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Microbial diversity as a soil quality indicator in agroecosystems in Brazilian Savannas

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The importance of sustainable use of natural resources, especially of soil and water, has been a subject of increasing relevance. The increase of human activity in ecosystems has great impact on the dynamics of soil organisms. The comparison between cultivated systems and native areas without anthropic interference can be used as soil quality index. Microorganisms are ideal indicators because they are very sensitive to changes and show variations in their community when subjected to stressful environments. The objective of the present study was to evaluate the quality of soil microbial abudance as an index of soil quality in agroecosystems Integrated Sustainable Agroecological Production, Agroforestry System and Isolation of springs in Brazilian Savanas. The experiment was conducted in the areas of the Vitória settlement, in the region of São Patrício Valley, Goianésia, Goiás, in an area of native "cerrado". The climate is classified as seasonal tropical (Aw), being characterized by two well defined seasons (dry and rainy), as well as with the occurrence of drought periods during the rainy season. The experimental design adopted was a 3 × 2 × 2 block factorial randomized with three replications, where factor 1 was represented by the systems used: Sustainable Integrated Agroecological Production (SIAP), Agroforestry System (AS) and springs isolation (SI), factor 2 was represented by the soil depth, 0-5 cm and 5-10 cm, and factor 3 was the installation time of the systems: 5 years and recently installed. Soil samples were collected at random in the rhizospheric soil in each plot. There was a greater number of fungal colonies in the AS system with 5 years of implantation, but did not differ with soil depth. There was a higher number of bacteria colonies in the SIAP system after 5 years. At the depth of 0 to 5 cm, the SIAP system had higher microbial abundance, but it was higher at 5 to 10 in AS system.

Key words: Cerrado Brazilian, agroecology, environment, natural resources.

INTRODUCTION

The importance of sustainable use of natural resources, especially of soil and water, has been a subject of

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increasing relevance. The increase of human activity in ecosystems has great impact on the dynamics of soil organisms (Araújo et al., 2007).

According to Doran et al. (1994), soil quality can be conceptualized as the ability of soil to perform various functions, within the limits of land use and ecosystem, to sustain biological productivity, maintain or improve environmental quality and contribute to plant, animal and human health.

The comparison between cultivated systems and native areas without anthropic interference can be used as soil quality index. Microorganisms are ideal indicators because they are very sensitive to changes and show variations in their community when subjected to stressful environments (Moreira and Siqueira, 2006). The establishment of soil quality indeces can be used as a criterion for the evaluation of environmental impacts on ecosystems (D'Andréa et al., 2002).

Aim of sustainable agro-systems in agricultural production is to stop the damage of the ecosystem's ability to recover from anthropogenic interference (Altieri, 1998); degraded areas can recover their productive capacity if managed with practices that aim to maintain the sustainability and preservation. Areas for permanent preservation, such as hillside areas and springs of water bodies, should be maintained without human cultivation and influence (Corrêa et al., 1996). However, permanent preservation areas already degraded must be recovered, and the soil microbial quality index can be used as a parameter of evaluation of this recovery.

Agroecology is a set of general principles applicable to sustainable farming systems. It can be described as a science that aims to study agroecosystems that seek to copy natural ecosystems, thus producing lower rates of environmental impact (Altieri, 1998).

According to Klink and Machado (2005), the "cerrado", Brazilian Savanas, productive areas are mostly occupied by degraded pastures, mainly because the producer does not treat these areas as crops, do not apply appropriate soil management to maintain the fertility of soils. An alternative for the management of pastures within sustainable systems is the use of plant species diversification, through the maintenance of polyculture of pasture species. The grass and legume consortium, together with the installation of native and exotic tree species, promotes better conditions for the development of soil microbiota diversity, such as agroforestry system (SA) (Soares et al., 2010).

