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Field and microcosms decomposition dynamics of European beech leaf litter: Influence of climate, plant material and soil with focus on N and Mn

Michele Innangi [a,*], Manfred K. Schenk [b], Francesco d'Alessandro [a], Stefania Pinto [c], Cristina Menta [c], Stefania Papa [a], Antonietta Fioretto [a]

[a] Department of Environmental, Biological, Pharmaceutical Sciences and Technologies, Second University of Naples, Via Vivaldi 43, 81100 Caserta, Italy
[b] Institute for Plant Nutrition, Leibniz University of Hannover, Herrenhäuser Str. 2, 30419 Hannover, Germany
[c] Department of Life Sciences, University of Parma, Strada Farini 90, 43121 Parma, Italy

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ABSTRACT

Leaf litter decomposition is one of the key phenomena in forest ecology. The patterns and trends of decomposition are related to the complex interaction of climate, soil biota and litter quality. The decay dynamics for the European beech are well-known for middle Europe, but lesser investigated in the Mediterranean area. In this study, we investigated mass loss and nutrient dynamics, especially nitrogen and manganese, in two Mediterranean beech forest located in northern and southern Italy. We used a litterbag experiment with leaves of each forest incubated in their own area of origin and vice versa. Moreover, we also used microcosms to follow early stages of decomposition under controlled conditions. The aims of this study were to investigate the role of climate and soil/litter quality at the different stages of decomposition and assess the response of diverse soils to changes in temperature and humidity. The results showed a faster field decomposition for the southern (warmer) site compared to the northern (colder) site, whereas under stable conditions in microcosms this trend reversed, implying different microbial adaptations to climate. Moreover, changes in temperature and humidity triggered complex microbial response during litter decay. Additionally, whereas our results showed trends of nitrogen concentration comparable to previous studies, the role of manganese in decomposition was very relevant even from the early stages. Noticeably, manganese was generally lower in both sites compared to middle Europe, but it was higher in the northern site than in the southern one. Manganese concentration, however, strongly increased for those leaves that had a lower initial content in all conditions, giving evidence of a strong mobilization of this nutrient and its essential role for decomposition in Mediterranean beech forests.

1. Introduction

Within forest ecology, a key role is played by the complex phenomenon of litter decomposition (Berg and Laskowski, 2006; Berg and McClaugherty, 2014; Swift et al., 1979) as only primary production can be seen as a more important ecosystem process (Moorhead and Sinsabaugh, 2006). Decomposition of plant litter is essential in the global carbon cycle, especially in boreal and temperate forests which are estimated to contain the largest pool of carbon in their soils (Dixon et al., 1994). Additionally, litter decomposition is fundamental in nutrient cycling and plant nutrition as well (Coûteaux et al., 1995; Guckland et al., 2009; Kaspari et al., 2008). Factors influencing litter decomposition are substrate quality, climate and soil biotic communities (Berg and McClaugherty, 2014).

There is a consensus that, under unfavorable climatic conditions, climate has a higher importance in litter decomposition, while under Mediterranean climatic conditions (i.e., milder temperatures also during winter and good amount of rainfall in all seasons, except summer), litter quality largely overcomes the influence of climate (Cortez et al., 1996). Moreover, at a regional scale, climate (mostly temperature and rainfall regimes) is the main driver of litter decomposition (Liski et al., 2003) but at smaller scales litter quality may be a far more important factor (Berg and McClaugherty, 2014).

Substrate quality is particularly significant both in terms of nutrient translocation from plant to soil and vice versa (Sariyildiz and Anderson, 2005) affecting the rates of decomposition, mainly

* Corresponding author at: Vivaldi 43, 81100 Caserta, Italy. Tel.: +39 0823 274550.
E-mail address: michele.innangi@unina.it (M. Innangi).

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on the basis of nitrogen and lignin content (Fioretto et al., 2005a; Melillo et al., 1982; Taylor et al., 1989). Additionally, in the last decades, manganese has been shown as a very significant nutrient in decomposition ecology (Berg et al., 2006, 2013).

Climate regulates the rates of decomposition in function of temperature and moisture regimes (Trofymow et al., 2002) and the consequences of the on-going climate changes have been taken into account into several studies about decomposition and C cycle (e.g., Briones et al., 2010; Davidson and Janssens, 2006; Meier and Leuschner, 2010; Sariyildiz and Anderson, 2003).

As for soil biota, fungi and bacteria form unique communities and successions during the decomposition process (Berg et al., 1998; Romaní et al., 2006), with fungi as the main protagonists in the production of exoenzymes capable of lignin degradation (Osono, 2007). Soil fauna, according to the size of the animals implicated, are involved in different parts of the decomposition process and soil quality (Knoepp et al., 2000), with relevance of groups as *Collembola* (Chamberlain et al., 2006) and *Oligochaeta* (Andriuzzi et al., 2013; Cortez and Bouché, 2001, 1998; Vliet et al., 2004).

