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ORIGINAL ARTICLE

Chemical fractionation of soil organic matter under different cropping systems

Fracionamento químico da matéria orgânica do solo sob diferentes sistemas de cultivo

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ABSTRACT: The soil organic matter has a great importance for agriculture and is the result of the decomposition of plant and animal residues, root exudates, excrements and microorganisms, and is part of a natural cycle that is constantly changing. The humified fraction of organic matter makes the soil more fertile and contributes to the availability of nutrients to plants. This article aimed to evaluate the humic fractions (humic acids and fulvic acids) and total organic carbon of the soil under different cropping systems. The experiment was conducted at the Federal Institute Sertão Pernambucano, Campus Petrolina Rural Area, where three areas with different use systems were evaluated, of which were denominated: *Vitis spp*. (SPV), *Pennisetum purpureum* (SPC) and natural area of hyper xerophytic Caatinga (NAC). Soil samples were collected at a depth of 0-10 cm, for chemical fractionation and determination of total organic carbon. The NAC system provides more adequate conditions for SOM humification.

KEYWORDS
Soil organic matter
Soil management
Humic substances

RESUMO: *A matéria orgânica do solo tem grande importância para a agricultura e é resultado da decomposição de resíduos vegetais e animais, exsudados radiculares, excrementos e microrganismos, fazendo parte de um ciclo natural em que está em constante transformação. A fração humificada da Matéria Orgânica torna o solo mais fértil e contribuí na disponibilidade de nutrientes às plantas. Esse trabalho teve como objetivo avaliar as frações húmicas (ácidos húmicos e ácidos fúlvicos) e carbono orgânico total do solo em diferentes sistemas de cultivo. O experimento foi conduzido no Instituto Federal Sertão Pernambucano, Campus Petrolina Zona Rural, onde foram avaliadas três áreas com sistemas de uso diferentes, dos quais foram denominados: cultivos Vitis spp. (SPV), Pennisetum purpureum (SPC) e área natural de Caatinga hiperxerófita (ANC). Foram coletadas amostra de solo na profundidade de 0-10 cm, para o fracionamento químico e determinação do carbono orgânico total. O sistema ANC proporciona condições mais adequadas para a humificação da MOS.*

PALAVRAS-CHAVE
Matéria orgânica do solo
Manejo do solo
Substâncias húmicas

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1 Introduction

In natural environments, soil presents a stabilized organic carbon content, resulting from the environmental circumstances provided by vegetation, topography, climate, and parent material. However, these conditions are altered when the soil undergoes anthropic interventions, in the implementation of agricultural areas (Balin *et al.*, 2017). In this sense, when the soil loses carbon, by inadequate management, due to the reduction of soil organic matter (SOM) levels, it compromises the physical, chemical and biological quality of the soil (Souza *et al.*, 2016; Primo *et al.*, 2011).

Considered a three-dimensional and dynamic system, in the soil are present organisms that are dependent on organic matter (SOM), resulting from plant, animal, and microorganism decomposition (Berilli *et al.*, 2019). In tropical regions, SOM is found around 1 to 5% in most agricultural soils, however, it plays an important role in maintaining quality and fertility, favoring the retention of cations, such as K^+, Ca^{2+}, Mg^{2+}, acting in increasing cation exchange capacity (CEC) and in physical and biological processes (Nanzer *et al.*, 2019).

The SOM is divided into living fraction (roots, fauna and microorganisms) and non-living fraction (humus and light organic matter) (Clemente *et al.*, 2018). Approximately 70% of the SOM consists of humic substances (HS), which are stable compounds that confer physical and chemical protection to aggregates, are divided into humic acids, fulvic acids and humin (Steverson, 1994; Primo *et al.*, 2011).

The HS differ in their solubility in aqueous environment with respect to pH (Silva *et al.*, 2018). Fulvic acids are soluble in alkaline and dilute acidic medium, consisting of polysaccharides, phenolic compounds and amino acids (Dortzbach *et al.*, 2020). Humic acids have high molecular mass, are soluble in alkaline medium and insoluble in acid medium (Clement *et al.*, 2018). Humin is insoluble in alkaline medium and acid medium, having reduced reaction capacity (Primo *et al.*, 2011).

