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Effect of N addition on home-field advantage of litter decomposition in subtropical forests

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The 'home-field advantage' (HFA) postulates that litter decompose faster in its home habitat than in other habitats. However, the HFA of litter decomposition appears to be highly variable, and the effects of environmental conditions on HFA have rarely been investigated. Thus, in this study, we performed a reciprocal litter transplant experiment using coarse and fine mesh litterbags under nitrogen (N) addition treatments in a subtropical coniferous forest dominated by *Pinus massoniana* and a broad-leaved forest dominated by *Quercus variabilis*. Results showed no significant difference in decomposition between the two dominant litters in the fine-mesh litterbags at home and away habitats under control and N addition plots. *P. massoniana* litter in the coarse-mesh litterbags decomposed twice as fast at home than in away habitats under N addition. The result suggests a positive HFA effect in the coniferous forest under N addition, but no significant HFA effect was observed in the control plots. N addition did not enhance *Q. variabilis* litter decomposition in the home habitat. The positive HFA effect of *P. massoniana* litter in the coarse-mesh litterbags in N addition plots was associated with more abundant soil fauna than in the control plots. However, N addition had no significant effect on the activity of most soil enzyme during litter decomposition. Moreover, soil microbial biomass showed no relationship with the HFA of litter decomposition. Our findings suggest that N addition likely enhances the feeding activity of soil fauna by increasing fauna abundance. This further reinforces the habitat specificity of soil mesofauna in coniferous forests, resulting in a positive HFA of *P. massoniana* litter decomposition. C and N cycling in coniferous forest may be enhanced by N addition, and coniferous forest management should be suitable for this change.

1. Introduction

Litter decomposition is a fundamental process in the functioning of forest ecosystems as it facilitates the recycling of nutrients and chemical elements, and regulates forest restoration and productivity (Cleveland et al., 2011). Physical and chemical environment (e.g., temperature, humidity, and UV), litter quality (e.g., C:N, lignin:N), and soil decomposers (e.g., bacteria, fungi, and invertebrates) affect decomposition (Hättenschwiler et al., 2005; Prescott, 2005). Different plant litters have different physical and chemical properties, and different organisms are involved in breaking down the materials, which affect the rate of decomposition. Decomposers may particularly decompose litter from a specific plant with which they are associated (Veen et al., 2015a). Previous research suggests that litter may decompose faster in the habitat from which it was derived than in other habitats. This phenomenon has been called the 'home-field advantage' (HFA) effect (Gholz et al., 2000; Ayres et al., 2009). After long-term competitive adaptation, soil decomposers and litter form coexistence mechanisms because litter is the main source of nutrients and energy for soil organisms. There is evidence that demonstrate the importance of substrate–microbial interactions leading to HFA (Strickland et al., 2009a). Plant species can influence the activity of the soil microorganism community directly through leaching or release of exudates (Pfeiffer et al., 2013), or indirectly by affecting competitive interactions among soil decomposers (Cesarz et al., 2013; Austin et al., 2014). With the continual input of a similar litter quality, microbial decomposers prefer to decompose this particular kind of litter (Ayres et al., 2009), which could generate specificity of decomposers for a particular plant species and its associated habitat.

Ayres et al. (2009) calculated the magnitude of HFA in forest ecosystems, showing that positive HFA accelerated litter mass loss

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by approximately 8% using reciprocal transplant experiments. However, Gießelmann et al. (2011) showed that both microorganisms and mesofauna had no significant effects on HFA of litter decomposition in an Atlantic rainforest. Similarly, St. John et al. (2011) found no HFA effect in a forest–grassland reciprocal transplant experiment and attributed the result to an adaptation of soil microbial communities to different litter resources. These studies suggest that HFA, based on specialization of soil microbial communities, does not exist and the magnitude and direction of the HFA effect varies considerably (Ayres et al., 2009; Veen et al., 2015b).

Differences in leaf litter quality could explain the occurrence of HFA. Low-quality litter that contains recalcitrant or toxic secondary compounds may generate a large HFA because fewer soil communities can decompose these compounds (Austin et al., 2014; Chomel et al., 2015). By contrast, high-quality litter, which contains easily degradable compounds, could be expected to have a lower HFA because most soil decomposers can decompose them (Ayres et al., 2009; Austin et al., 2014; Veen et al., 2015b). The litter quality of subtropical coniferous forests and broad-leaved forests differ largely in terms of initial N, P, and lignin concentrations, C:N and lignin:N ratios, as well as secondary compounds (Ushio et al., 2012; Wang et al., 2012).

The effects of microbial specialization on litter decomposition can be demonstrated by extracellular enzyme activity (Wallenstein et al., 2013; Chomel et al., 2015). Microbes produce specialized enzymes to break down complex compounds found in recalcitrant litter. Bacteria, such as *Actinomycete* sp., release peroxidase, esterase, and oxidase to decay humus and lignin. Fungi, such as *Trichoderma* sp. and *Pythium* sp., release acids and alkaline phosphatase (ALP), urease (URE), β-glucanase, cellulase, and chitinase (Naseby et al., 2000; Zhang et al., 2004). Extracellular enzymes perform different activities according to the litter matrix composition. For example, in the forests where litter has high contents of lignin, the biomass of lignin-degrading fungi tends to be more abundant than other fungi. Recalcitrant and low-quality litter requires more specialized enzymes to break down these compounds (Chomel et al., 2015). In contrast to higher-quality litter, low-quality litter is more likely to generate an HFA effect due to specialization of extracellular enzymes. However, only a few studies have examined the role of soil extracellular enzyme activities in the HFA of litter decomposition.

