividad fue 42 bolsas ha^{-1} más alta que el control. Por lo tanto, podemos concluir que la borra de café puede ser una alternativa muy viable para su uso como fertilizante orgánico en la agricultura.

Palabras-clave: Fertilizante orgânico; Biomasa microbiana; *Zea mays*; Desechos orgánicos.

1. Introduction

Corn (*Zea mays* L.) has great economic importance in the world. Originating in Central America, it is cultivated in practically all regions due to its high productive potential, chemical composition and nutritional value, assuming the position of the most produced cereal in the world (Lopes et al., 2020). In Brazil, the national planting estimates, an area of 19.6 million hectares and a record production of approximately 102 million tons in the 2019/2020 season (Conab, 2020).

The continuous and excessive use of chemical fertilizers containing synthetic minerals can lead to physical, chemical and biological degradation of the soil in addition to polluting the atmosphere and water sources. Thus, concerns have risen to create alternatives and appropriate technologies to reduce these impacts (Cavalcante et al., 2019).

Among these alternative, technologies the use of organic residues as biological fertilizer has been proposed due to the high concentration of important nutrients for the development of the plant and its high content of organic matter, important in the biological activity of the soil (Kumar & Kumar, 2017).

Many organic residues are produced by human activity, whether of urban, industrial or agricultural origin. All possess potential for use in agriculture, such as animal manure (cattle, poultry and pork), filter cake (residues from the manufacture of alcohol and sugar), composting of vegetable waste and sewage sludge and industrial waste such as spent coffee grounds (Lima et al., 2014). Their agricultural use has a positive effect in the economic, social and environmental fields, as their recycling significantly reduces impacts on the environment.

Coffee is one of the most popular drinks in the world. During its processing, a large amount of waste is generated such as spent coffee grounds, material obtained from the production of soluble coffee (Nzekoue et al., 2020).

This residue has a considerable amount of nutrients such as nitrogen, phosphorus, potassium, phenolic acids important in soil fertility and plant nutrition, since it increases the cationic exchanges in the soil, in addition to fertilize and condition the soil. The addition of coffee grounds in the soil can have positive effects on the fixation of carbon in the soil, in contrast to the incorrect disposal, such as the burning that leads to the release of CO_2 into the atmosphere (Chrysargyris et al., 2020).

The inappropriate use of any organic waste can result in changes or disturbances in the balance of the ecosystem, leading to the deletion or suppression of biological activity in the soil. Microorganisms are the living part of organic matter, responsible for nutrient cycling and maintaining soil fertility (Magalhães, 2013). These microorganisms are sensitive to variations and alterations promoted by anthropic activity, constituting an excellent indicator of soil quality (Costa et al., 2014).

The use of organic waste is growing in agriculture. Nonetheless, there are limited studies that evaluated the effect of organic waste use on soil microbiological attributes and on crop development. The objective of the work was to evaluate the effect of soluble coffee grounds on the development and production of off-season corn and its influence on the microbiological attributes of the soil.

2. Methodology

Spent Coffee Grounds

The tested raw material was spent coffee grounds residue provided by Cia. Iguaçu de Café Solúvel. The material was pre-fermented for a period of 6 months. The chemical composition of the waste is shown in Table 1.

Table 1. Chemical composition of spent coffee grounds.

Description	Content
Total Organic Matter	80 - 85%
Total Nitrogen	3.0 – 3.5%
C/N Ratio	13
Calcium (CaO)	1.5 - 2.0%
Magnesium (MgO)	1.0 – 1.5%
pH	6.0

Source: produced by the authors

The test was conducted in the experimental area of the State Center for Agricultural Professional Education Fernando Costa, in the city of Santa Mariana – PR, at latitude 23°08' 43.5"S, longitude 50°33' 22.1"W. Soil classified as eutrophic RED LATOSOL, very clayey texture, with the chemical characteristics in Table 2.

Table 2. Chemical analysis of experimental areas (A and B) – Pre Planting.

O.M.	pH	P	K	Ca	Mg	Al	H+Al	SB	CEC	Bases
g kg^{-1}	$CaCl_2$	mg dm^3	....	....	....	$cmol_c$ dm^3	....	....	....	(V %)
29.07	5.03	10.33	0.18	6.60	1.87	0.00	5.05	8.65	13.70	63.13

Data: Organic Matter (O.M.); Fosforum (P); Potassium (K); Calcium (Ca); Magnesium (Mg); Aluminum (Al); Hydrogen+Aluminum (H+Al); Sum of Bases (SB); Cationic Exchange Capacity (CEC); Base Saturation (V%). Source: produced by the authors

The corn crop was installed in the no-tillage system, at the expected time, at a density of 3 to 4 seeds per linear meter, at a spacing of 45 cm between rows, using the variety KWS 9004, where the seeds were sown with the aid model planter machine. Together with the sowing, a basic fertilization was carried out with 250 kg ha^{-1} of the formulated fertilizer (NPK) 10-15-15.

