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OXIDATIVE AND CARBON FRACTIONS OF MICROBIAL BIOMASS OF SOILS IN SUGARCANE CULTIVATION SYSTEMS

Frações oxidáveis do carbono orgânico e biomassa microbiana de solos em sistemas de cultivo de cana-de-açúcar

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Abstract

Sugarcane (Saccharum spp.) is a crop of great importance in the Brazilian scenario, its management directly influences the attributes of the soil, independent of the cultivation system, be it conventional or organic. The system as well as cultivation can alter the fractions of carbon in the soil, which can be evaluated and monitored through the accumulation of carbon or its fractions contained in organic matter, since various physical, chemical and biological functions and processes occur in the soil are directly related to organic matter. The objective of this work was to verify the levels of total organic carbon (TOC), oxidizable fractions and microbial biomass carbon present in soils managed with different cropping systems in Goianésia. It was evaluated the conventional and organic systems, with and without vinasse application in three cutting ages (2nd, 4th and 6th cuts). The management of sugarcane cultivation in the organic system contributes to the increase of the total organic carbon content of the soil and the carbon of the microbial biomass. The use of vinasse is a practice that increases organic carbon in soils under sugarcane cultivation. The cut age does not present a linear relationship in the total carbon contents and the fractions analyzed.

Resumo

A Cana-de-açúcar (Saccharum spp.) é uma cultura de grande importância no cenário brasileiro, o seu manejo influencia diretamente nos atributos do solo, independente do sistema de cultivo, seja ele convencional ou orgânico. O sistema, bem como o cultivo podem alterar as frações de carbono no solo, que pode ser avaliada e monitorada através do acumulo de carbono ou de suas frações contidas na matéria orgânica, uma vez que diversas funções e processos físicos, químicos e biológicos que acontecem no solo têm relação direta com a matéria orgânica. Objetivou-se com este trabalho verificar os teores do carbono orgânico total (COT), das frações oxidáveis e do carbono da biomassa microbiana presentes nos solos manejados com diferentes sistemas de cultivo em Goianésia. Avaliou-se os sistemas convencional e orgânico, com e sem aplicação de vinhaça em três idades de corte (2º, 4º e 6º cortes). O manejo do cultivo de cana-de-açúcar em sistema orgânico contribui para o incremento dos teores de carbono orgânico total do solo e o carbono da biomassa microbiana. O uso de vinhaça é uma prática que incrementa carbono orgânico nos solos sob cultivo de cana-de-açúcar. A idade de corte não apresenta relação linear nos teores de carbono total e das frações analisadas

INTRODUCTION

Sugar cane (*Saccharum* spp.) is one of the best options among renewable energy sources, presents great importance in the Brazilian agricultural scenario and a promising future in the world scenario. (Maule et. al. 2001).

In sugarcane cultivation, soil preparation causes changes in its attributes, so Jendiroba (2006) recommends strict monitoring of the areas cultivated with sugarcane. Therefore, soil management is extremely important for the quality of the material to be harvested. In general, conventional management has been used, this system follows pre-established standards, such as the use of pesticides and hormones, the practice of burning that destroys organic matter in the soil, usually using monoculture, which generates a biggest imbalance ecological, excessive use of water.

In parallel to the conventional system, some sugarcane plants have invested in the production of sugarcane in an organic system, in which soil management plays a decisive role, since the objective is to maintain a dynamic equilibrium, formed by living organisms such as bacteria, fungi, parasites of the earth and a high rate of organic matter, so that plants develop well.

In the processing of sugarcane for ethanol and sugar production, Brazilian mills produce several by-products, such as straw, bagasse, filter cake, yeast, vinasse and molasses in large quantities (Paoliello, 2006). It is estimated that one tonne of processed cane produces, on average, 700 to 800 liters of vinasse (Ferreira, 2009).

The correct destination of by-products is of extreme importance for the contribution of environmental conservation. Regarding vinasse, practically all the material was used in sugarcane plantations (Torres et. al., 2012).

The quality of the soil in the productive environment determines the success of the production. Several authors have evaluated parameters to indicate soil quality (Vezzani, Mielniczuk, 2011). Among the studied parameters, the organic matter has been emphasized against other parameters (Xavier et. al., 2006) since several physical, chemical and biological processes and processes occurring in the soil are directly related to organic matter. One of the ways to evaluate this quality is to monitor the accumulation of carbon or its fractions contained in organic matter (Souza et. al., 2014).

