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Short communication

Comparing differences in early-stage decay of macrophyte shoots between in the air and on the sediment surface in a temperate freshwater marsh

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ABSTRACT

Litter decay is a fundamental process in ecosystem carbon flux and nutrient cycling. In wetlands, shoot litters on the sediment surface and in the air are important components of the detritus pool. We used the litterbag method to compare mass losses and nutrient dynamics of culms, sheaths, and leaves from *Deyeuxia angustifolia* on the sediment surface and in the air from October 2011 to October 2012 in a freshwater marsh in Northeast China. The mass losses for the three litters in the air were only approximately 3% and less than that on the sediment surface after 180 days of decay, but increased to 16–44% after one year of decay and thus exceeded or approached that of surficial corresponding litters. For leaves and sheaths, the increased nutrient (nitrogen and phosphorus) concentrations of aerial litters resulted in an approximately 10% increase in the nutrient amounts after 180 days of decay, which was greater than that of surficial corresponding litters; however, surficial litters exhibited a greater increase or a lesser decrease of nutrient amounts than did aerial corresponding litters after one year of decay. For culms, the litter nutrient amounts in the air were always more or not less than those on the sediment surface during one year of decay, although effects of the litter position on nutrient concentrations were negligible (for nitrogen) or varied over time (for phosphorus). Overall, the litter position significantly affected the decay processes in this marsh. Therefore, it is essential to consider litter mass and decay processes at different positions to comprehensively understand carbon cycle and nutrient turnover in temperate freshwater marshes.

1. Introduction

Plant litter decay is not only an important component of the global carbon (C) budget, but also a major determinant of nutrient cycles (Aerts, 1997), especially for the ecosystems in which little plant biomass is consumed during the growing season and most ends up in the detritus food web (Menéndez et al., 2003). Most wetlands are often characterized by less herbivory (Mann, 1988; Kuehn et al., 2004); thus, they are often viewed as detrius-based, with decaying plant litters representing an important energy input (Mann, 1988). Furthermore, many wetlands are typical ecosystems with limited nutrients unless impacted by human activities (Rejmánková and Houdková, 2006; Moore et al., 2007). Therefore, continued nutrient availability mainly depends on decomposing organic matters (Aerts and de Caluwe, 1997; Alvarez and Guerrero, 2000).

In most wetlands, a significant quantity of emergent macrophyte shoots does not collapse onto the sediment surface immediately after senescence, but remains standing and can decompose in a standing position (Kuehn et al., 2004). Similar to the litters on the sediment surface, the standing litters are also important components of the detritus pool (Kuehn et al., 2011). The litter decay processes on the sediment surface have been well studied in recent decades (e.g., Kim and Rejmankova, 2005; Aerts et al., 2012; Connolly et al., 2014). Several studies have also indicated significant changes in litter C and nutrient contents during the standing-dead phase (e.g., Gessner, 2001; Kuehn et al., 2011; Zhang et al., 2014a). However, there are only few studies comparing the decay processes in the air with those on the sediment surface (e.g., Chimney and Pietro, 2006; Liao et al., 2008),

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although such comparisons could directly demonstrate their own characteristics and help reveal the role of the litter position in energy transfer and nutrient turnover in wetlands.

The Sanjiang Plain is the largest freshwater marsh region in China (Zhao, 1999). In this region, most marshes are dominated by emergent macrophytes, such as *Carex lasiocarpa* and *Deyeuxia angustifolia*. A small fraction of the shoots of these macrophytes immediately collapses after senescence, and most often remains standing for an extended period. Recent studies have reported detailed litter decay processes both on the sediment surface (e.g., Song et al., 2011; Sun et al., 2012) and in the air (e.g., Zhang et al., 2014b,c). Due to differences in materials and methods, however, these studies could not be directly compared to quantify the differences in decay rates and nutrient release and to comprehensively reveal litter decay processes at the ecosystem level. Surficial litters are continuously under humid or submerged conditions; thus, the associated microorganisms could easily acquire nutrients from the marsh water or the sediment (Welsch and Yavitt, 2003). In contrast, standing litters are often in an environment with lower water and nutrient availability (Liao et al., 2008). Considering that environmental conditions can substantially affect litter-associated microbial activity and thus litter decomposition (Aerts and Chapin, 2000), we hypothesized that (1) surficial litters decompose more rapidly than do aerial litters, and (2) nutrient enrichment is greater for the litters on the sediment surface relative to those in the air. To verify our hypotheses, we used the litterbag method to examine differences in the mass loss and nutrient dynamics of *D. angustifolia* shoots in the air and on the sediment surface during the early stage of decay (one year for this study) in a freshwater marsh of the Sanjiang Plain.