The European beech (*Fagus sylvatica* L.) is one of the most interesting species in central Europe, as it might potentially be the forest species with the largest area of occurrence. It forms mostly monospecific stands in a wide variety of site conditions ranging from humid to semiarid climates and from basic to acid soils (Ellenberg and Leuschner, 2010). Within Europe, beech in the Mediterranean region is mostly confined to mountain ecosystems (Von Wühlisch, 2008). Given that the Mediterranean climate strongly affects temperature and moisture regimes even at higher altitudes, during the summer plants have an adaptation to longer periods of water stress (Amoriello and Costantini, 2000). Finally, the Mediterranean region is one of the most threatened by climate changes (IPCC, 2013) and potential changes on decomposition rates and C dynamics have not been investigated as extensively as in central Europe (Incerti et al., 2011).

In point of fact, decomposition of beech plant material, in pure and/or mixed forests of central Europe, has been extensively studied both in the field (e.g., Albers et al., 2004; D'Annunzio et al., 2008; Kooijman and Martinez-Hernandez, 2009; Melillo et al., 1982; Sariyildiz and Anderson, 2005) and/or under laboratory conditions (e.g., Brandstätter et al., 2013; Cortez et al., 1996). On the contrary, there are few studies investigating decomposition regimes in beech forests in the Apennines (Rutigliano et al., 1998, 1996).

The aim of this study was to follow litter decomposition dynamics in two beech Apennine stands with climatic and pedological differences, one in northern Italy (Pradaccio), and the other in southern Italy (Laceno). In the field, when dealing with litter decomposition, it is almost impossible to discriminate the relationships between litter quality, microbial community, and site conditions (Ono et al., 2013). In order to evaluate the impact of plant material and climate on decomposition, we performed an in the field litterbags experiment which has been set up with leaves from Pradaccio incubated in both forests and vice versa with Laceno's litter. Moreover, a microcosm laboratory litterbags experiment has been performed to evaluate the reactions of the microbial communities of the two soils to changes of temperature and moisture according to the different leaf material being decomposed under controlled conditions. Microcosms were created to simulate the forest environment while exerting control on temperatures and soil humidity. This study will focus on evaluating the relative impacts of plant material, climate and microbial communities during the different stages of the decomposition process both in the field and under controlled conditions. Particular focus has been given to nutrients dynamics as the main driver of variance induced by the differences in the plant material, especially for N and Mn.

We can hypothesize that (a) litter quality will not impact as much as climate in the decomposition on the field, with a faster loss of weight in the southern site (Laceno) and (b) the decomposition under controlled conditions will allow to better discriminate the relative impact of individual factors (especially nutrients such as N and Mn), at least in the early stages of decomposition.

2. Materials and method

2.1. Site descriptions

The northern site, Pradaccio, is located on the northern section of the Apennines, in the upper part of the Parma river valley, within a National Reserve called "Guadine-Pradaccio" extending for 289 ha. The southern site, Laceno, lies within the Regional Park of Monti Picentini, which extends for 62,200 ha in region Campania. Pedological surveys, done in the past years in nearby areas, identified the soil from Pradaccio as Lithic Haploborolls according to Soil Taxonomy USDA with a loamy-sand to sandy-clay-loam texture (Leoni, 2008) while Laceno has been classified as Humic Haplustands according to Soil Taxonomy USDA with a loamy-sand to sandy-loam texture (Alvarez Romero, 2012). Details for the main features of the two study locations can be found in Table 1.

2.2. Sample preparation and collection

Between the second half of September and the end of November 2011, newly shed leaves were collected from the surface of 1 ha plots in the two forests with 6 equally distanced nets suspended from the ground through plastic circles of 80 cm ∅ with a mesh size of 1 cm^2. Litter in the nets was collected several times until complete litter fall, taken in the laboratory where it was air dried for two weeks. Subsequently, subsamples were oven dried at 60 °C for 48 h, weighted and then stored at 20–25 °C inside plastic bags.

For the field experiments, terylene litterbags of 20 × 20 cm with a mesh size of 1.5 mm^2 were prepared, which allowed interaction

Table 1
Main features of the two study locations.

Parent material	Pradaccio (North) Sandstone	Laceno (South) Limestone
Soil pH (0–10 cm depth)	4.0	5.5
Water holding capacity (ml H_2O/100 g dry soil)	90	120
Mean tree age (yr)	75	75
Annual litter input (kg/ha)	2500	4300
Elevation (m a.m.s.l.)	1350	1150
Mean annual temperature (°C)	6.0	8.7
Mean spring–summer temperature (°C)	11.0	13.7
Mean autumn–winter temperature (°C)	0.7	3.7
Mean annual precipitation (mm)	2900	2300