Forest Ecology and Management 391 (2017) 309–320

Contents lists available at ScienceDirect

Forest Ecology and Management

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

Thinning alters the early-decomposition rate and nutrient immobilization-release pattern of foliar litter in Mediterranean oak-pine mixed stands

Andrés Bravo-Oviedo [a,b,*], Ricardo Ruiz-Peinado [a,b], Raquel Onrubia [a], Miren del Río [a,b]

[a] INIA-Forest Research Centre, Ctra. A Coruña, km. 7.5, 28040 Madrid, Spain
[b] Sustainable Forest Management Research Institute, University of Valladolid & INIA, Spain

ARTICLE INFO

Article history:
Received 27 December 2016
Received in revised form 9 February 2017
Accepted 14 February 2017
Available online 24 February 2017

Keywords:
Foliar decomposition
Forest management
Mediterranean mixed forest
Litterbag
Plant-soil interaction
Species interaction

ABSTRACT

Leaf litter decomposition is a major pathway for nutrient recycling and a chief factor controlling ecosystem primary productivity. The aim of this study was to analyze the effect of forest thinning on the early-stage foliar decomposition rate and nutrient immobilization-release pattern in a mixed *Quercus pyrenaica-Pinus pinaster* forest growing in the western Mediterranean basin. Two thinning treatments, differing in the intensity of canopy reduction, were compared with a control (unthinned) situation. Oak leaves showed faster decomposition rates than pine needles in unthinned plots. Intense canopy reduction (40% of basal area removed) reduced decomposition rates in both species whereas intermediate reduction (25% of basal area removed) increased decomposition of needles to a rate similar to that of oak leaves. C and N transfer from N-rich to N-poor foliar litter was not detected, indicating a marginal role of canopy reduction in this process. A decoupling of the decomposition rate from immobilization-release pattern was found for mobile elements (K and Mg) at intermediate levels of canopy cover whereas Ca dynamics indicated that pine needles had not started the lignin-mediated degradation phase two years after incubation. We finally hypothesized that strong reductions of canopy cover in dry Mediterranean sites might have an aridification effect on litter decomposition.

1. Introduction

Plant organic production and the subsequent decomposition process are essential parts of the cycle of life on Earth (Berg and Laskowski, 2006). Plant decomposition is a key functional process since it is the main source of nutrient supply in forest ecosystems (Wardle et al., 2002), it links aboveground and belowground processes (Wang et al., 2015) and it is a process which is concomitant with the rates of primary productivity (Cameron and Spencer, 1989). The role of litter decomposition in the nutrient budget is measured through nutrient release from decomposed material which is determined by the rate of litter decay.

Berg and Laskowski (2006) identified three litter mass decay phases or stages: leaching, accumulation and release. The early decay stages are controlled by N concentration (i.e. N rich vs N poor species) whereas the final stages are driven by lignin content. Climate influences the length and speed of these three phases (Berg and Staaf, 1980). However, climate and litter type factors can often be confounded when comparisons are made between different forest types or climatic conditions (Berg et al., 2000). Besides litter type and climate, the decomposer community plays a key role in litter decay (Gartner and Cardon, 2004), which can be exacerbated by mechanisms of adaptation to tree cover. All three factors can be affected by the removal of trees (Li et al., 2009), which alters the microclimate or ground conditions where the litter decomposes.

The interaction between the environment underneath the tree canopy and the tree species (i.e. litter quality) may have a strong influence on litter decay rate and nutrient dynamics as predicted by the 'Home field advantage' (HFA) hypothesis (Ayres et al., 2009; Gholz et al., 2000). The hypothesis states that decomposition of litter occurs more rapidly under the cover of the plant that has yielded the litter, although empirical evidence has shown that exceptions also occur (Aponte et al., 2012). Studies testing the HFA hypothesis have dealt with the adaptation of decomposers to the tree species above them by incubating endogenous and exogenous litter under the same canopy cover. We refer here to endogenous litter as that produced by the current vegetation above

* Corresponding author at: Department of Silviculture and Forest Management, INIA-Forest Research Centre, Ctra. A Coruña, km. 7.5, 28040 Madrid, Spain.
E-mail address: bravo@inia.es (A. Bravo-Oviedo).

http://dx.doi.org/10.1016/j.foreco.2017.02.032
0378-1127/

the litter substrate, whereas exogenous in this case refers to litter coming from outside the ecosystem under investigation to test HFA hypothesis. In so doing, we try to avoid confusion with local, native or alien vegetation. A second hypothesis about drivers of decomposition is that, on a global scale and within the same biome, specific leaf traits drive decomposition rates rather than climate (Cornwell et al., 2008). Under these two hypotheses, endogenous foliar litter will decompose in accordance with specific traits and adaptation of decomposers. Despite this general trend, changes in decomposition rates occur in mono-specific forests if small or moderate changes in canopy cover are induced, i.e. changes in light environment due to removal of trees (Blanco et al., 2011; Lado-Monserrat et al., 2015a). However, the litter decay rate and nutrient dynamics associated with changes in the light environment in pluri-specific forests is little understood. Species with poor leaf litter quality usually immobilize nutrients from leaf litter of higher quality when mixed (Gartner and Cardon, 2004), indicating a nutrient transfer from high to low concentration. However, the question of whether or not the direction of this transfer changes with the reduction of litter input through thinning remains largely unexplored.

