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Effects of fire on arbuscular mycorrhizal fungi in the Mountain Chaco Forest

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ABSTRACT

The aim of this study was to evaluate the fire effects on the AMF spore communities and soil chemical properties as well as the existence of possible correlations between them in the Chaco Serrano Forests of central Argentina. Our hypothesis is that the fire has a negative impact on the community of AMF spores (i.e. density, diversity, richness and evenness) and soil chemical properties. In addition, we expect to find a high correlation between changes in the communities of fungi and soil chemical properties. We selected five areas in the "Sierras Pampeanas" mountain ranges within the Chaquean region in central Argentina. In each of them we selected adjacent burned and unburned forest sites. Burned sites have all the same time since fire occurrence (August–November 2009) and soil samples were collected in autumn (April) and spring (November) in 2010. The fire events had direct negative effects on AMF spore communities. Evenness, and notably diversity and richness of AMF spores decreased in the burned sites. Density of AMF spores was not affected by fire. With the exception of C:N, nitrate and electrical conductivity, soil parameters showed significant differences between burned and unburned sites. The changes in AMF spore composition were not significantly correlated with most of the soil variables measured here. The results of this study suggest that fire occurrence negatively affect AMF communities. These effects do not seem to be mediated by changes in soil abiotic properties. Rather, they suggest direct effects of fire on soil fungi.

1. Introduction

Disturbances alter biological diversity (Bengtsson et al., 2002). Fire is among the most widespread disturbance that affects biological organisms, either directly or indirectly (Busse and DeBano, 2005). Direct effects mainly include reduction or elimination of the aboveground and belowground biomass, loss of soil organic horizon, and increase in soil temperature and ash deposition. Among the indirect effects, changes in soil properties such as organic matter, carbon, nitrogen, phosphorus, pH are frequently reported (e.g. Neary et al., 1999; Certini, 2005; Kara and Bolat, 2009; Dias et al., 2010; Longo et al., 2011; Switzer et al., 2012; Wang et al., 2012; Williams et al., 2012).

Among belowground organisms, arbuscular mycorrhizal fungi (AMF) are known to colonize the majority of land plants and provide them with access to soil nutrients in return for carbon compounds (Smith and Read, 2008). Because AMF taxa differ in their effects on plant growth, the composition of AMF communities influence the structure of plant communities (van der Heijden et al., 2008).

After severe disturbances such as fire, AMF mycelium is impaired and spores could act as source of plant colonization. Plant establishment after fire might depend on the composition of AMF spores in soil. Although many studies have evaluated the direct effects of fire on AMF the results are contradictory, reporting either negative (e.g. Dhillion et al., 1988; Valariño and Arine, 1991; Allsopp and Stock, 1994), neutral (e.g. Bellgard et al., 1994; Rashid et al., 1997; Treseder et al., 2004; Haskins and Gehring, 2004; Docherty et al., 2012), or positive effects on spore abundance (Eom et al., 1999; Moreira et al., 2006). Prescribed burning in grassland increased the total number of spores, mainly of *Glomus etunicatum* and *G. fecundisporum*, reduced the diversity and did not reduced mycorrhizal infection (Eom et al., 1999). Furthermore, in N.W. Spain wildfire reduced the number of spores in the soil and negatively affects the viability of spores of *Aculospora leavis* (Valariño and Arine, 1991). Indirect effected of fire, such as the alteration of soil nutrients availability might also cause changes in the AMF spore communities, usually reflected by a decrease in the number of AMF propagules (Allen et al., 1984). It is hard to generalize the effects of fire on the HMA. The response of this group of organisms to fire differed substantially in both the direction and magnitude of their responses. Those differences in AMF response

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Table 1
Location and year of fire occurrence at each study area.

Area	Fire	Latitude (°S)	Longitude (°W)	Elevation (m a.s.l.)
Agua de Oro (AO)	2009	31° 02′ 30.95″	64° 19′ 29.73″	902
Salsipuedes (SA)	2009	31° 07′ 10.20″	64° 17′ 03.90″	743
La Serranita (LS)	2009	31° 45′ 56.75″	64° 28′ 14.92″	659
Cuesta Blanca (CB)	2009	31° 30′ 04.87″	64° 35′ 27.58″	847
Bialet Massé (BM)	2009	31° 17′ 55.46″	64° 29′ 42.59″	770