Among the carbon fractions, Chan et. al., (2001) suggest the evaluation of the oxidizable fractions which is divided into four fractions (F1, F2, F3 e F4), according to the degree of susceptibility to oxidation in the presence of different concentrations of sulfuric acid. Fractions F1 and F2, which are more easily oxidized, are associated with nutrient availability and the formation of macro aggregates (Chan et. al., 2001). The F3 and F4 fractions are related to compounds of higher chemical stability and molar mass, resulting from the decomposition and humification of soil organic matter (Steverson, 1994).

On the other hand, soil microbial biomass (SMB) is the living fraction of OM, responsible for biochemical and biological processes in the soil and significantly altered by the conditions imposed by the environment. (Balota et al., 2008). Thus, BMS is influenced by climate, aeration, availability of mineral nutrients and soil organic C. In situations with greater deposition of organic residues in the soil and with a great number of roots there is stimulation of the microbial biomass, causing a population increase (Souza, 2010).

In view of the above, the objective of this work was to evaluate the influence of conventional and organic cultivation systems, the application of vinasse and the age of cut in the oxidizable fractions and in the carbon of the microbial biomass cultivated with sugar cane.

MATERIAL AND METHODS

The experiment was conducted in commercial sugarcane growing area in partnership with Sugar and Alcohol Plant Jalles Machado S / A - Goianésia GO. For this, soil samples were collected at two depths (0-0.1 m and 0.1-0.2 m). The experiment was arranged in a 2 x 2 x 3 factorial design, the first factor constituted by the management system (conventional and organic), the second by the application of vinasse as fertirrigation (with and without vinasse) and the third with three cutting ages cut, 4th cut and 6th cut).

Samples were collected using auger, each sample was composed of four subsamples. These were homogenized and conditioned in identified plastic bags and stored in a cold room at 4° C for microbiological analysis. Part of this sample was air dried, macerated and all the soil passed through 0.5 mm mesh sieve for the other analyzes.

The oxidizable fractions of the organic matter were determined according to the procedure proposed by Chan et. al., (2001) adapted by Rangel (2008) thus summarized: 0.5g of dry air-dry earth (TFSA) were placed in 250 ml Erlenmeyers, 10 ml $K_2Cr_2O_7$, 0.167 mol L^{-1} and amounts of H_2SO_4, 2.5 ml, 5 ml, 10 ml and 20 ml corresponding respectively to the final concentrations of 3, 6, 9 and 12 mol L^{-1}.

The oxidation was carried out without external heat source and the titration of the extracts was carried out with a solution of $Fe(NH_4)_2(SO_4)_2.6H_2O$ 0,4 mol L^{-1} (salt of Mohr), using as an indicator phenanthroline ($C_{12}H_8N_2H_2O$), prepared as a function of the mixture of 1.465 g of indicator with 0.985 g of $Fe(NH_4)_2(SO_4)_2.6H_2O$, which were dissolved in 100 ml of distilled water. The fractionation of C produced four fractions, with decreasing degrees of oxidation: Fraction 1 (F1): C oxidized by $K_2Cr_2O_7$ in acid medium with 3 mol L^{-1} of H_2SO_4; Fraction 2 (F2): difference between C oxidized by $K_2Cr_2O_7$ in acidic medium with 6 and 3 mol L^{-1} of H_2SO_4; Fraction 3 (F3): difference between C oxidized by $K_2Cr_2O_7$ in acid medium with 9 and 6 mol-1 of H_2SO_4; Fraction 4 (F4): difference between C oxidized by $K_2Cr_2O_7$ in acid medium with 12 and 9 mol L^{-1} of H_2SO_4, analyzes were done in triplicates.

For the determination of the Carbon of the microbial biomass, the samples were removed from the refrigeration, sieved in a 2 mm sieve, and after leaving the root remains, left at room temperature for 12 hours. The determination of microbial biomass carbon (MBC) was performed by the irradiation-extraction method, proposed by Islam & Weil (1998).

The carbon of the microbial biomass was calculated by the formula: MBC = (CI-CNI) / Kec, where, CI and CNI: represent the total organic carbon released from irradiated and non-irradiated subsamples, respectively; the Kec: factor that represents the amount of carbon from the microbial biomass. The values of Kel cited in the literature are very variable. In this study, the Kec = 0.33 was used (Mendonça & Matos, 2005).