The Sustainable Integrated Agroecological Production System (SIAP) is a small-scale irrigated cultivation system, conducted in circular beds formed around a system of production of small animals such as birds or fish. The purpose of this system is to meet local needs by developing a model of family farming also based on the cultivation of several different species of vegetables (Mendonca et al., 2010). This system is widely used by settled communities in the St. Patrick's Valley region.

Agroforestry Systems (AS) are ways of use and management of natural resources, in which perennial woody species (trees, shrubs and palms) are used in association with agricultural crops and/or grazing animals, in the same area, simultaneously or in a temporal sequence, resulting in a biological diversity promoted by the presence of different plant and animal species which explore diverse niches within the system, integrated with the application of management practices compatible with traditional cultural techniques of farmers (Carvalho et al., 2004).

Among the microbiological indicators of soil quality, microbial diversity (MD) stands out. Soil biomass is the measure of CO_2 production resulting from the metabolic activity of macro and microorganisms (Doran et al., 1994; Azevedo and Melo, 1998; Da Silveira and Dos Santos Freitas, 2007).

The activity of these organisms in the soil is considered a positive attribute for soil quality and is used as an indicator because it is more generic and encompasses the activity of communities and consortia of micro-organisms present, showing better reproducibility (Rice et al., 1996).

Agroecology is defined as a new productive paradigm, being agroecology linked to sustainability and sustain-ability which is key to the maintenance of productive processes over time. This type of management should not be exclusive of extensive production systems. Family agriculture, when well structured, leaves the subsistence level and becomes responsible for the maintenance of products, such as vegetables that cannot be produced by large-scale monoculture systems. This project carried out through the partnership of "Gente do Cerrado" Association with the Evangelical Faculty of Goianésia has installed agroforestry systems in parcels of a Settlement region of the São Patrício Valley.

It is necessary to quantify the benefit of the installation of these systems using as a parameter, the soil microbial quality index comparing them with native "cerrado" vegetation areas.

The objective of this study was to evaluate the quality of soil microbial activity as an index of soil quality in Integrated Sustainable Agroecological Production, Agroforestry System, and springs in Brazilian Savannas.

MATERIALS AND METHODS

The experiment was conducted in the areas of the Vitória settlement, in the region of the São Patrício Valley, in Goianésia, Goiás, in an area of native "cerrado". The climate is classified according to Koppen (1931), as seasonal tropical (Aw), being characterized by two well defined seasons (dry and rainy), as well as the occurrence of drought periods during the rainy season.

The experimental design adopted was a 3 × 2 × 2 block factorial randomized with three replications, where factor 1 was represented by the systems used: Sustainable Integrated Agroecological Production (SIAP), Agroforestry System (AS), and springs isolation (SI), factor 2 was represented by the soil depth of 0 to 5 cm and 5 to 10 cm, and factor 3 was the installation time of the systems: 5

Table 1. Mean CFU values of fungi in each agroecosystem.

Systems	Mean
AS	6.50000[a]
SIAP	3.33333[b]
SI	2.33333[b]

CV% = 42.47. *Sustainable Integrated Agroecological Production (SIAP); Agroforestry System (AS); Springs Isolation (SI).

Table 2. Mean CFU values of fungi per soil depth.

Depth	Mean
0 - 5	3.94444[a]
5 - 10	4.16667[a]

CV% = 42.47

Table 3. Mean CFU values of fungi per time of system implantation.

Season	Mean
Newly	2.94444[b]
5 years	5.16667[a]

CV% = 42.47

years and recently installed.

Samples were collected at random. Each repetition was composed of the rhizospheric soil in each plot. The rhizospheric soil was collected at a depth of 0 to 5 cm and 5 to 10 cm, the composite samples were homogenized and stored under refrigeration.

The number of fungi and bacteria was determined by quantification of colony forming units (CFU) using the method of inoculation of diluted suspensions of soils in Potato-Dextrose-Agar (PDA) culture medium, with four replicates per dilution. From the collected samples, 1.0 g of soil was removed and diluted in Erlenmeyer, adding 10.0 mL of distilled water, the same procedure being carried out until the dilution of 10^4. During preparation of the culture medium, 1.0 g of antibiotic was placed and the number of fungal colonies and number of bacterial colonies were counted.

