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RESEARCH ARTICLE

ARBUSCULAR MYCORRHIZAL FUNGI AS INDICATIVE OF SOIL QUALITY IN CONSERVATION SYSTEMS IN THE REGION OF VALE DO SÃO PATRÍCIO, GOIÁS

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ABSTRACT

Sustainable production in an agro-ecosystem derives from the balance between plants, soils and organisms. The objective of this work was to evaluate the rate of mycorrhizal colonization and spore density as an index of soil quality in agricultural ecosystems in the region of Vale do São Patrício. The experiment was conducted in the areas of settlements, new dawn and Itajá in Goianésia-Goiás. The experimental design was a factorial 5 x 3 in randomized blocks with three replications plus the additional comparative treatment of native Cerrado (vegetation typical of the Brazilian interior), where the factor 1 was represented by systems used: Ecological Sustainable Integrated Production, Agrossilvipastoril System, Agroforestry System and Isolation of springs. Factor 2 was represented by the time of installation of systems: 4 years, 2 years, and newly installed. There were no differences between the treatments studied. Independent of the agroecosystem and the age of systems, the density of spores and the rate of colonization were equivalent to the system of native Cerrado.

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INTRODUCTION

The importance of the sustainable use of natural resources, especially land and water, has incurred increasing theme relevance due to increased human activities. The increase of human activities in ecosystems has great impact on the dynamics of soil organisms (ARAÚJO; GOEDERT; LACERDA, 2007). The soil reaches the quality through the system, soil, plant and organisms, integrated and adapted to their place in the environment, and not only by the soil itself. Therefore, the quality of the soil is the integration of the physical, biological and chemical properties of the soil, which enables it to perform its functions (VEZZANI; MIELNICZUK, 2009). The comparison between cultivated and native areas without human interference can be used as a soil quality index. Microorganisms are ideal indicators because they are very sensitive to change and show variations in their community when subjected to stressful environments (MOREIRA; SIQUEIRA, 2006). Sustainable production in an agro-ecosystem derives from the balance between plants, soil, nutrients, sunlight, moisture and other organisms coexisting. Featuring a productive and healthy system when these conditions prevail (ALTIERI, 2009).

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Thus, the ecological basis of production systems act to keep or change the conditions of equilibrium between the participating bodies in the process of production, and the environment. They are characterized by the use of technologies which respect the nature (ASSIS; AQUINO, 2007). Agroforestry systems (SAF's) occur by the association of perennial woody plants with herbaceous plants, agricultural crops, usually with or not the introduction of animal fodder. Ecological interactions are benefited by the great diversity of species, emphasizing that the existence of the forestry component is fundamental to a system to be characterized as Agroforestry (ABDO; VALERI; MARTINS, 2008). The consortium of grasses and legumes, along with the installation of native and exotic tree species promotes better conditions for the development of diversity of soil microbiota, such as the SASP, Agrossilvipastoril System (SOARES; CAVALCANTE; JUNIOR, 2010).

The Integrated Sustainable Agro-ecological Production system (PAIS) is a form of irrigated farming on a small property, conducted in circular plats formed around a production system of small animals such as birds or fish. Whose goal is to meet the local needs by developing a model of family farming based on the cultivation of several different species of fruits and vegetables (MENDONCA*et al.*, 2010). The arbuscular mycorrhizal fungi are soil quality indicators. These microorganisms are being considered as critical parameter for an effective recovery of the vegetation cover of degraded areas, being through both inoculation in plants (POUYUROJAS; SIQUEIRA; SANTOS, 2006) as through the management of native communities (SCHREINER, 2007).

Due to the active and meaningful participation in the dynamics of carbon and soil aggregation, the arbuscular mycorrhizal fungi (FMAs) impact to the stability of ecosystems, influencing the diversity of plant communities, in their relations with plants and in the process of absorption of nutrients (BERBARA; SOUZA; FONSECA, 2006). The objective of this work was to evaluate the rate of mycorrhizal colonization and spore density as an index of soil quality in agroecosystems: Ecological Sustainable Integrated Production (PAIS), Agrossilvipastoril System (SASP), Agroforestry (SAF's) and Isolation of springs in the region of Vale do São Patrício.

