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Litter decomposition, residue chemistry and microbial community structure under two subtropical forest plantations: A reciprocal litter transplant study

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ABSTRACT

Litter decomposition is a key process for ecosystem fertility and carbon (C) balance, key uncertainties remain about how this fundamental process is affected by microbial community composition. Evidence is growing that plant litter generally decays fastest at the site from which it was derived, owing to the presence of specialized microbial communities that can decompose specific types of litter. The objectives were to determine the impact of sites on litter decomposition and to examine the relationships among microbial community composition, litter chemistry, and decomposition rates of coniferous *Cunninghamia lanceolata* litter of higher lignin content and broadleaved *Mytilaria laosensis* litter of lower lignin content at different stages of decomposition under plantations of the respective species. The study was conducted for 16 months using a randomized split-plot design experiment with four replications of all combinations of treatments, the treatments being litter type and site (plantation species). The results showed that decomposition rates were the same for all combinations of amendments and sites, meaning that both sites had microbial communities equally capable or adapted to decompose plant substrates it had not previously encountered, despite marked differences in soil microbial communities between sites and the chemistry of the two litter types. Initial *M. laosensis* litter was of lower lignin content and C:N ratio and decomposed faster in the first 8 months than *C. lanceolata* litter under either *M. laosensis* or *C. lanceolata* forest. Litter decomposition was significantly slower in the environment from which it was derived between month 8 and month 16. This could be attributed to the exceptionally poor decomposition of *M. laosensis* litter which was significantly higher lingnin content at month 8 under *M. laosensis* than under *C. lanceolata* due to the impact of site on preferential degradation of litter C. Decomposers under *C. lanceolata* forest were more efficient in degrading alkyl C and/or less efficient in degrading *O*-alkyl C than those under *M. laosensis* forest during the experimental period, which might be related to the microbial community composition in the decomposing litter. Our study clearly showed interactions between changing litter chemistry and litter microbial communities and their impacts on litter decomposition. Site was not important in impacting decomposition rates, but played an important role in the preferential degradation of C components. However, further studies are needed to examine the conditions in forests where more rapid litter decomposition beneath the parent species than another species is considered to be common, in order to improve our ability to model decomposition globally.

1. Introduction

The rate and magnitude of CO_2 fluxes from the biosphere to the atmosphere and the recycling of plant nutrients in terrestrial ecosystems are critically dependent on decomposition of plant litter (Cusack et al., 2011; Raich and Schlesinger, 1992). Plant litter decomposition is influenced by climate (e.g., temperature, moisture), litter chemistry and decomposer organisms

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(e.g., microbial community and invertebrates) (Aerts, 1997; Li et al., 2012, 2013). However, whereas climate and litter chemistry can explain about 70% of variation in plant litter decomposition at continental scales (Parton et al., 2007), the factors contributing to the remaining 30% of variation are unclear (Austin and Vivanco, 2006; Gartner and Cardon, 2004).

Recent empirical studies have shown that litter tends to decompose more rapidly at the site from which it was derived than at other sites, which has been attributed to adaptive mechanisms of microbes (Ayres et al., 2009). Soil microbes in the native plot and litter environments can adapt to using multiple resources, or stages of decomposition of a single resource better than those at other sites and therefore decompose litter more effectively (Allison et al., 2013). Another explanation for the quicker litter decomposition at the site which it was derived than at other sites is the specialization of decomposer organisms in decomposing litter derived from the plants above them (Ayres et al., 2009). Indeed, due to the progressing competition for nutrients and energy among decomposers, a selective pressure is likely to favor the most efficient decomposers in degrading their litter matrix. It is therefore not surprising that lignolytic fungi are often more abundant under forests that produce litter with greater lignin concentrations, and as a result soil microbial communities under these forests can break down the litter more efficiently than communities under forests with lower lignin concentrations in the litter (Coleman et al., 1990; Lindahl et al., 2007).