Irrigated fruit growing in the semi-arid region is characterized as a system that practices the use of irrigation throughout the production cycle (Lemos Filho *et al.*, 2015). According to Preston *et al.* (2017), this region of the Submédio do São Francisco Valley has sandy soils with low cation exchange capacity and characteristics close to the parent material, generally depending on SOM in the formation of adsorption sites; however, temperature variations, solar radiation, powered by anthropic actions, favor the rapid decomposition of SOM, due to stresses generated to microorganisms (Primieri *et al.*, 2017).

According to Rossi *et al.* (2011), the dynamics of SOM in production systems can support the establishment of management strategies that guarantee to increase or maintain soil quality over time. The present work aimed to evaluate the humic fractions (humic acids and fulvic acids) and total soil organic carbon in different cropping systems.

2 Material and methods

The experiment was conducted at the Federal Institute of Education, Science and Technology of Sertão Pernambucano, Campus Petrolina Rural Area, located at PE 235, km 22, Projeto Senador Nilo Coelho, Núcleo 04, in the city of Petrolina-PE, latitude 09°23'55" South and longitude 40°30'03" West. The region's climate is of type BSw'h Semi-arid hot as per Köppen's classification. The average annual temperature is 27 ºC, and evapotranspiration is of the order of 2700 to 3000 mm per year Inmet (2020).

In three areas with 17-year-old grapevine (*Vitis spp.*) (SPV), Napier grass (*Pennisetum purpureum*) (SPC) and hyper xerophytic Caatinga (NAC) cropping systems, with different soil classes – Yellow Oxisols, Yellow Ultisols and Cambisols - respectively, and characterized as to their granulometry and density (Table 1).

Table 1. Sand, silt, clay content and apparent soil density in each management system.

Tabela 1. Conteúdo de areia, silte, argila e densidade apararente do solo em cada sistema de manejo.

Trataments	System	Sand	Clay	Silt	Apparently density *
		---------------	$g\ kg^{-1}$	---------------	$g\ cm^{-3}$
1	NAC	760.8	164	109.2	1.3
2	SPC	841.5	105	47.35	1.6
3	SPV	802.7	162	65.95	1.3

*Density quantified by the volumetric ring method, hyper xerophytic Caatinga (NAC), Napier grass (*Pennisetum purpureum*) (SPC) and grapevine (*Vitis spp.*) (SPV).

*Densidade quantificada pelo método do anel volumétrico, Caatinga hiperxerofítica (ANC), capim Napier (*Pennisetum purpureum*) (SPC) e videira (*Vitis spp.*) (SPV).

Twenty-five deformed simple samples were collected at a depth of 0.0-0.10 cm to obtain 15 composite samples. Subsequently sent to the soil and plant analysis laboratory of the Federal Institute Sertão Pernambucano, Campus Petrolina Rural Area, to perform the chemical fractionation of organic matter performed as described by Swift, (1996), with modifications proposed by Benites *et al.* (2003), obtaining the fulvic acid (FAF) and humic acid (HAF) fractions, and the organic carbon content of each fraction (TOC).

It was weighed 2.0 g of soil in 50 mL tubes, adding 20 mL of NaOH 0.1 mol L^{-1}, subsequently, being shaken manually and left to rest for 24 hours. Post 24h, centrifuged for 30 min at 3000 rpm, collecting the supernatant and reserved, added 20mL of NaOH 0.1 mol L^{-1} to the precipitate leaving it at rest for 1h. Post established time, centrifuged again for 30 minutes, then reserved the supernatant along with the previous, adjusting the pH of the alkaline extract to pH 1.0, by adding H_2SO_4 to 20%.

The acidified material was left to stand for 18h, then centrifuged, then the supernatant was separated (fulvic acid fraction). The quantitative determination of total organic carbon (TOC) and carbon in the extracts of fulvic acid and humic acid fractions were determined by oxidation of the carbon with $K_2Cr_2O_7$ and H_2SO_4, being titrated with ferrous ammoniacal sulfate at 0.1 mol L^{-1} and 0.0125 mol L^{-1} respectively.