MATERIALS E MÉTODOS

The experiment was conducted in the areas of settlement Vitória (latitude -15.46113139,longitude -49.07644666), Nova Aurora (latitude-15.31924036, longitude-49.38826099) and Itajá(latitude-15.3157786, longitude -49.32434083), in the region ofVale do São Patrício, in the city of Goianésia -Goiás, and in a native "Cerrado" (vegetation typical of the Brazilian interior) area (latitude -15.326302, longitude-48.903626), in Vila Propício- GO.The climate is classified, according to Koppen (1931), as seasonal tropical (Aw), being characterized by two well defined seasons (dry and rainy season), as well as the occurrence of periods of drought during the rainy season.

The experimental design was a factorial 5 x 3 in randomized blocks with three replications plus the additional comparative treatment of native Cerrado, where the factor 1 was represented by systems used: Ecological Sustainable Integrated Production, Agrossilvipastoril System, Agroforestry System and Isolation of springs. Factor 2 was represented by the time of installation of systems: 4 years, 2 years, and newly installed. Collections were undertaken, at random. Each repetition was made up of the set of roots of three plants and rhizospheric soil on each parcel. Rhizospheric soil, particularly in areas closer to the roots of plants was collected with a gardener at a depth of 0-20 cm thus separated from the roots the composite samples were homogenised and stored under refrigeration. The roots were washed and stored until the moment of submitting them to the laboratory processes in 50% ethanol (v/v).

For the mycorrhizal colonization of fungi on plant roots and its quantification, mycorrhizae samples were used through the inside of the root cortex. These thin roots collected were preserved in a container containing 50% alcohol solution until the colouring. Whose process was done by Vierheilig technique *et al*. (1998). Where the roots collected were subjected to a wash through a solution of KCl to 10% heated to 90° C in 1 hour, right after and a wash cycle to the next step, the colouring was made using acetic acid composition and stamping ink, heated in blanket for 10 minutes completing the colouring process. And finally, stored in a lactoglicerol solution (glycerol, lactic acid, distilled water) until the time of the counting. The spores of arbuscular mycorrhizal fungi (FMAs) were extracted from soil using 50 cm ^{3} of each composite sample, by wet sieving technique (GERDEMANN; NICOLSON, 1963), followed by centrifugation in water at 3000 rpm for 3 minutes. Later the water was disposed and the process of centrifugation repeated, but with a 50% sucrose solution for just 2 minutes.

The spores were separated according to their phenotypic characteristics such as colour, size and shape, composing the different morphotypes, under stereoscopic binocular magnifying glass.For statistical analysis we used the beta 7.7 ASSISTAT statistical programme (SILVA, 2009), by applying the test of Scott Knott to 5% probability.

RESULTS AND DISCUSSION

The results of the statistical analysis showed that there was no minimum significant difference between the treatments studied. The F-test showed no significance between the variables and systems and age between interactions with the additional Native Cerrado treatment (Table 1).

Table 1. F-test of spore density and mycorrhizal colonization in different agro-ecological production systems in different ages

SourceofVariation	SporeDensity	MycorrhizalColonization
System	0,72 ns*	1,80 ns*
Age	0,72 ns*	0,41 ns*
System x Age	0,93 ns*	1,81 ns*
Factors x Native Cerrado	0,08 ns*	0,54 ns*

*non-significant (p >= .05by Skott-Knott's test)

There was no statistically significant difference when comparing each treatment with the control Native Cerrado (Table 2). There are no differences between the treatments evaluated and comparative treatment under Native Cerrado vegetation. Therefore, when considering the activity of mycorrhizal fungi as an indicator of environmental quality, the agroecosystems evaluated feature quality comparable to native ecosystems.

