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Changes in arbuscular mycorrhizal fungal communities along a river delta island in northeastern Brazil

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ABSTRACT

Arbuscular mycorrhizal fungi (AMF) play a key role in the maintenance of the balance of terrestrial ecosystems, but little is known about the biogeography of these fungi, especially on tropical islands. This study aims to compare AMF community structure along a transect crossing a fluvial-marine island and relate these communities with soil and vegetation parameters to shed light on the forces driving AMF community structure on a local scale. We tested the hypothesis that the composition of AMF communities changes across the island, even within short distances among sites, in response to differences in edaphic characteristics and vegetation physiognomies. We sampled roots and soils in five different natural and degraded habitats: preserved mangrove forest (MF), degraded mangrove forest (MD), natural *Restinga* forest (RF), and two regeneration *Restinga* forests (RR1 and RR2) on Ilha da Restinga, northeastern Brazil. We determined the mycorrhizal colonization rate and AMF community structure based on morphological spore identification. The island soils were sandy with pH varying from acid to neutral; higher levels of organic matter were registered in RF and lower in MF; other chemical and physical soil attributes differed along the habitat types on the island. In total, 22 AMF species were identified, without any difference in species richness. However, the diversity and composition of AMF communities, spore abundance per families, and mycorrhizal colonization were statistically different among the habitats. The composition of AMF communities was strongly related to soil characteristics, especially the sum of exchangeable bases. Our results indicate that the different habitat types have diverse AMF communities even within short distances among habitats. In conclusion, islands with high spatial heterogeneity in soil parameters and diverse vegetation are potential refuges for the diversity conservation of AM fungi.

1. Introduction

Several factors may affect species community structure and distribution along spatial and temporal scales (Gotelli and Graves, 1996; Chase, 2003). On a local scale, environmental heterogeneity, abiotic, edaphic and micro-climatic factors are responsible for the maintenance of biological communities, while at larger scales, the historical-geological processes and regional climatic conditions are the main factors affecting community structure and influencing speciation, colonization and extinction of species (Buckley and Jetz, 2007; Dobrovolski et al., 2012).

Islands have been considered key environments to perform studies on ecological and evolutionary aspects of species. Terrestrial (or continental) islands are separated from the mainland environments by geographic barriers, decreasing accessibility and connection between island and mainland biological communities (MacArthur and Wilson, 1967; Walter, 2004). These islands

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sometimes have connections to the mainland, which contribute to sharing species between these environments; however, the species richness in islands is lower due to less diversity of niches, which can influence the establishment of some taxa (Triantis et al., 2012).

Arbuscular mycorrhizal fungi (AMF), ubiquitous mutualists of terrestrial plants, promote several benefits and ecosystem services that aid to maintain ecosystem balance, contributing to edaphic quality and providing nutritional and non-nutritional benefits to plant communities (Smith and Read, 2008; Gianinazzi et al., 2010). AMF also contribute to the maintenance of plant diversity, participate in successional ecological processes and promote plant colonization in different habitats including island environments (Allen and Allen, 1988; Koske and Gemma, 1990; Francis and Read, 1994).

Traditionally, AMF taxa have been identified based on spores morphology extracted directly from field samples. However, considering that sporulation is a part of AMF life-cycle, the establishment of trap cultures represents a strategy to recover spores from previously undetected taxa as well as to obtain healthy spores which can contribute to species identification (Morton et al., 1993; Douds and Millner, 1999).

Regarding ecological aspects of these microorganisms, some studies have indicated that AMF are influenced by the host plant (Kawahara and Ezawa, 2013; Pagano et al., 2013; Soteras et al., 2016) and abiotic characteristics, such as soil attributes and climatic factors (Bennett et al., 2013; Hazard et al., 2013; Pellissier et al., 2014). However, there is no consistent conclusion about factors shaping AMF communities (Xu et al., 2016), mainly because more information on distribution and diversity of these fungi is still needed.

Only a few studies on AMF diversity have been carried out in island environments and those have mainly been performed in large environments, for instance, in the Galapagos (Schmidt and Scow, 1986), Hawaii (Koske, 1988; Koske and Gemma, 1995, 1996a), and Great Nicobar, India (Kothamasi et al., 2006). In Brazil, research of this type has only been performed in two sites: Ilha do Cardoso, in the Southeast (Trufem et al., 1989, 1994; Trufem, 1990) and the island of Santa Catarina, in the South region (Stürmer and Bellei, 1994; Stürmer et al., 2013). Thus, information on AMF occurrence and distribution collected in other island environments can contribute to broaden knowledge about the biogeographical and ecological patterns of these fungi, especially in poorly studied environments such as tropical areas (Rodríguez-Echeverría et al., 2017).