The results obtained were submitted to variance analysis, when they presented significance greater than 5% by the F test, they were submitted to Tukey's tests at 5%, using the SISVAR 5.3 program (Ferreira, 2011).

3 Results and Discussion

The analysis of variance of the studied variables, HAF, FAF and the HAF/FAF ratio, indicated that there was no significant difference in the different cropping systems (Figure 1). According to Pinto *et al.* (2020), the fractions of SOM present distinct characteristics and their distribution in the soil, demonstrating changes resulting from the management adopted.

Evaluating the chemical fractions of SOM in an irrigated banana plantation, with conservation practices and cover crops, Barbosa *et al.* (2020), found HAF values ranging from 3.2 to 5.6 g kg^{-1}, results different from those obtained in this work. The HA fraction indicates the intermediate portion between the stabilization of compounds, due to the interaction with mineral material and free oxidized organic acids in the soil solution (Canellas *et al.*, 2003).

Figure 1 shows a superiority of HAF in soils compared to FAF, with a variation of 27% between HAF and FAF. Because it contains a greater amount of carboxylic and phenolic groups, FAF is more reactive compared to the other fractions (Primo *et al.*, 2011). However, they are more soluble and mobile in soil, containing easily degradable compounds, susceptible to microbial actions (Barbosa *et al.*, 2020).

The HAF/FAF ratio is used as an indicator of humus quality, as it approaches 1, the greater is the degree of humification, it has a greater balance between humified reactive fractions, that is, it demonstrates a better quality of the soil (Ramos *et al.*, 2020).

According to Barros *et al.* (2012), tropical soils commonly have HAF/FAF ratios lower than one, due to the high rate of decomposition of SOM. In this sense, there is evidence that in semi-arid soils the activity is similar. No values lower than 1 were found in the HAF/FAF ratio (Figure 1), according to Ebeling *et al.* (2013), the higher this ratio, the greater the degree of SOM polymerization.

The content of total organic carbon (TOC) indicated that there were significant differences ($p<0.01$), in the different cropping systems, in which the SPV obtained the highest average 18.26 g.kg^{-1}, followed by SPC with 11.7 g.kg^{-1} (Figure 2). The high TOC content in areas with agricultural activity, is associated with the addition of SOM, which is part of crop management, mainly in the form of manure. Using Pueraria phaseoloides as soil cover in banana cultivation, Barbosa *et al.* (2020), obtained a maximum value of 19.2 g.kg^{-1}, results similar to those found in this research. Sousa *et al.* (2020), obtained TOC values considered as high in the depth 0.00-0.05 m in corn and cassava cultivation, with average contents of 59.50 g.kg^{-1}.

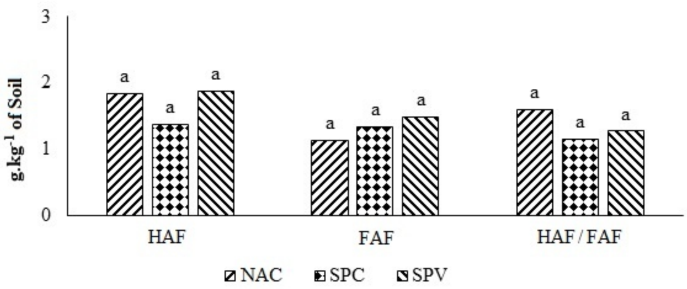

Figure 1. Values of humic acid fractions (HAF), fulvic acid (FAF) and HAF/FAF ratio in hyperxerophytic Caatinga (NAC), Vineyards (SPV) and napier grass (SPC) areas.

Figura 1. Valores das frações ácido húmico (FAH), ácido fúlvico (FAF) e relação FAH/FAF em área de Caatinga hiperxerófita (ANC), videira (SPV) capim napier (SPC).