The experimental design was randomized block with 4 treatments with 5 repetitions, being Witness (T0) (without application of coffee grounds) and 3 treatments (T3, T6 and T9) with application of 3, 6 and 9 t ha^{-1} of coffee grounds respectively. Each plot measured 20 x 10 m, totaling an area of 4,000 m^2.

Collection and preparation of soil samples for chemical and microbiological analysis

Soil collection for chemical analysis was performed before planting to assess the need for soil correction and for microbiological analysis, post-harvest soil collection was performed. In the microbiological analyzes, Microbial Biomass Carbon (MBC), Soil Basal Respiration (SBR), Metabolic Quotient (qCO_2) and Microbial Quotient (*q*MIC) were evaluated. All collections consisted of 20 samples taken at a depth of 0 – 10 cm, where each sample consisted of 5 sub-samples taken at random points within each plot.

The collected sub-samples were homogenized, packed in plastic bags and transported in a thermal box to the Soil Microbiology Laboratory, in the State University of Northern Paraná, *Campus* Luiz Meneghel, where they were separated from plant and animal waste and sieved in a 2 mm mesh.

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Soil chemical analysis

After air drying the soil samples, the pH was determined in 0.01 M $CaCl_2$, P, Ca^{2+}, Mg^{2+}, K^+ and Al^{3+}. The contents of Ca^{2+}, Mg^{2+}, K^+ and Al^{3+} were extracted with 1 M KCl and determined by atomic absorption (Ca^{2+} and Mg^{2+}) and titrated with 0.025 M NaOH (Al^{3+}); P and K^+ were extracted with Mehlich-1 extractor and determined by flame ionization spectrophotometry (K^+) and by the molybdenum blue method (P).

Carbon from soil microbial biomass determination

The carbon from microbial biomass of the soil was determined by the fumigation-indirect extraction (FIE) method.

Basal respiration and soil metabolic quotient (qCO_2) determination

Basal soil respiration and qCO_2 were determined according to the methodology proposed by Silva et al. (2010).

Total organic carbon (TOC) and microbial quotient (*q*MIC) determination

TOC determination was carried out in combustion of organic matter via wet, using 0.5 g of sample, according to Walkley & Black (1934 – modified), without external heating in the plate.

*q*MIC was determined by the SMBC/TOC ratio.

Agronomic evaluation of the plant and productivity

The agronomic evaluation took place in two moments, at 43 and 86 days and 10 plants were collected per plot. In the area, the height and diameter of the stem was evaluated with the aid of a digital caliper. Regarding the root, the fresh mass (FM) and then the dry mass (DS) were evaluated using a forced circulation oven at 65 ºC for 72 hours, until constant weight was obtained, in addition to the root volume at 86 days.

Grain productivity was assessed by harvesting plants in the area of 0.9 m^2 (2 linear meters) per plot. The weight of 200 grains and the weight of grains in 10 ears were evaluated.

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All statistical analyses were carried out using SISVAR (Version 5.7, DEX/UFLA) (Ferreira, 2018). The averages were submitted to ANOVA. When confirming a statistically significant P value, the Tukey test ($P < 0.05$) was applied for comparison purposes.

3. Results and Discussion

The application of spent coffee grounds to 9 t ha^{-1} of corn crop showed an significant increase in organic matter in the soil and in the microbial population (SMBC) and *q*MIC compared to the other treatments (Table 3).

Soil microbial biomass (MB) is considered the living fraction of the soil, excluding megafauna organisms (>0.2mm) and the active roots of plants. This biomass acts in the transformation of the organic matter releasing nutrients (N, P, S among others) readily available to the plants. MB also acts directly on the energy flow of the system, defining the nutritional and environmental qualities of the different edaphic conditions (Moreira & Malavolta, 2004).

MB's efficiency in using soil C can be measured by the relationship between MBC and TOC, which is considered in balance in agrosystem values between 1.8% to 2.2% (Baretta et al., 2005). This relationship is important due to the decomposition of residues, promoting considerable increase in yield in subsequent crops. High values of *q*MIC reflect the amount of organic carbon immobilized in the MB and point to the potential reserve of this element in the soil, resulting in a decrease in the loss of these nutrients in the soil-plant system. In soils which organic matter is of low nutritional quality, MBC is under stress and is unable to fully use organic C, leading to a decrease in *q*MIC (Gama-Rodrigues et al., 2018). This result were observe in treatments T0 and T3 (Table 3)

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Table 3. Soil Microbiological Analysis.