2. Materials and methods

2.1. Study site

This investigation was conducted in a freshwater marsh located in the Sanjiang Plain, Northeast China (47°35′N, 133°31′E, 56 m a. s. l). This marsh has 0–6 cm of standing water, and the sediment and standing water remain frozen from late October to early April. *D. angustifolia*, a perennial clonal grass with overwintering belowground rhizomes, is the dominant species in this marsh. The shoots of this species senesce in October, and only 10–15% of the senesced shoots collapse within half a month. Furthermore, there is still 50–65% and 20–30% of the senesced shoots remaining in a standing position at the end of April and July, respectively, in the following year. The study site has a temperate continental monsoon climate, with a mean annual temperature of 2.5 °C (monthly value ranging from −20.4 °C in January to 21.6 °C in July) and precipitation of approximately 558 mm (approximately 50% falling in July and August). The soil is a typical meadow mire soil with a high organic matter content and a pH of 5–6. An additional description of this study site is provided in Song et al. (2009).

2.2. Litter collection and preparation

Shoot litters, collected after *D. angustifolia* senescence in late October 2011, were divided into leaves, sheaths, and culms in the laboratory. The litter samples for a given plant tissue were mixed carefully and divided into two subsamples. The first group of subsamples was cut into pieces of approximately 6 cm long for the decomposition experiments. The second group of subsamples was used to determine the initial litter moisture content and chemical properties. The subsamples were weighed, oven-dried at 65 °C for 48 h, and reweighed. Portions were milled (<0.25 mm) for chemical analyses. Following digestion with concentrated H_2SO_4, the litter nitrogen (N) concentration was determined by the indophenol-blue colorimetric method, and phosphorus (P) concentration was analyzed using the molybdenum blue colorimetric method (Temminghoff and Houba, 2004).

2.3. Litter decomposition

The litterbag method was adopted to quantify litter decomposition. Two grams of leaves, sheaths, or culms were put into 15 × 15 cm litterbags with a mesh size of 0.85 × 0.85 mm as the upper surface and 0.32 × 0.32 mm as the lower surface. Then, the litterbags were randomly placed at five sites in the chosen marsh. There were six litterbags for each tissue at each site. Therein, three litterbags were hung from wooden stakes at a height of 0.6 m to simulate aerial decomposition, and another three litterbags were placed on the sediment surface to simulate surficial decomposition. After 180, 270, and 360 days of incubation (i.e., April, July, and October 2012), five replicate litterbags for each tissue (one from each site) were retrieved.

After retrieval, the remaining litters were taken out of the litterbag, carefully rinsed in de-ionized water, oven-dried at 65 °C for 48 h, weighed for determination of litter mass remaining, and then milled (<0.25 mm) for determination of the N and P concentrations with the methods described above. Litter mass remaining was adopted to represent the decay rates rather than the exponential decay coefficient, because the litter decay could not follow the typical exponential decay well enough in this study. The amount of N or P remaining in litters was calculated by multiplying the remaining litter mass by the N or P concentration, and expressed as a percentage of the initial amount of litter N or P.

2.4. Data analyses

Analysis of the data was done with SPSS (v. 13.0), and the accepted significance level was $P = 0.05$. The data were tested for normality using the Kolmogorov–Smirnov test and all of the data conformed to a normal distribution (data not shown). A repeated measures analysis of variance was used to test the effect of the litter position, plant tissue, sampling date, and their interaction on litter mass remaining and nutrient concentrations and amounts; an independent-samples t test was used to determine the differences in the means of mass remaining and nutrient concentrations and amounts between aerial and surficial litter samples; and the Pearson product–moment correlation coefficient (r) was used to examine the correlation between the mass losses and changes in the nutrient concentrations.

3. Results

3.1. Litter mass remaining

During one year of decay, the litter position, plant tissue, and their interaction produced significant effects on litter mass remaining, and these effects varied with the sampling date (Table 1). The culms decomposed slower than did the other two tissues during both surficial and aerial decomposition (Fig. 1). The mass losses for the three litters in the air were only approximately 3% and were less than those on the sediment surface after 180 days of decay, but gradually increased to 16–44% after one year of decay, thereby exceeding or approaching those of the surficial corresponding litters (Fig. 1).

3.2. Litter N and P concentrations

During the incubation, the litter position, plant tissue, sampling date and their interaction significantly affected the litter N and P concentrations (Table 1). The N and P concentrations of surficial