This study aims to determine mycorrhizal colonization and to compare the AM fungi community structure along a transect crossing a fluvial-marine island, characterized by different environments in an area of only 530 ha, and relate the data to vegetation types and soil parameters to shed light on the forces driving AMF community structure. Considering that plant hosts and environmental factors are important drivers of AMF communities on a local scale (Li et al., 2010; Kawahara and Ezawa, 2013; Silva et al., 2015a), we tested the hypothesis that AMF community composition changes across the island, even within short distances among sites, in response to differences in the edaphic characteristics and vegetation physiognomies, with AMF community composition being more strongly determined by soil characteristics than by physiognomic conditions.

2. Material and methods

2.1. Study area

The study was performed on the Ilha da Restinga ('Restinga Island', 07°0′10.60″S and 34°51′32.01″W), located at the mouth of the Northern Paraíba River, in the municipality of Cabedelo, Paraíba, northeastern Brazil. With 530 ha and a relatively flat topography, ranging from 0 to 11 m above sea level, the island is part of the Atlantic Forest domain and the vegetation consists primarily of mangroves in flooded regions and sandbank woods, estuaries and lagoons (Farias, 1980). The formation of the island occurred through soil accumulation brought by the Paraíba River (Oliveira, 2012). The average annual temperature is 25 °C, the climate is As' - tropical hot and wet, according to the Köppen classification, and the average annual precipitation is 1764 mm (Alves, 2011).

A transect of approximately 1500 m was established across the island in the east-west direction, due to the impossibility to establishing north-south transect, because the island has lagoons and Atlantic Forest areas (Alves, 2011). At approximately every 350 m, we established a sampling area, which corresponded to a distinct vegetation type (Fig. 1 - Google Earth, 2016).

The transect went across the following habitats: 1 – a mangrove forest (MF; 07°0′15.66″S; 34°51′50.49″W; 5 m asl) representing a conserved mangrove forest area located in the west side of the island, which is frequently flooded; 2 – a regeneration *Restinga* forest 1 (RR1; 07°0′14.99″S; 34°51′40.93″W; 8 m asl), a *Restinga* forest area which was devastated and is currently still under a recover process; 3 – a natural *Restinga* forest (RF; 7° 0′10.60″S; 34°51′32.01″W; 8 m asl); 4 – a second regeneration *Restinga* forest 2 (RR2; 07°0′9.19″S; 34°51′19.30″W; 10 m asl), which was also devastated and is currently in a recovering process; 5 – a degraded mangrove forest (MD; 07°0′14.30″S; 34°51′2.35″W; 5 m asl), characterized by a mangrove area degraded for two years and currently presenting some exotic plant species. More information about the habitats can be found in Guedes (2002) and Alves (2011).

2.2. Soil and roots samplings

Soil and root sampling was conducted in August 2011 (end of wet season). We delimited three plots of approximately 3 m^2 at each habitat. In each plot, two subsamples were collected to form a composite sample, totaling three composite samples per habitat type. Each composite sample (about 3 kg) was placed in plastic bags and transported to the laboratories of the Department of Mycology (UFPE). About 300 g of soil were used to determine the soil chemical and physical attributes, 2 kg of soil were used to set up AMF trap cultures, and 100 g of soil were used for AMF spore extraction for morphological species identification. Samples of field roots were used to determine rates of mycorrhizal colonization.

2.3. Soil attributes

Three soil samples of each habitat type were used to determine the physical and chemical attributes of the soil. The analyses were performed at the "Estação Experimental de Cana-de-açúcar da Universidade Federal Rural de Pernambuco" in Carpina, Pernambuco.

The chemical attributes were evaluated following the methods described in Silva et al. (1999): the pH was measured in water (1:2.5; weight:volume); Ca^{2+} and Mg^{2+} were extracted with 1 M KCl and quantified by atomic absorption; K^{+}, Na^{+}, P, Cu, Zn and Mn were extracted using Mehlich 1 reagent (0,05 of HCl + 0,0125 of H_2SO_4), for the analysis of Cu, Zn, Mn and Fe a soil:reagent proportion of 1:5 was used, while for macronutrients a proportion of 1:10 was used. K^{+} and Na were determined by flame photometry, P by colorimetry, and Cu, Zn, Mn and Fe by atomic absorption spectrophotometry; organic carbon was evaluated by oxidation in potassium dichromate and titration of the excess potassium dichromate by ferrous ammonium sulfate; H^{+} and Al^{3+} were determined by the calcium acetate method and alkaline titration;