Petri dishes with inoculated media were incubated at room temperature (±35°C) by counting the colonies of fungi and bacterial colonies which was performed 5 days after incubation. The data for statistical treatment was obtained through the program Assistat (Silva, 2016).

RESULTS AND DISCUSSION

The colony forming units of fungi and bacteria were quantified with the objective of identifying systems, depth and periods of time that present greater microbial diversity. Tables 1 to 6 show the CFUs of fungi and Tables 7 to 11 refer to the CFUs of bacteria. Table 1 shows the average of CFUs of fungi by agroecological system. Results showed that the Agroforestry System was superior to the other agroecosystems, so that system presented higher amount of fungi in soil (Altieri, 2002), since plants residues are decomposed in soil and serve as energy source for soil microorganisms, such as fungi.

Table 2 presents the average values of fungal CFU in relation to soil depth. Values were not significantly different. In the work of Angelini et al. (2012), it was observed that in the 0 to 5 cm layer there was a significant effect when associated with crops and vegetation cover, thus it is possible to explain the highest values in the AS and layer of 5 to 10 for crop species.

Table 3 shows the average of fungal CFU in relation with the time of system implantation, demonstrating that the systems that were implanted 5 years ago were superior to the value found in the newly implanted systems. Thus, the longer the systems, the greater the amount of fungi present in the soil. Factors as environmental conditions favor the increase of fungi.

In relation to the effect of the interaction between agroecological systems and soil depth, the values found do not present significant statistical differences. Although, not significantly different, the higher value of the agroforestry system can be was explained by Facci (2008) who stated that due to the diversity of trees, it has an accumulation of plant residues on the surface, having an accumulation of organic matter, becoming a favorable environment and source of energy for fungi.

Table 4 presents the interaction averages of the agroecological systems in relation to the time of implantation. The results obtained showed that the newly installed systems were statistically similar, and that in the time of 5 years, the Agroforestry System presented a superior value in relation to the SIAP systems and SI. However, the Agroforestry System presented lower value in relation to the amount of fungi presented in the newly implanted system. Angeline et al. (2012), stated that areas with crops up to the 10 cm layer have a significant value of fungi, thus, the forest that contributes to the greatest amount of organic matter in the soil over time, due to plant residues, makes it an ideal environment.

Table 5 shows the interaction effect between soil depth and time of implantation. Results obtained show that the depth of 0 to 5 cm in the system installed at 5 years had higher fungi CFUs as compared to other soil depth and recent system, and can be explained by a higher accumulation of organic matter on the soil surface. At the depth of 0 to 5 cm, there was a lower value in the newly installed system, showing less amount of fungi colonies. After counting bacterial colonies, the following results were obtained. Table 6 shows the mean values in each cropping system. The AS and SIAP did not differ between both systems, but were significantly higher than SI. The same result was obtained by Moreira et al. (2010), who verified high diazotrophic density in agriculture and agroforestry.

Table 4. Interaction effect between agroecosystems and time of system implantation on fungi CFUs.

System	Time	
	Newly installed	5 years
AS	6.8333^{aB}	6.1667^{aA}
SIAP	2.3333^{aA}	4.3333^{bA}
SI	2.6667^{aA}	2.0000^{bA}

Lowercase letters for columns; uppercase letters for lines; CV% = 42.47. *Sustainable Integrated Agroecological Production (SIAP); Agroforestry System (AS); Springs Isolation (SI).

Table 5. Interaction effect between soil depth and time of system implantation on fungi CFUs.

Depth	Time	
	Newly installed	5 years
0 – 5 cm	2.1111^{aB}	5.7778^{aA}
5 – 10 cm	3.7778^{aA}	4.5556^{bA}

Lowercase letters for columns; uppercase letters for lines. CV% = 42.47.