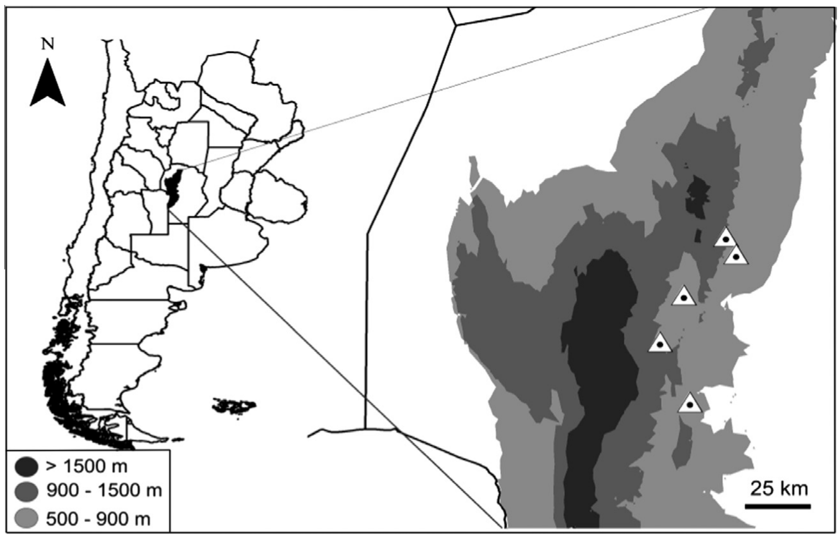

Fig. 1. Location of the five study areas in the Sierras Pampeanas within the Chaquean mountains region in central Argentina.

to fire might be related to variation in the fire characteristics (intensity, duration, wildfire vs. prescribed fire, time after burning, among other factors).

In the Chaco Forest of Argentina, the effects of certain types of disturbances, such as plant removals and forest fragmentation, on AMF spore communities have been recently documented (e.g. Urcelay et al., 2009; Grilli et al., 2012). However, no studies have evaluated fire effects, which constitute one of the most frequent disturbances in the vegetation of the Chaco Forest (Zak et al., 2004). Therefore, experimental designs including replicates of the fire/non-fire situation keeping the above mentioned variables fixed are highly desirable. We selected five areas in the "Sierras Pampeanas" mountain ranges within the Chaquean region in central Argentina in order to assess the impact of fire on AMF spore communities and chemical soil properties as well as the existence of possible correlations between them. In each area we selected adjacent burned and unburned forest sites. Our hypothesis is that the fire has a negative impact on the community of AMF spores (i.e. density, diversity, richness and evenness) and soil chemical properties. In addition, we expect to find a high correlation between changes in the communities of fungi and soil chemical properties.

2. Materials and methods

2.1. Study area

The study region is located in the Chaco Serrano District in Córdoba province, Argentina. This district belongs to the Chaquean region that constitutes South America's most extensive dry seasonal forest (Cabrera, 1976; Moglia and Giménez, 1998), and covers in Córdoba, Argentina an area between 29° and 33° 30′ (S), ranging in elevation from 400 to 1300 m above sea level. Soils are lithosolic (Vázquez et al., 1979) sandy, well drained and shallow (Gorgas and Tassile, 2003). This type of forest is characterized by an open tree stratum that is up to 15 m high and is dominated by *Zanthoxylum coco Gillies ex Hook. f.* & *Arn.* (*Rutaceae*) and *Lithraea molleoides* (*Vell.*) *Engl.* (*Anacardiaceae*); shrubs (1–3 m) primarily dominated by *Celtis ehrenbergiana* (*Klotzsch*) *Liebm.* (*Celtidaceae*) and *Acacia* spp. (*Fabaceae*); herbs and grasses (0–1 m) and numerous vines and epiphytic bromeliads (Luti et al., 1979). The annual rainfall (±750 mm) is concentrated mostly in the warm season (October–April), with mean maximum and minimum temperatures of 26 °C and 10 °C respectively (Luti et al., 1979; Moglia and Giménez, 1998). In these forests most fires are human caused, either by accident or related to farming practices. It has been estimated that fires present a return interval ranging from 2 to 15 years. They generally occur at the end of the dry season, from June to November (Miglietta, 1994). In these ecosystems, woody vegetation is dominated by species that resprout after fire (Gurvich et al., 2005; Giorgis, 2012; Torres et al., 2013). Nonetheless, in the short term, burned sites show more open and lower statured vegetation than unburned ones (Giorgis, 2012). One year after fire occurrence, in unburned sites the herbaceous vegetation was dominated by grasses while burned sites are dominated by forbs (Verzino et al., 2005). Soil properties are strongly affected by fires in these ecosystems; the fire promotes lower organic matter and higher levels of nitrate in soil (Abril and González, 1999).

2.2. Sampling design and soil collection

Five study areas were selected (Table 1 and Fig. 1). In each area, nearby burned and unburned sites were studied. Burned sites have all the same time since fire occurrence (August–November 2009) and soil samples were collected in autumn (April) and spring (November) in 2010. In each site, ten samples of soil (10 replicates × site) spaced by 5 m were randomly collected in a single plot with a soil corer at 0–15 cm depth (2 sites × 5 areas × 2 seasons, total = 200).