The lowest TOC concentration was observed in NAC (9.42 g.kg^{-1}). Santana *et al.* (2019), evaluating the carbon stock under Caatinga Densa cover, obtained values of 98.3, 54.5 and 27.7 mg. ha^{-1} at depths of 0-100, 0-50 and 0-60cm, in Ultisols, Entisols and Planosols, respectively. The TOC values, regardless of the system, were low, considering that these are soils with low clay content and intense mineralization of SOM.

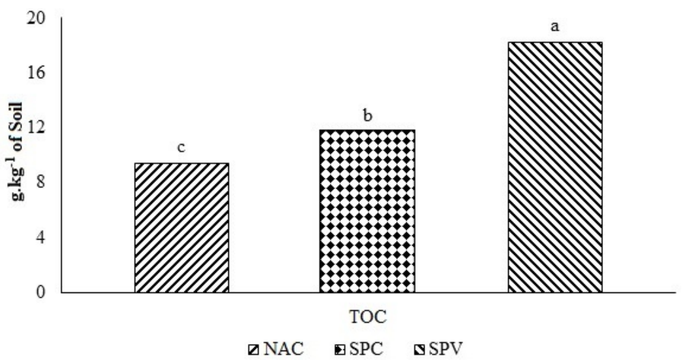

Figure 2. Total organic carbon (TOC) in area hyperxerophytic Caatinga (NAC) Vineyards (SPV) and napier grass (SPC).

Figura 2. Carbono orgânico total (COT) em área de Caatinga hiperxerófita (ANC), videira (SPV) capim napier (SPC).

Note that the HAF of organic matter indicated that there were significant differences, in the cropping system in which NAC corresponded to 19.53% of the TOC present on the surface of the soils (Figure 3). The presence of HAF is related to fertile soils, with a high content of exchangeable bases. In a Oxisols cultivated for 11 years under no-till with different mulches, mucuna-preta (*Mucuna aterrima*) and millet (*Pennisetum glaucum*), Souza *et al.* (2016), obtained results of 17 and 18%, respectively, in the depth 0.00-0.05 m for FAF/TOC.

Comparing the different cropping systems, observing the NAC characteristics the non performing of soil tillage and conservation of leaf mass, consequently, less stress on microorganisms favors heterogeneity of the SOM, as well as the difference in intensity of the humification process, influencing contents of the humic fractions present (Martins *et al.*, 2015).

It can be observed that the SPC and SPV obtained lower averages in relation to NAC. According to Guimarães *et al.* (2020), the use of irrigation in conventional systems favors microbial activity, consequently, greater mineralization of SOM due to the environmental conditions created by the entry of the water blade.

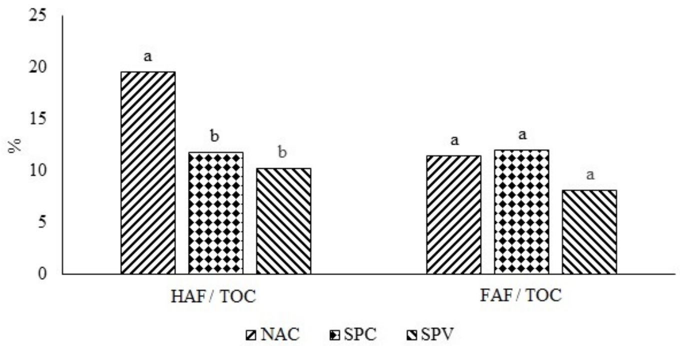

Figure 3. Relationship of humic acid/total organic carbon (HAF/TOC), fulvic acids/total organic carbon (FAF/TOC) in area hyperxerophytic Caatinga (NAC) Vineyards (SPV) and napier grass (SPC).
Figura 3. Relação das frações ácidos húmicos/carbono orgânico total (FAH/COT), ácidos fúlvicos/carbono orgânico total (FAF/COT) em área de Caatinga hiperxerófita (ANC), videira (SPV) capim napier (SPC).

4 Conclusion

The hyper xerophytic Caatinga area provides more suitable conditions for the humification of the SOM.

The disturbance and irrigation, in anthropized areas, favor less accumulation of humic substances.

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