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Fungal community succession and sporocarp production following fire occurrence in Dry Afromontane forests of Ethiopia

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ABSTRACT

Fire is among the main threats to forest ecosystems in Ethiopia and is affecting the forest biodiversity, including fungal communities. This study was aimed to examine the effects of fire on macrofungal taxa richness, diversity and sporocarp production in the Dry Afromontane forests in Ethiopia. Sporocarps were collected from nine plots (100 m^2) established in one- and ten-year-old burned stands, and in an unburned stands. The data were used to quantify fungal richness and sporocarp fresh weights. Morphological and molecular analyses were used to identify the fungi. Composite soil samples were also collected from each stand and used to determine main edaphic explanatory variables for taxa composition. A total of 61 fungal taxa, belonging to *Basidiomycota* division were reported, of which 22 were edible. Fungal diversity, richness and sporocarp production were affected just after the fire. Fungal community composition was significantly correlated with Organic matter, P and Ca. Generally, the result is encouraging from the point of view of fungal conservation. It provides novelty information about the macrofungal communities in Ethiopian dry Afromontane forests, likely including many taxa are still unknown to science as well as several edible species which could supply complementary incomes for the rural populations in the study area.

1. Introduction

The Ethiopian highlands cover more than 44% of the country's land area. Afromontane vegetation originally dominated these highlands, characterized by high-altitude natural forests classified as either Dry or Moist Afromontane forests (Friis et al., 2010). Of these two, the Dry Afromontane forests form the largest part and are distributed mainly in the Central, Northern and Western parts of Ethiopia (Eshete et al., 2011; Friis et al., 2010). The existence of high humidity with a variable rainfall pattern and a prolonged dry season characterize the Dry Afromontane forests making them complex and rich in biodiversity (Wassie et al., 2005). The main tree species found in these forests include *Juniperus procera*, *Podocarpus falcatus*, *Hagenia abyssinica* and *Olea africana*. These tree species serve as the main sources of timber to the country (Kassa et al., 2009). The Dry Afromontane forests also harbor various types of Non-Timber Forest Products (NTFPs) (Shumi, 2009), including edible fungi (Dejene et al., 2017).

Fungi are key components of the forest ecosystems (Lindahl et al., 2007), since they are responsible for the decomposition of organic materials and recycling of nutrients (Ferris et al., 2000). Fungi play a key role in the mobilization, uptake and translocation of nutrients in forest soils. They can also improve plant water uptake and resistance to abiotic stresses; thereby influencing plant diversity, productivity and ecosystem functions (Pietras et al., 2013; Van Der Heijden et al., 2008). In addition to ecological functions, fungi have become a strategic component in the conservation and management of forest systems. This is because of their economic value, as during the last decade, there has been an increasing demand for wild edible fungi (Pettenella et al., 2007), which are becoming an important source of rural income (Boa, 2004). In fact, in some cases forest fungi may generate even higher economic benefits than timber production (Martín-Pinto et al., 2006).

Although reliable data on cover change is scarce, the forest history of Ethiopia indicates that forest land degradation and fragmentation is a continuous process, notably in the Dry Afromontane forests (Wassie et al., 2005). The ever-increasing demand for wood products as well as crop and grazing land expansion, stimulated by rapid population and livestock growth are factors aggravating the degradation of these forests in Ethiopia

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(Lemenih and Bekele, 2008). In addition, fire is also responsible for the loss of forest in the country, affecting the distribution, diversity and composition of forests resources (Lemenih and Bekele, 2008; Wassie et al., 2005). For instance, the most devastating wave of forest fires, which occurred in 2000 due to an extended drought, damaged over 150,000 ha (ha) of forested lands throughout the country (Teketay, 2001). This trend is more pronounced in the Dry Afromontane forests compared to other ecosystems, and has a direct implication on the loss of biological diversity of these forest ecosystems (Lemenih and Bekele, 2008).

As an ecological factor, fire is affecting forest fungal communities (Bastias et al., 2006). Differences in its return interval can modify the composition and diversity of fungi (Buscardo et al., 2010). A change in ecological conditions effects fungal growth and perpetuation depending on the intensity and duration of fire in the forests (Hart et al., 2005). Furthermore, fire produces direct effects on fungal communities by affecting belowground organisms (Buscardo et al., 2012). Thus, the subsequent structure of fungal communities following succession patterns will be affected, mainly driven by the dynamics of post-fire plant communities (Cairney and Bastias, 2007). On the other hand, some fungi might also benefit from fire since they fruit as a result of fire (Hart et al., 2005). Hence, some level of fire in the ecosystem could provide higher abundance of fire-loving fungal species. Also, fungal communities are closely influenced by other biotic and abiotic factors such as soil characteristics. Indeed, fungal species composition in the forest tends to be correlated with edaphic variables (Straatsma et al., 2001), especially saprotrophic fungi which are more dependent upon their respective substrates than mycorrhizal fungi (Reverchon et al., 2010).

