Applied Soil Ecology 96 (2015) 7–17

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Communities of arbuscular mycorrhizal fungi on a vegetation gradient in tropical coastal dunes

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ARTICLE INFO

Article history:
Received 25 March 2015
Received in revised form 19 May 2015
Accepted 11 June 2015
Available online 18 July 2015

Keywords:
Coastal ecosystems
Diversity
Ecology
Richness
Indicator species

ABSTRACT

The community composition of arbuscular mycorrhizal fungi (AMF) was studied related to AMF species richness, abundance and frequency in coastal dune areas, northeastern Brazil. Soil samples were collected periodically in 2010 and 2011 in three dune areas (herbaceous, shrubby and arboreal) that form an environmental gradient from the beach to the inland tropical rainforest. Fifty AMF species were identified belonging to 18 glomeromycotan genera and 10 families. Several remarkable observations were made: higher AMF spore density was observed in the arboreal dune compared to the shrubby and herbaceous dunes, while the highest number of infective propagules was observed in the herbaceous dune, followed by the shrubby and arboreal dunes. Although AMF species richness and AMF root colonization were similar in all dunes, the Shannon's diversity and Pielou's evenness indices were higher in the herbaceous dune than in the shrubby and arboreal dunes, which was the opposite in relation to the Simpson dominance index. Thus, surprisingly, the areas closest to the sea had greater diversity compared to the later successional dunes in farer distance from the sea. *Funneliformis halonatus* was the indicator species of the arboreal dune, *Ambispora appendicula*, *Gigaspora gigantea* and *Paradentiscutata maritima* were the indicator species of the shrubby dune, while two undescribed *Cetraspora* species and *Sclerocystis sinuosa* were the indicator species of the herbaceous dune. The study areas can be considered as hotspots for the conservation of diversity of AMF.

1. Introduction

Terrestrial coastal ecosystems are naturally fragile environments due to their particular characteristics, such as nutrient deficiency and low levels of organic matter, salt-spray, sand movement, high insolation, wide range of humidity and temperature, and strong winds (Rippley and Pammenter, 2008; Yamato et al., 2012). These environments are of utmost ecological importance, providing a variety of ecosystem services, including coastal protection, erosion control, water capture and purification, maintenance of fauna and flora, carbon sequestration, in addition to being used for tourism, recreation and research (Barbier et al., 2011).

In Brazil, the coastal terrestrial environments belonging to the Atlantic Forest Dominium occupy about 80% of the coast (Lacerda et al., 1993) and are considered one of the hotspots for biodiversity conservation (Myers et al., 2000). Despite their immeasurable importance, these environments are subject to anthropogenic (mining, pedestrian traffic, urbanization, port and tourist activities, deforestation) disturbances, which compromise the local ecology and affect various above and below ground communities (Emery and Rudgers, 2010).

Studies that consider the microbiota associated with these areas are important for local conservation, as soil microorganisms play a fundamental role in the maintenance of terrestrial ecosystems. Among these microorganisms, arbuscular mycorrhizal fungi (AMF), forming symbiotic associations with most flowering plant species, promote numerous benefits on plant communities. They act as facilitators for the absorption of nutrients, especially phosphorus,

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http://dx.doi.org/10.1016/j.apsoil.2015.06.009
0929-1393/

and contribute to the maintenance of the ecosystem (Smith and Read, 2008). By generally occurring in all terrestrial environments and at the soil–plant interface, AMF are considered as a key functional group of soil biota due to the nutritional and non-nutritional benefits they provide (Gianinazzi et al., 2010). These fungi have been included in the Glomeromycota phylum which currently has around 270 described species (www.mycobank.org).

Studies on AM fungi along a vegetational gradient in dune areas have been conducted in many countries including Scotland (Nicolson and Johnston, 1979), United States (Rose, 1988), Poland (Błaszkowski, 1994), Mexico (Corkidi and Rincón, 1997), and Japan (Funatsu et al., 2005; Yamato et al., 2012), and have generally shown an influence of the environmental gradient on the abundance of glomerospores, inoculum potential and species richness. In Brazil, only two studies, conducted in the southern part of the country, have evaluated the influence of the vegetational gradient on AMF (Córdoba et al., 2001; Cordazzo and Stürmer, 2007). The authors found that species richness increased with the distance from the sea. In the Brazilian Northeast three studies on AMF were performed in areas of *restingas* and dunes (Santos et al., 1995; Silva et al., 2012; Souza et al., 2013), but none of these addressed the effect of a vegetational gradient on the AMF community.

The characterization of AMF communities in protected areas contributes to the knowledge about the importance of such areas as genetic reserves and also for long-term maintenance and conservation of mycorrhizal symbionts in their natural habitats (Turrini et al., 2010). Therefore, the dune areas of the present study, which belong to a private reserve of a mining company, are important for knowing the structure of the AMF communities in these environments. This information will serve for the definition of conservation strategies, especially in threatened environments, as it is the case of coastal ecosystems.