(1)TREAT.	(2)TOC (g.Kg^{-1})	(3)MBC (mg C. Kg $^{-1}$ solo)	(4)*q*MIC (%)	(5)SBR (mg de C-CO_2 Kg^{-1}h^{-1})	(6)*q*CO_2 (mg C-CO_2 g^{-1}.h^{-1}/ BMS-C mg.kg^{-1})
T0	13.09 ab	40.62 c	0.32 c	0.58 a	14.31 a
T3	11.06 b	36.36 c	0.33 c	0.51 a	14.31 a
T6	11.84 b	115.80 b	0.98 b	0.36 b	3.18 b
T9	14.65 a	219.01 a	1.50 a	0.21 c	0.98 b
C.V.	10.11	19.49	20.82	18.47	24.09

Data: (1)T0 (Witness); T1 (3 t ha^{-1}); T2 (6 t ha^{-1}); T3 (9 t ha^{-1}); (2)TOC (Total Organic Carbon); (3)MBC (Microbial Biomass Carbon); (4)*q*MIC (Microbial Quotient); (5)SBR (Soil Basal Respiration); (6)*q*CO_2 (Metabolic Quotient). Averages followed by the same lower case letter in the column do not differ significantly by Tukey's test at the 5% probability level. Source: produced by the authors

The SBR was lower at T9 (0.21) compared to the other treatments, directly reflecting in *q*CO_2, demonstrating that at the highest dose of coffee grounds the microbial activity is in balance. This was not observed in treatments T0 and T3 where metabolic stress in observed (Table 3).

qCO_2 expresses the relationship between SBR and MBC, reflecting the influx of energy (C) through microbial biomass (Lacerda et al., 2013). High values demonstrate a condition of stress, where the microbial biomass requires greater carbon input for its maintenance (Mendes et al., 2009). Low values of *q*CO_2 indicate energy savings and a more stable and balanced environment (Tótola & Chaer, 2002).

In agronomic parameters, the area using spent coffee grounds showed an increase of fresh root weight (FRW) (99.15 g with 43 days and 203.41 g with 86 days), dry root weight (DRW) (16.90 g at 43 days and 35.67 g at 86 days), plant height (PH) (1.13 m at 43 days and 2.21 m at 86 days) and stem diameter (SD) (2.02cm at 43 days and 2.99 cm at 86 days), followed by T6, T3 and T0 (Table 4).

Table 4. Agronomic parameters of corn crop at 43 and 86 days of emergence.

(1)TREAT.	FRW (g)		DRW (g)		RV (mL)	PH (m)		SD (cm)	
	43	86	43	86	86	43	86	43	86
T0	43.00d	122.79d	6.01d	23.60d	457.00d	0.77d	1.84d	1.24d	2.39d
T3	54.20c	136.60c	7.44c	24.92c	482.94c	0.84c	2.01c	1.45c	2.59c
T6	81.31b	165.58b	14.83b	31.22b	625.58b	1.01b	2.13b	1.79b	2.99b
T9	99.15a	203.41a	16.90a	35.67a	653.04a	1.13a	2.21a	2.02a	2.99a
C.V (%)	1.43	0.66	1.74	1.91	1.04	1.19	0.61	1.54	0.77

Data: (1)T0 (Witness); T1 (3 t ha^{-1}); T2 (6 t ha^{-1}); T3 (9 t ha^{-1}); FRW (Fresh Root Weight); DRW (Dry Root Weight); RV (Root Volume); PH (Plant Height); SD (Stem Diameter).
Averages followed by the same lower case letter in the column do not differ significantly by Tukey's test at the 5% probability level. Source: produced by the authors

This response is possibly related to the values demonstrated in the microbiological analyzes of the soil (Table 3), in which the microbial activity was significantly higher in area treated with coffee grounds. Graciano et al. (2020) observed the direct relationship between microbial activity and the increase in nutrients in pasture areas and semi deciduous forests. This was cause by microbial biomass, which directly participates in the cycling of organic matter in the soil.

The increase in productive characteristics through the use of organic compounds is likely due to the better development of the plant through the efficient use of nutrients available in the soil (Davari et al. 2012).

The positive effect on the root mass is possibly caused by the improvement in the chemical, physical and biological qualities of the soil, and the reduction in the release rate of nutrients, in order to meet the need of the crop for a long period (Perreira et al., 2020). Additionally the presence of organic matter, which provides direct positive effects on the soil (e.g. reduced compaction) increased water retention and greater availability of nutrients (Santos et al., 2017).

The use of organic compounds can significantly affect the height and diameter of the stem (Uchôa et al., 2020). This is possibly attributed to the presence of humic substances, which promote greater absorption of nutrients leading to better plant development (Soares et al., 2014). The increase in FRW and DRW is also related to the humic substances, which contribute to the improvement of the physical-chemical and biological properties of the soil. (Silva & Mendonça, 2007).