Table 2. Dunnett's test at 5% probability (bilateral) in different agro-ecological production systems compared to native bushland

Treatment	Age	SporeDensity (nº/50g ofsoil)	Mycorrhizal Colonization (%)
SASP	Deployment	85,00b	48,76%a
	2 years	75,33b	46,26%a
	4 years	56,66b	73,33%a
SAF	Deployment	61,00b	21,66%a
	2 years	46,00b	37,50%a
	4 years	61,33b	46,26%a
PAIS	Deployment	79,00b	50,00%a
	2 years	67,00b	30,00%a
	4 years	94,00b	46,66%a
Riparian Forest	Deployment	67,00b	65,83%a
	2 years	56,66b	31,26%a
	4 years	100,00b	36,26%a
Isolationof Springs	Deployment	83,66b	45,00%a
	2 years	76,66b	73,76%a
	4 years	45,00b	50,00%a
Cerrado		64,00b	55,83%a
DMS		77,96	55,83%

The communities of FMAs have their composition and diversity influenced by agricultural culture and vegetation cover (ANGELINI *et al*., 2012), therefore the values of density and colonization can be used as an indicator of environmental impact. Colodete; Dobbss and Ramos (2014) point out that the FMAs are important environmental sensors and, consequently, have great significance in monitoring these areas. Additionally, the selection of isolates of FMAs with beneficial functions of these environments to host plants, can contribute to the establishment of vegetation and recovery of impacted areas. Ramos *et al*. (2012) correlated that between functional groups of micro-organisms and chemical soil attributes were variables in different management systems, thus concluding that there was no difference in microbial density between the staging systems in dry period, beyond which the Cerrado soil had higher microbial density. Comparing mycorrhizal activity of native ecosystems with agroecosystems grown by man can be used as an indicator of environmental quality (MOREIRA; Siqueira, 2006).

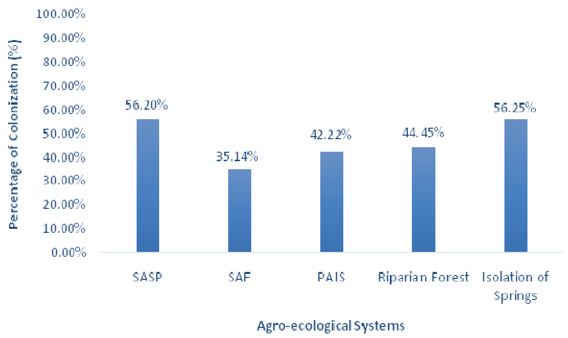

Figure 1. Percentage of mycorrhizal colonization in different agro-ecological production systems (%)

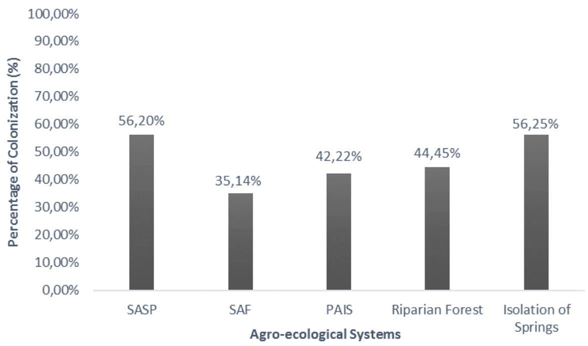

Figure 2.Number of Spore density in different agro-ecological production systems (nº/50g of soil)

Table 3. Mycorrhizal colonization in different agro-ecological production systems in different deployment times (%)

Production Systems	Age of Deployment		
	NewlyInstalled	2years	4years
SASP	48.76%	46.26%	73.33%
SAF	21.66%	37.50%	46.26%
PAIS	50.00%	30.00%	46.66%
Riparian Forest	65.83%	31.26%	36.26%
Isolationof Springs	45.00%	73.76%	50.00%
Cerrado	55,83%a		
CV	43,29%		

Table 4. Spore density in different agro-ecological production systems in different deployment times (nº/50g of soil)

Production Systems	Age of Deployment		
	NewlyInstalled	2 years	4years
SASP	85.00	75.33	56.66
SAF	61.00	46.00	61.33
PAIS	79.00	67.00	94.33
Riparian Forest	67.00	56.66	100.00
Isolationof Springs	83.66	76.66	45.00
Cerrado	64,66		
CV	45,38%		

The data in Table 2 shows that the values of the density of spores and mycorrhizal colonization of cultivated systems are equivalent to the values found in the ecosystem without interference from human activity.