Table 6. Mean CFU values of soil bacteria in each agroecosystem.

System	Mean
AS	28.92^{a}
SIAP	31.92^{a}
SI	15.17^{b}

CV% = 17.21; *Sustainable Integrated Agroecological Production (SIAP); Agroforestry System (AS); Springs Isolation (SI).

Table 7. Mean CFU values of soil bacteria in different soil.

Depth	Mean
0 – 5 cm	27.83^{a}
5 – 10 cm	22.83^{b}

CV% = 17.21.

Table 8. Mean CFU values of soil bacteria as affected by time of implantation of agroecological systems.

Time	Mean
Newly	16.61^{b}
5 years	34.06^{a}

CV% = 17.21.

Table 9. Interaction effect between agroecological systems and soil depth on CFU values of soil bacteria.

System	Depth	
	0 – 5 cm	5 – 10 cm
AS	24.17^{bB}	33.67^{aA}
SIAP	45.33^{aA}	18.50^{bB}
SI	14.00^{cA}	16.33^{bA}

Lowercase letters for columns; uppercase letters for lines; CV% = 17.21; *Sustainable Integrated Agroecological Production (SIAP); Agroforestry System (AS); Springs Isolation (SI).

As shown in Table 7, the average values of the depths were found, in which, in the range of 0-5 cm, higher values were found, thus, in this range, there was a greater amount of bacteria. In the work of Pereira (2015), even with the presence of fungi in all the layers, the deeper layers presented a decrease in the diversity of bacteria.

Table 8 presents the average of the systems implementation times, in which, in systems installed for a longer period of time, there was a greater amount of bacteria in the soil. This is explained as follows, in the course of time, with favorable environment and energy source, the bacteria carries out its dissemination.

Table 9 presents the interaction effect of agro-ecosystems and soil depths. The results demonstrated that SIAP had higher bacteria colomies than lower depth and other cropping systems. At 5 to 10 cm depth, the AS had the highest CFU value than other systems. Table 10 presents the interaction effect between agroecological systems and time of their installation. Results showed that in the newly installed AS bacteria, abundance was superior in relation to the other newly installed systems, but in the systems implanted 5 years ago, the SIAP system had greater abundance than other systems. All systems had significantly higher bacteria abundance for those implanted 5 years ago as compared to recent systems.

Table 11 presents the interaction effect of soil depth and implantation time. In the 5-year-old system, the amount of bacteria colonies in the 0 to 5 cm layer was higher than at 5 - 10 cm depth, which is different from the newly installed systems. At both depths, the 5-year period had more bacteria colonies than the newly installed systems.

Conclusions

There was a higher number of fungal colonies in the Agroforestry System oldest system, but did not vary with soil depth. There was a higher number of bacteria colonies in the Sustainable Integrated Agroecological

Table 10. Interaction effect between agroecological systems and implantation time on CFU values of soil bacteria.

System	Time	
	Newly installed	5 years
AS	25.83 aB	32.00 bA
SIAP	17.00 bB	46.83 aA
SI	7.00 cB	23.33 cA

Lowercase letters for columns; uppercase letters for lines; CV% = 17.21; *Sustainable Integrated Agroecological Production (SIAP); Agroforestry System (AS); Springs Isolation (SI).

Table 11. Interaction effect between soil depth and implantation time on CFU values of soil bacteria.

Depth	Time	
	Newly installed	5 years
0 – 5 cm	16.78 aB	38.89 aA
5 – 10 cm	16.44 aB	29.22 bA

Lowercase letters for columns; uppercase letters for lines; CV% = 17.21.

Production system after 5 years. At the depth of 0 to 5 cm, the Sustainable Integrated Agroecological Production system had high microbial abundance, but at 5 to 10 cm, the Agroforestry System showed higher number of bacteria colonies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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