Forest thinning involves the removal of selected trees to increase the growing space of standing individuals. The effect of thinning on litter production and decomposition rate was recognized in early forestry literature (Baker, 1934, page 359). However, the quantification of thinning effects on litter dynamics has mainly been studied in the first decade of the 21st century (Kunhamu et al., 2009; Li et al., 2009; Ma et al., 2010; Son et al., 2004; Thibodeau et al., 2000), and more recently in the Mediterranean area (Bravo-Oviedo et al., 2015; Roig et al., 2005; Ruiz-Peinado et al., 2013). The vast majority of these studies are based on pure stands rather than mixed stands.

The Mediterranean region is characterized by an intense drought period with maximum precipitation outside the vegetative period. This climatic pattern makes water the most limiting factor in contrast to other temperate regions where low temperature is the main constraint. This translates to a greater influence of moisture in the decomposition process in Mediterranean sites where more light availability (i.e. higher soil temperature) through thinning reduces the decomposition rate in mono-specific forests (Blanco et al., 2011; Lado-Monserrat et al., 2015a).

In many areas of the Mediterranean basin, the removal of unproductive forests in terms of economic return and the introduction of more profitable native and non-native species has led to the expansion of new mixed forests. For example, the plantation of Mediterranean Maritime pine for resin production on forest sites dominated by hardwoods was relatively common in Central Spain in the mid-20th century. The fall in resin prices in the seventies lead to the abandonment of tapping and the re-colonization of natural oak vegetation.

The role of mixed-species forests, both natural and man-made, is currently a focus of forest research (Bravo-Oviedo et al., 2014). Mixed forest managers and researchers are facing new challenges such as the characterization of complex mixed forests (del Río et al., 2016), the productivity of mixed versus pure stands (Pretzsch et al., 2015; Sprauer and Nagel, 2015), the inclusion of mixed species effects on forest growth models (Hans Pretzsch et al., 2015) or how highly diverse forests can cope with global change (Scherer-Lorenzen, 2014).

The main concern of forest managers is to understand the dynamics of the species growing together and the consequences of human intervention in mixed stands which are considered more resilient and resistant to global change (Jactel et al., 2009; Knoke and Seifert, 2008; Kolström et al., 2011).

The objective of this work is to determine the relationships between early-stage litter decay, nutrient dynamics and management intensity in a Mediterranean mixed oak-pine ecosystem. We hypothesized that (1) Mixed forests in the Mediterranean area show an increasing decay rate with increasing tree canopy cover and (2) The sign and magnitude of human induced change on litter decay rate and on C and nutrient dynamics is species-specific.

2. Material and methods

2.1. Experimental area and layout

The experimental site is located in Montes de Toledo, central Spain, (39°31′N, 4°16′40″W). The climate is classified as Mediterranean with annual precipitation of 469 mm and average temperature of 12.9 °C. The original dominant tree cover is Pyrenean oak (*Quercus pyrenaica* Willd). Despite its scientific name, this species is seldom found in the Pyrenees and is native of sub-Mediterranean areas of central and southern Spain and Portugal as well as southern France. Hereafter we will refer to *Q. pyrenaica* as oak. A plantation in rows of Mediterranean Maritime pine (*Pinus pinaster* Ait. ssp. *mesogeensis*) was incorporated into the stand in 1950 after the removal of standing oaks. Between the plantation rows, oak sprouts have grown and the stand is currently a mixed stand in rows with a dominant canopy of Mediterranean Maritime pine and an understory of oak. However, in some places the oak has reached the same height as the pine. The site has a north-west facing aspect and the slope is 21.5%. This type of mixtures covers 105.325 ha in Spain (MAPAMA, 2006).

In 2009, a long term thinning experiment was established by the Forest Research Centre-INIA to analyze the adaptive management role of thinning in the mitigation capacity of the stand to cope with climate change. The experimental layout consisted of two thinning treatments from below: treatment LT, light thinning or removal of 25% of basal area found in unthinned plots; treatment HT, a heavy thinning or removal of 40% of basal area found in unthinned plots and a control (treatment CT or unthinned). The three levels were replicated three times yielding 9 plots with an average size of 0.06 ha plot^{-1}. In order to avoid slope effects the shape of the plots is rectangular with the longest side (30 m) placed orthogonally to the slope. Treatments were arranged in a latin-squared design. Thinning consisted of removing pines from the lower diameter classes until the desired intensity was reached with the objective of analyzing the growth response of the remaining oaks and pines to changes in competition intensity.

In parallel to the thinning experiment, a nutrient cycling study was established in the same plots after the first thinning in 2009. Four littertraps were installed per plot. In February 2011, a decomposition bag experiment was incubated next to each littertrap (4 litter bag experiments on each plot) 8 bags were placed on each point containing 5.11 ± 0.01 g of air dried foliar material from oaks and pines shed in the previous autumn following a similar proportion to that found in the litterfall traps (3.40 ± 1.16 g for needles and 1.68 ± 1.19 g for leaves). The total number of incubated bags were 8 bags/point × 4 points/plot × 9 plots = 288. Every three months, a bag per sample point was harvested (4 bags per plot) and transported into a raffia fiber bag to the lab the same day to avoid mass losses. The first collection date was May 2011 and the last collection date was February 2013.

2.2. Mass loss and nutrient calculations

The air dried weight of needles and leaves was measured separately at every harvest and half of the sample was dried at 65 °C to analyze nutrient content in the foliar material. The other half was dried at 105 °C to constant weight. Total mass loss was calculated for the whole sample. The elements analyzed were total carbon (C)