A recent review work on the effects of forest fire on fungal association reveal that fungal-fire relations studies were mostly located in temperate and Mediterranean forest ecosystems (Taudière et al., 2017). The tropical forests are yet understudied, and comprehensive studies are recommended to improve understanding of the fungi–fire relationships with current global scale changes. Despite their ecological and economic importance, fungal communities are the most neglected components of Ethiopian forest systems, mainly of the Dry Afromontane forests (Dejene et al., 2017). This poor knowledge is worrying as fungi are highly sensitive towards anthropogenic threats like human induced fire, which are common in the Dry Afromontane forest ecosystems (IBC, 2014). Off course, the influence of fire on the diversity and sporocarp production of fungi remains understudied in the country overall. Thus, a close examination of fungal ecology in relation to fire factor may facilitate the diversity conservation and production of economically important fungal species in our study area.

This pioneering work was designed to provide baseline information about macrofungi assemblage, diversity and sporocarp production in the Dry Afromontane forests which helps to derive benefits through management strategies, and also to supplement the current knowledge about the fungal community in Ethiopia. The specific objectives included; (i) to analyze fungal richness after fire, (ii) to analyze the total and edible sporocarp yields after fire and (iii) to relate taxa composition to explanatory edaphic variables.

2. Material and method

2.1. Study area

The study was conducted at Wondo Genet natural forest area, one of the remnant Dry Afromontane forests, located in Southern Ethiopia. Wondo Genet is found approximately 265 km from Addis Ababa, the capital city of Ethiopia (Fig. 1). It is located at 7°06′–7°07′N latitude and 38°37′–38°42′E longitudes with an altitudinal range between 1600 m and 2580 m above sea level (m.a.s.l.) (Belaynesh, 2002; Fenta, 2014). The climate of the study area is characterized by the Woyna Dega agro-climatic type, and the rainfall pattern is bi-modal, with minor rainfall during spring and the major rain season during summer. The average annual rainfall of the study area is 1210 mm, which peaks in July. The average annual temperature of the study area is 20 °C (Belay, 2016; Fenta, 2014).

The topography is slightly undulating and the soils are young and of volcanic origin, characterized by sandy loam (Eriksson and Stern, 1987) with a pH average value of 5.7 (Eshetu and Högberg, 2000). The soil physical and chemical properties of the study plots are presented in Table 1.

The study area covers about 797 ha of natural forests lands (Ango and Bewket, 2007; Belaynesh, 2002; Fenta, 2014) that are characterized by remnant Dry Afromontane forest patches, home to important fauna and flora. This forest also provides a variety of important ecosystem services that can be expressed in terms of watershed protection and carbon sequestration. *Juniperus procera*, *Albizia gummifera*, *Afrocarpus falcatus*, *Bersama abyssinica*, *Prunus africana*, *Podocarpus falcatus*, *Cordia africana*, *Croton macrostachys* and *Olea africana* tree species mainly characterize the natural forests of our study area (Ango and Bewket, 2007; Belay, 2016). Forest fire is a recurrent phenomenon, occurring yearly in small patches in the natural forest of the study area (Bekele et al., 2013).

We established our study plots in the natural forests in 2015, taking into consideration the similarity of the stands in terms of ecological conditions such as climate, altitude and soil. Information from the Department of Forest Management in Wondo Genet College of Forestry was used to find patches of forest stands with similar fire history. The control stand was patches of forest representative of the original natural forest not affected by fire at least in the last 40 years. Burned stands were patches of forests affected similarly by high fire severity, with canopy and understory burned, and the soil organic layer consumed (Rincón and Pueyo, 2010). Three stands could be clearly differentiated: (1) unburned natural forest stand, hereafter UB stand: no fire occurred previously since the inception of the nearby college of forestry (1976) where it is located, (2) one-year-old burned forest stand, hereafter B-1 stand: mainly characterized by different kind of shrubs species and burned standing trees and logs, (3) ten-year-old burned forest stand, hereafter B-10 stand which resembles the unburned stands in terms of vegetation composition but without reaching the maturity and complexity of the unburned stand. Within each of the selected stands, plots were established systematically about 250 m apart. Differences in fungal diversity and productivity among stands prior to fire were thus unlikely.

2.2. Sporocarps sampling

A total of nine sample plots, three per stand (UB, B-1 and B-10), were established as described in Gassibe et al. (2011) and Hernández-Rodríguez et al. (2013). Each plot covered an area of 100 m^2, with a rectangular shape (2 m × 50 m). All sporocarps found in the plots were fully harvested weekly during the major rainy season in July and August in 2015. Fresh weight measurements were carried out *in situ* and the data are given in kilograms per hectare per year (kg fw/ha/year). Also abundance data of each species was taken from each plot. Sample fruit bodies from each species were taken to the laboratory and dried. Herbaria specimens were used for molecular and microscopic taxa identification. Furthermore, in the field, specimens were photographed and their ecological characteristics were noted in order to assist and facilitate taxa identification processes. This work could be considered as a case