According to Chrysargyris et al. (2020), the use of spent coffee grounds on the substrate affects the availability of minerals in plants, increasing the accumulation of nitrogen, potassium, phosphorus and copper levels, affecting their physical-chemical characteristics.

Regarding the weight of 200 grains, there was no difference between treatments with spent coffee grounds. However, they differed significantly compared to the control. For the weight of 10 corn cobs, the treatment with spent coffee grounds stood out with 1.45 kg, differing statistically from the other treatments, including the control. Yield increased by 10, 32 and 42 bags ha^{-1} respectively with 3, 6 and 9 t ha^{-1} of coffee grounds compared to the control (Table 5).

Table 5. Corn grain yield parameters.

[(1)]TREAT.	Weight 200 grains (g)	Weight 10 corncobs (kg)	Yield Kg ha^{-1}	Yield Bags ha^{-1}
T0	53.60 b	1.07 d	7.133 d	118.9
T3	61.80 a	1.16 c	7.733 c	128.9
T6	64.80 a	1.36 b	9.066 b	151.1
T9	66.40 a	1.45 a	9.666 a	161.1
C.V.	4.33	2.02	2.02	

Data: [(1)]T0 (Witness); T1 (3 t ha^{-1}); T2 (6 t ha^{-1}); T3 (9 t ha^{-1}).
Averages followed by the same lower case letter in the column do not differ significantly by Tukey’s test at the 5% probability level. Source: produced by the authors

The increases observed may be related to the addition of available nutrients to plants, mainly nitrogen, which has a structural function, participating in the composition of aminoacids and proteins, in addition to nucleic acids and nitrogenous bases (Epstein & Bloom, 2006).

The organic matter in the soil plays a fundamental role in the development of the plant, providing consequently yield increased (Costa et al., 2014).

The supply of essential elements to plants is of enormous importance for the performance of their physiological functions (Fernandes et al., 2018). In addition, the formation of humic substances from the application of these compounds can have effects on the vital functions of plants, resulting in increased mineral nutrition and ion absorption (Souza et al., 2016).

In Pearson’s correlation, all variable analyzed had a strong correlation, being higher than r = 0.889. Indicating a positive trend (+) of the parameters evaluated with an increase in the dose of spent coffee grounds or a fall (-) in the same direction (Table 6). This high correlation indicates an increase in yield to be inferred from the good results obtained in all parameters (agronomic and microbiological) evaluated.

Table 6. Pearson correlation (r) of microbiological, agronomic and yield parameters as a function of the applied dose of coffee grounds

	DOSE	***SMBC***	***qMIC***	***SBR***	***qCO_2***	***DRW86***	***PH86***	***VOL***	***SD86***	***YIELD***
DOSE	1									
SMBC	0.901	1								
qMIC	0.911	0.986	1							
SBR	-0.889	-0.821	-0.821	1						
qCO_2	-0.891	-0.878	-0.908	0.877	1					
DRW86	0.969	0.938	0.944	-0.894	-0.935	1				
PH86	0.986	0.833	0.860	-0.866	-0.866	0.929	1			
VOL	0.951	0.884	0.915	-0.858	-0.950	0.971	0.931	1		
SD86	0.944	0.807	0.859	-0.830	-0.909	0.928	0.957	0.976	1	
YIELD	0.976	0.902	0.929	-0.855	-0.926	0.972	0.959	0.977	0.962	1

Data: MBC (Microbial Biomass Carbon); *q*MIC (Microbial Quotient); SBR (Soil Basal Respiration); qCO_2 (Metabolic Quotient); Dry Root Weight with 86 days = [DRW86]; Plant Height with 86 days = [PH86]; Root Volume = [VOL]; Stem Diameter with 86 days = [SD86]; Yield = [Yield].
Source: produced by the authors

The addition of spent coffee grounds increases the nutritional value of plants promoting greater development efficiency and plays an important role in the environment, ensuring the implementation of good agricultural practices and sustainable development. This can result in the reduction of the use of conventional inorganic fertilizers (Cervera-Mata et al., 2019).

In addition, the incorporation of 1 t of spent coffee grounds induces the sequestration of C, with a consequent reduction of 506 kg of CO_2 emitted into the atmosphere, an important fact from an environmental point of view (Cervera-Mata et al., 2019).

4. Conclusion

The use of spent coffee grounds showed a positive relationship with the soil microbial community, increasing the biomass and the microbial activity of the soil. This provided better decomposition and mineralization of organic matter, and consequently a significant increase in the root and plant aerial part.

The dose of 9 t ha^{-1} of spent coffee grounds showed the best index in microbiological and agronomic attributes, and a yield of 42 bags ha^{-1} compared to the control.

Spent coffee grounds can be a good alternative of organic fertilizer in agriculture, however further studies are needed.

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