The obtained variables were submitted to analysis of variance and the means were compared by the Scott-Knott test at 5% probability, using the statistical program Assistant Beta 7.7.

RESULTS AND DISCUSSION

The total carbon contents found in this study varied from 27.60 to 33.38 $g.kg^{-1}$ with a decrease in depth. These values are above those found in Cerrado soils (Costa Junior et. al., 2011, Souza et. al., 2014). However, they are still below the minimum sustainability threshold of 40 g.kg $^{-1}$ suggested by Papa et al. (2011).

Table 1 presents the values of total organic carbon evaluated in the organic and conventional culture systems at depths of 0-0.1 m and 0.1-0.2 m.

In general, the values of total carbon found in the organic system were higher than those of the conventional system differing statistically in both the 0-0.1 m layer as well as the 0.1-0.2 m layer. These results confirm those found by Abbruzzini (2012), where sugarcane cultivation areas in the organic system had a higher inventory of organic carbon than in the conventional system.

Table 1. Total Organic Carbon (TOC) of the soil in conventional and organic sugarcane cultivation system, with and without vinasse application and ages of 2nd, 4th and 6th cut.

SYSTEM	TOC ($g.kg^{-1}$)	
	0-0.1m	0.1-0.2 m
Organic	32,45 a	29,78 a
Conventional	31,20 b	28,85 b
with vinasse	33,52 a	29,70 a
without vinasse	30,14 b	28,92 b
2nd court	32,53b	28,87 b
4th court	33,38 a	31,47 a
6th court	30,59 c	27,60c

Means followed by the same letter in the column do not differ from each other, by the Scott-Knott test at 5% probability

According to Bayer et al., (2004) in conventional cropping systems, soil acts as a source of C for atmosphere, C is fixed in less quantity in the soil, being lost to the atmosphere. This may explain the higher levels observed in the organic system, in which it tends to keep this C fixed in the soil.

In general, the means of management with vinasse application showed higher levels of total organic carbon, which differentiated the management without vinasse application, both at 0-0.1m depth and at 0.1-0.2 depth, results similar to those found by Vasconcelos et. al., (2010).

These results can be explained according to Rosset et al. al., (2014) due to the fact of the Fert irrigation practice to improve the contribution of organic matter in the soil. In addition, vinasse has positive effects on several soil characteristics, increases pH, increases the availability of some ions, increases cation exchange capacity (CTC), and improves soil physical structure. According to Gloria & Orlando Filho (1983), vinasse must also be seen as an agent of population increase and microbial activity in the soil that favors the fixation of carbon in the soil that is associated with the availability of nutrients and the formation of macro aggregates.

The carbon contents presented different behaviors according to the time of implantation, that is, the number of cuts. In the 4th cut presented higher amount of total organic carbon, followed by the 2nd cut and finally, in a smaller quantity the 6th cut. This situation occurred for both the 0-0.1 m layer and the 0.1-0.2 m depth layer.

Similar to that described by Skjemstad et. al., (1999), where areas cultivated the longest in sugarcane cultivation present soils with lower levels of organic carbon on the surface, which rise in the subsoil layers when compared to newly implanted areas.

For the oxidizable fractions, in this study, they were grouped according to lability and recalcitrance in F1 + F2 and F3 + F4.

For Majumder et al. (2008) the F1 and F2 fractions can be considered a good indicator of system sustainability, whereas F3 and F4 fractions are more resistant to the soil, being called "passive compartment" in Organic Matter Soils simulation models, with time of recycling of up to 2,000 years (Chan et al., 2001).

Table 2 presents the values of carbon for the F1 + F2 and F3 + F4 fractions evaluated in the organic and conventional systems, in the 0-0.1 and 0.1-0.2 m layers.

Table 2. Fractions of F1 + F2 and F3 + F4 of the soil in conventional and organic sugarcane cultivation system

SYSTEM	F1 + F2 (g.kg^{-1})		F3 + F4 (g.kg^{-1})	
	0-0.1m	0.1-0.2 m	0-0.1m	0.1-0.2 m
Organic	14,15 a	11,19 b	18,30 b	18,58 a
Conventional	11,22 b	12,52 a	19,98 a	16,33 b

Means followed by the same letter in the column do not differ from each other, by the Scott-Knott test at 5% probability

The organic system presented higher carbon contents of the fractions F1 + F2 in the 0-0.1 m depth. These results are explained, because the fractions F1 and F2, of easier oxidation, are associated to the organic materials deposited on the surface of the soil. In organic management, the use of organic fertilizers is common, which contributes to the increase of C levels in the soil, especially in the more oxidizable fractions (F1 + F2) as well as the higher deposition of plant residues by the absence of chemical control of invasive plants.