Several factors can affect the occurrence and distribution of AMF species. On a global scale the main factors that shape natural AMF communities are macroclimatic changes, followed by overall environmental factors such as huge differences in geology, soil type and soil pH, and natural plant communities developed under such climatic and edaphic conditions (Kivlin et al., 2011; Öpik et al., 2013). On local and spatial scales the communities are more influenced by microclimatic changes and a series of specific soil properties such as pH, soil organic matter, soil texture and soil hydrology, besides the plant community shifts (Ji et al., 2012; Silva et al., 2014b; Njeru et al., 2015). Stochastic processes and competitive interactions between plants and AM fungi, or within the AM fungal communities may also substantially affect AMF communities both on macro and micro-scales (e.g. Horn et al., 2014).

The distribution pattern of vegetation varies with distance from the sea, and this variation is mainly influenced by the wind and by changes in the soil properties along the gradient (Fenu et al., 2013). Therefore, we expected that AMF communities vary both in relation to abiotic characteristics (related to soil P, organic carbon and pH) and according to changes in the plant communities along environmental gradients. In the present case the plant community varies from an herbaceous area (where members of Poaceae, Fabaceae and Convolvulaceae predominate) to an arboreal area (with species of Leguminosae, Anacardiaceae, Bignoniaceae, Rhamnaceae, Myrtaceae, Rubiaceae, Annonaceae, Malvaceae, Chrysobalanaceae, and Sapotaceae), and plant species richness generally increases with increasing distance from the sea, from herbaceous over shrubby to arboreal dunes (Castanho et al., 2012).

Besides, there are evidences of co-variation of plant and AMF communities' composition on environmental gradients, but this phenomenon is not completely understood (Silva et al., 2014b; Zobel and Öpik, 2014). Based on that, we decided to study the AMF community along a gradient on coastal areas. The objectives of this study were to determine the diversity and community structure of AMF and to assess aspects such as species richness, abundance and frequency of these beneficial fungi in three types of dunes, at the coast of Paraíba, Northeastern Brazil.

2. Material and methods

2.1. Study area

The study was performed in undisturbed areas of dunes belonging to a mining company (Millennium Inorganic Chemicals Mineração Ltda) located in the municipality of Mataraca, Paraíba (6°28′20″–6°30′00″S, 34°55′50″–34°57′10″W). Information about the climate, temperature and precipitation in these areas was already given in Silva et al. (2012).

Collections were made in a vegetational gradient of a dune system, comprising three areas: (a) arboreal dune (or fixed dune) – consisting of trees generally 4–10 m tall, where epiphytes and lianas are also found; (b) shrubby dune (or foredune) – located between the areas of herbaceous and arboreal dune and characterized by a predominantly shrub-sized vegetation; (c) herbaceous dune (or embryonic dune) – an area with creeping vegetation, adjacent to the beach. The most common species of the arboreal dune are: *Tabebuia roseo-alba*, *Ziziphus joazeiro*, *Psidium decussalum*, *Xylopia nitida*, *Buchenavia capitata*, *Duguetia gardneriana*, *Hymenia rubriflora* var. glabra, *Apeiba tibourbou*, *Tapirira guianensis*. These species are also typical for several other forest types, such as Northeastern Atlantic forest, *Caatinga* (dry forest) and "*mata de brejo*" (highland forests; Oliveira-Filho and Carvalho, 1993). Shrubby dune vegetation includes as common species: *Anacardium occidentale*, *Byrsonima gardneriana*, *Eugenia ovalifolia*, *Guapira pernambucensis*, *Guettarda platypoda*, *Jacquinia brasiliensis*, *Sporobolus virginicus*, and *Tocoyena selloana* (Oliveira-Filho and Carvalho, 1993). The herbaceous dune is dominated primarily by two species: *S. virginicus* and *Ipomoea pes-caprae* (Oliveira-Filho and Carvalho, 1993). The arboreal dune is 392 m distant from the shrubby dune, and the distance between the herbaceous and shrubby dune is 30 m.

2.2. Sampling

Rhizospheric soil samples were collected in March (end of the dry season), July (rainy season) and November (beginning of the dry season) of 2010 and 2011. In each area, four plots of 100 m^2 (5×20 m) were delimited, and in each plot a composite sample consisting of six sub-samples was taken (0–20 cm depth) with an auger, totaling four composite samples of soil per area, in each one of the six sampling times. The distances between plots were 30 m. The samples were transported in plastic bags to the Mycorrhizae Laboratory/UFPE and kept air-dried at room temperature until analyzed (approximately one month). Part of the soil samples was sent for chemical and physical analyses (Table 1) and the remainder was used for AMF analyses.

2.3. Evaluations

2.3.1. Physical and chemical analyses

The soil analyses were made at the 'Estação Experimental de Cana-de-açúcar' of the Universidade Federal Rural de Pernambuco; the analyses were performed for each soil sample using the protocols adopted by Embrapa (1997) and included: pH, P, K, Ca, Mg, Na, Al, Fe, organic matter (OM) and cation exchange capacity (CEC). The pH was measured in water (1:2.5-v/v; soil:water), P, Na and K were extracted with HCl and H_2SO_4; P was quantified by colorimetry and Na and K by flame photometry. Al, Ca and Mg were extracted (KCl) and determined by titration (Al) and atomic absorption (Ca and Mg). The organic matter (OM) was determined by oxidation