This indicator suggests that the ecological systems analysed do not lose in quality when compared to the native Cerrado.Through the results, is evidenced that the ecological systems collaborate for soil microbial diversity, which equal with native Cerrado soils, and that do not resemble with soils that are resigned to intense agricultural activity. Thus, it can be emphasized that according to Schneider (2011) that conventional systems lead to a reduction in mycorrhizal colonization and, consequently, reducing the beneficial effects of the FMAs for plants, reducing soil quality and sustainability. Assis (2006) states that in agriculture, the appreciation of the local dimension, together with the application of ecological principles, ensures the maintenance of the local crops and varieties that can be eliminated with the conventional farming practices. In relation to the values of the mycorrhizal colonization rate between the agro-ecological productions systems studied disregarding the age of deployment of systems, was observed that there was no statistically significant difference (Figure 1). Cordeiro *et al.* (2007) when assessing the colonization and the density of spores of mycorrhizal fungi in two soils of the Cerrado under different management systems, found no differences between the analysed handling systems, however, showed lower values when compared to native ecosystems. According to Santos; Scoriza and Ferreira (2013) the FMAs showed great differences in composition and diversity in the forest, which covers the largest number of species and endemics, beyond the perspective of new species. Further studies are needed to assert if the values of colonization and spore density can be used as indicators of environmental quality. Brazil presents huge potential for use of mycorrhizae, if considered soil and climate conditions, the ecological systems such as the agrosilvopastoril and the scarcity of financial resources can make this technology viable. Using these mycorrhizae promotes production gain and, consequently, financial return (DASGUPTA *et al*., 2006). When evaluating the spore density of cropping systems regardless of the age of implementation, minimal significant difference was not observed between treatments (Figure 2).

Table 2 and figures 1 and 2 claim that the activity of arbuscular mycorrhizal fungi is similar in all treatments compared to native ecosystems, due the ecological systems having goals of recovering soil quality. According to Carrenho and Garcia-da-Costa (2011) the results of their work suggests that environmental degradation had negative reflections on the establishment and in the diversity of arbuscular mycorrhizal fungi. Which confirms the presence of these organisms in the soil even under conditions of degradation. According to Ferreira; Carneiro and Saggin-Junior (2012) the change in land use promotes changes in the community of FMAs, spore density and diversity of arbuscular mycorrhizal fungi, in the case of pasture are extended, or, in the case of monocultures and deforestation are reduced. There were no statistically significant differences in mycorrhizal colonization rate values (Table 3) and spore density (Table 4) between the agro-ecological productions systems studied considering the age of the systems deployment. Under various stress conditions, the majority of higher plants is colonized by FMAs, which can have several beneficial effects on plant growth. And as mycorrhizae are biological systems, they are quite influenced by the environment and by numerous edaphic factors that influence directly or indirectly the formation, functioning and the occurrence of mycorrhizae (FOLLIPEREIRA *et al*., 2012).

According to Berude *et al*. (2015) mycorrhizae are useful for nature and for man, as exercising a significant role for the functionality and the maintenance of natural and managed ecosystems, assisting in the development of plants and contributing to structuring plant communities. The Cerrado ecosystem through its great biodiversity with agro-ecological systems promotes not only the microbial diversity, but also other factors like soil macrofauna, which can be seen through the results obtained by Silva *et al*. (2006) in which characterize the total soil macrofauna density is favoured by management practices that stimulate the dynamics of soil organic matter such as no-till systems, crop-livestock integration system and continuous grazing.Aburjaile *et al*. (2011) found that microbial diversity has important advantages as an indicator of soil quality. And for the current knowledge has been a very important advance, therefore, account for the importance of microbial diversity as the result of this study elucidates.

Conclusion

Through methodological techniques, the spore density values and mycorrhizal colonization in this study showed no difference between the treatments studied. Such an occurrence can be understood by the fact of not having accomplished the inoculation of fungi, as they were obtained from nature. Regardless of the agro-ecosystem and the age of establishment, the spore density values and mycorrhizal colonization rate do not differ from the values found in the native Cerrado.

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