The conventional system presented higher carbon concentration of the F1 + F2 fractions in the depth of 0.1-0.2 m, a fact that can be explained, since the conventional management besides revolving the layers of soil can move the organic matter from the surface to the depth.

The conventional system presented higher concentration of F3 + F4 carbon in the depth of 0-0.1 m, while in the organic system it presented higher carbon concentration of the F3 + F4 fractions in the depth of 0.1-0.2 m.

The fractions F3 and F4 are related to compounds of higher chemical stability and molar mass, resulting from the decomposition and humification of soil organic matter (Steverson, 1994). Thus, organic systems contribute to an increase of carbon in the more subsurface layers.

Table 3 presents the values of carbon for the fractions F1 + F2 and F3 + F4 evaluated in the management with vinasse application and without application of vinasse, in the depth of 0-0.1 m and in the depth of 0.1-0.2m.

Table 3. Carbon F1 + F2 and F3 + F4 Fractions of the soil in sugar cane system with and without vinasse application

SYSTEM	F1 + F2 (g.kg^{-1})		F3 + F4 (g.kg^{-1})	
	0-0.1 m	0.1-0.2 m	0-0.1 m	0.1-0.2 m
with vinasse	12,98 a	10,68 b	20,54 a	17,59 a
without vinasse	12,39 a	13,03 a	17,75 b	17,32 a

Means followed by the same letter in the column do not differ from each other, by the Scott-Knott test at 5% probability

The use of vinasse application did not influence the carbon contents of the F1 + F2 fraction in the 0-0.1 m depth. Results different from those presented by Abreu et. al., (2016), that with the application of vinasse observed increase of carbon in all the layers analyzed.

In the subsurface layer, 0.1-0.2 m, the management without the application of vinasse presented higher carbon contents, disagreeing with the data published by Canellas et. al., (2003) who observed higher carbon contents mainly in the intermediary layers evaluated when the vinasse was used via fertirrigation.

The carbon contents belonging to the F3 + F4 fraction were higher in the 0-0.1 m layer when the soil was ferriticated with vinasse. This shows that the use of this practice as promoter of increase of Carbon of the most oxidizable fractions (F1 and F2) and of those more recalcitrant (F3 and F4).

However, for the 0.1-0.2 m layer the management with vinasse application did not show statistical difference in the fraction, which can be explained by the lower carrying capacity of organic carbon in the soil profile.

Table 4 shows the values for carbon of the F1 + F2 and F3 + F4 fractions evaluated by age, represented by the 2nd cut, 4th cut and 6th cut, in the depth fractions of 0-0.1 m and in the depth of 0.1-0.2 m.

Table 4. Fractions of F1 + F2 and F3 + F4 Carbon in the soil of 2nd, 4th and 6th cut in the cultivation of sugar cane

AGE	F1 + F2 ($g.kg^{-1}$)		F3 + F4 ($g.kg^{-1}$)	
	0-0.1 m	0.1-0.2 m	0-0.1 m	0.1-0.2 m
2nd Court	13,61 a	12,71 a	17,92 b	16,59 b
4th Court	11,39 b	10,20 b	21,98 a	20,62 a
6th Court	13,06 a	12,65 a	17,53 b	15,15 b

Means followed by the same letter in the column do not differ from each other, by the Scott-Knott test at 5% probability

The fractions presented different behaviors according to the time of implantation, that is, the number of cuts. In the 2nd and 6th cuts, the carbon content of the F1 + F2 fraction was higher than that obtained in the 4th cut. These results were observed in both the 0-0.1 m depth fractions and the 0.1-0.2 m depth fractions.

The obtained results can be explained by the fact that the soils in areas of 2nd cut suffered, soon, reform in the cane field. This reform may contribute to an increase in the carbon content, especially of the more oxidizable fractions (F1 and F2), since the reforming practice helps in the incorporation of organic residues deposited superficially at the time of harvest.

Over time (4th cut), the action of decomposing microorganisms contributes significantly to the decrease of their carbon content over the years (Góes et al., 2005). With the amount of straw being deposited at the time of harvesting and the reduction of the aggregation caused by the traffic of machines (Corrêa, 2002) in crop and harvesting, the carbon contents of fractions F1 and F2 again increased significantly in the 6th court.