Anthropogenic N input, including that of NHx and NOx, results in a proportional increase in terrestrial N addition (Hinkel et al., 2015). Many studies have demonstrated that N addition significantly influences the activity of microorganism and soil fauna during decomposition (Bardgett et al., 2013; Gan et al., 2013; Amend et al., 2015). The effects of N addition on soil communities will vary based on ecosystem, litter quality, and decomposition (Meunier et al., 2016). N addition could be beneficial to decomposition through the following: (1) N addition stimulates the activities of microorganisms; the input of extra N meets the N demands of microbes and accelerates the litter decomposition (Deng et al., 2007). (2) N addition increases the activity of enzymes; cellulase and amylase activities are limited by N content, so an extra N subsidy increases their activities and other glucosidase activities (Berg et al., 2000). (3) N addition increases plant biomass production and litter input, thereby decreasing litter C:N ratio (Henry et al., 2005). As often observed, the lower the litter C:N ratio is, the faster it decomposes (Taylor et al., 1989; Aerts, 1997; Ge et al., 2013). However, the added N may also polymerize with certain substances, such as polyphenol, produced in decomposition to form recalcitrant substances, thereby increasing litter lignin content and reducing litter decomposition rates (Aerts et al., 2006; Manning et al., 2008). Although the effects of N addition on decomposition have been studied, only a few studies have examined the effects of N addition on the HFA of litter decomposition (Vivanco and Austin, 2011; Allison et al., 2013). Thus, studying what affects the occurrence, direction, and magnitude of HFA from a diverse number of ecosystems during litter decomposition is necessary.

Currently, conclusions on the direction and magnitude of HFA are not consistent. Previous studies on HFA mainly focus on single species litter in mono-specific forests or monoculture plantations (Mayor and Henkel, 2006; Barlow et al., 2007; Bachega et al., 2016). Furthermore, whether activities of specialized decomposers associated with the dominant species litter would be affected or not by environmental factors, such as N addition remains unclear. To better understand the HFA effect, we performed a field reciprocal litter transplant using mesh litterbags under different N-added treatments in a Chinese subtropical coniferous forest (dominated by *Pinus massoniana*) and broad-leaved forest (dominated by *Quercus variabilis*). The main objective of this study was to explore the effects of litter quality, habitat (home vs away) and soil communities (microorganisms and mesofauna) on decomposition rate depending on subtropical broad-leaved and coniferous forests. In addition to the HFA measurement for *Q. variabilis* and *P. massoniana* litter, we investigated the effect of N addition on the HFA with a particular focus on whether the specialized decomposer community that leads to a HFA of litter decomposition could be influenced. Because N addition improves the nutrient status of the ecosystem that with poor soil nutrition and promotes specialized decomposers activities, we expect that N addition would enhance the HFA effect in the low-nutrient coniferous forest.

2. Methods and materials

2.1. Study site

This study was conducted in a 24 km^2 subtropical forests on Zijin Mountain (447.1 m asl, 32°50′N, 118°48′E), Nanjing, Jiangsu, China from February to December 2014. The area has a subtropical monsoon climate. Mean annual rainfall is 1106.5 mm falling mostly between June and July, and mean annual air temperature is 15.4 °C (minimum of 1.9 °C in January and maximum of 28.2 °C in July). The soils are a slightly acidic humic cambisol with a pH of 5.0 ± 0.02 (Lv et al., 2014). The bedrock materials are sandstone and shale, and a large amount of nutrient and organic matter is deposited in the humus layer. The dominant forest types are deciduous broad-leaved forest and evergreen coniferous forest. In the broad-leaved forest, the dominant species is *Q. variabilis* with a relative basal area of approximately 85%, and that of *P. massoniana* is approximately 75% in coniferous forest (unpublished data of the field investigation 2011).

2.2. Experiment design

In each forest, 30 plots of 1 m × 1 m were established with 5 m between two adjacent plots. In half of the plots, an aqueous solution of NH_4NO_3 was added in equal doses each month at a rate of 47 kg N per hectare per year.

Litter decomposition was measured in each forest using the litterbag method (Verhoef and Brussaard, 1990). In each plot, nylon litterbags (15 cm × 20 cm) with two mesh sizes were used. A fine mesh of 0.2 mm was assumed to selectively impede the activity of the whole soil biota except microorganisms. A coarse mesh of 2 mm was assumed to allow microorganisms plus mesofauna activity. In October and November 2013, freshly senesced leaves of *P. massoniana*, *Q. variabilis*, were collected and air-dried for one month to a constant weight. Then, 6 g (±0.1) dry weight of each species litter was added to the litterbags.

In February 2014, litterbags were placed in plots. Before the placement of litterbags, the litter layer and humus layers were