It was observed that the fractions presented different behaviors according to the time of implantation, that is, the number of cuts. In the 2nd cut and 6th cut, similar results were obtained, showing a lower F3 + F4 organic carbon concentration than in the 4th cut with the highest organic carbon concentration. This situation occurred for both fractions at depths 0-0.1 m and depth fractions of 0.1-0.2 m.

The results obtained can be clarified by the fact that the soils in areas of 2nd cut suffered, in a short time, reform in the cane field. This reform may contribute to the increase of organic matter in the soil, thus containing higher concentration of the most oxidizable fractions (F1 and F2) and consequently lower concentration of recalcitrant fraction (F3 and F4). Over time (4th cut), the action of decomposing microorganisms contributes significantly to the increase of the F3 and F4 fractions, since they decompose the most oxidizable fractions (F1 and F2), leaving only the recalcitrant ones, the most difficult to break, increasing so the content of the fractions F3 and F4.

With the amount of straw being deposited at the time of harvesting and the reduction of the aggregation caused by the traffic of machines (Corrêa, 2002) in the cultural dealings and harvest, the carbon contents of fractions F3 and F4 again decreased in the 6th cut.

Table 5 shows the carbon values of the microbial biomass evaluated in the study and different systems, management and cuts in the 0-0.1 and 0.1-0.2 m layers.

Soil management systems promoted changes in microbial biomass carbon in the two soil layers evaluated (0-0.1 and 0.1-0.2 m).

Regardless of the depth, the organic system was the one with the highest carbon contents of the microbial biomass, which indicates a more favorable condition to the microbiota of the soil, attributed, possibly, the non-application of phytosanitary products and greater supply of organic materials that serve as substrates for the development of these organisms as reported by Cardoso et al. (2009) and Souza et al (2014).

Table 5. Soil microbial biomass carbon in conventional and organic sugarcane cultivation system, with and without vinasse application and ages of 2nd, 4th and 6th cut.

SYSTEM	MBC (mg.kg^{-1})	
	0-0.1 m	0.1-0.2 m
Organic	581,99 a	560,37a
Conventional	302,77 b	203,61b
with vinasse	581,99 a	443.33 a
without vinasse	302,77 b	320,65 b
2nd cut	474,56 a	423,68 a
4th cut	425,50 a	438,28 a
6th cut	427,08 a	284,01 b

Means followed by the same letter in the column do not differ from each other, by the Scott-Knott test at 5% probability

Regardless of the depth, an effect of vinasse application on soil microbial biomass was observed. These results can be explained because in environments where there is a greater flow of residues and organic matter, they make possible the existence of greater amounts of carbon of the biomass, indicating the greater balance of the soil microbiota in this ecosystem (Pôrto et al., 2009; Ferreira et al., 2010).

The results found in this study corroborate with the data of Neve and Hofman (2000) who found an initial increase in soil biomass carbon with the highest number of organic residues added, attributing this to the increase in the organic matter content and nutrients in the soil, which favors microbial growth. According to Yancheng et al. (2009), the use of vinasse in the production of sugarcane implies an improvement in the biological quality of the soil, which increases the populations of microorganisms, bacteria in general, and actinomycetes, in comparison with other commonly used residues.

No influence of cutting age was observed on the carbon contents of the biomass for the 0-0.1 m layer. These results agree with those presented by Souza et al. (2014) who state that changes in soil organic matter content occur in the medium or long term, and thus require more time to be quantified.

At the depth of 0.1-0.2 m there was a reduction of the amount of carbon of the microbial biomass at the age of the 6th cut in relation to the other ages (2nd and 4th cuts). The results found differ from those found by Balota et al. (1998) suggest that the maintenance of the surface straw, due to the greater input of residues from the crops, and the reduction of soil compaction, due to the lower traffic of machinery, contribute to the increase of the microbial biomass.

CONCLUSIONS

The management of sugarcane cultivation in the organic system and the application of vinasse contribute to the increase of total organic carbon contents;

The application of Vinhaça does not show increase in the oxidizable fractions (F1 and F2).

The cut age does not present a linear relationship in the total carbon and fractions analyzed;

The carbon of the microbial biomass is strongly influenced by the management system and the application of vinasse in the soil.

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