While most soils are likely to contain a range of decomposers, which together are able to decompose a wide range of substrates, differences in decomposition efficiency should exist among soil microbial communities due to the varying relative proportion of each functional group of decomposers. A microbial community is relatively unlikely to decompose highly efficiently litters of both high- and low lignin contents (Wardle et al., 2004). In addition, litter chemistry changes during the course of its transformation. At the early stages of decomposition, litter contains more easily decomposable carbohydrates and rates of decay are determined by rapidly proliferating bacteria, whereas at later stages fungi exert the major control on decomposition rate because of an increase in the proportion of more recalcitrant materials, such as lignin (Aneja et al., 2006; Baumann et al., 2009). In this respect, specialization of a microbial community in decomposing certain types of leaf litter may not be able to be manifested over the whole course of decomposition. It is therefore not surprising that growing evidences did not demonstrate significant impact of site on litter decomposition (Gieβelmann et al., 2011; John et al., 2011). On the contrary, slower litter decomposition occurred at the site from which it was derived than at other sites when took the interaction between the chemistry of experimental litter and the surrounding litter into consideration (Freschet et al., 2012). Detailed studies assessing the changes of residue chemistry at different litter decomposition stages and their relationships with microbial community composition and decomposition rates at different sites are required to determine the site impact on litter decomposition.

Broadleaf species and coniferous Chinese fir (*Cunninghamia lanceolata*) forest plantations are important forest types in subtropical China. *Mytilaria laosensis* is an evergreen broadleaf tree and one of the commercial tree species which is increasingly planted following *C. lanceolata* harvest. *M. laosensis* and *C. lanceolata* forests produce significantly different litter types and *M. laosensis* usually provides litterfall of lower carbon(C)/nitrogen (N) and lignin/N ratios compared with *C. lanceolata* (Huang et al., 2013). In this study, litter decomposition in *C. lanceolata* and *M. laosensis* plantations was investigated by reciprocally transplanting litter between the two forests.

The objectives of the experiment were to determine if: (1) litter decomposition would be faster in the environment from which it was derived than another soil environment where it does not occur; and (2) decomposition of *M. laosensis* litter in *M. laosensis* forest would be faster initially because the decomposer community in *M. laosensis* soil would specialize in the decomposition of more easily decomposable materials; and accordingly, at a later stage of decomposition, quicker decomposition of *C. lanceolata* litter in *C. lanceolata* forest might arise due to the adaptation of the decomposer community to decomposing more recalcitrant residues. It was predicted that decomposition environment (site) would significantly affect the variation of residue chemistry during the litter decomposition and the microbial community composition in litter residues. We expected to see correlations between a decomposition related adaptation index and litter C chemical composition or microbial community composition (e.g., the ratio of fungi to bacteria).

2. Materials and methods

2.1. Study site and experimental design

The experimental site is located at Xiayang forest farm (26°48′N, 117°58′E), northwest Fujian Province, South Eastern China. It is comprised of 20-year-old *M. laosensis* and *C. lanceolata* plantations that were planted in 1993 after a 29-year-old *C. lanceolata* plantation was harvested. The site has a deep red soil classified as a clay loam Ferric Acrisol according to the FAO/UNESCO classification. The experimental site has a humid subtropical climate, with short and mild winters (with occasional frost) in January and February, and long, hot and humid summers between June and October. Mean annual rainfall and average temperature between 2012 and 2014 were 1669 mm and 19.3 °C, respectively. Understory vegetation included occasional grasses along with a mix of native herbs in *C. lanceolata* plots, but there was little understory vegetation in *M. laosensis* plots despite the same tree density as *C. lanceolata* forest.

The experiment used a randomised plot design with four replications of all combinations of all treatments, the treatments being site and litter species. The site treatment was set up in April 1993 when eight 20×30 m plots were established after removal of the *C. lanceolata* plantation. The two tree species were then randomly planted in the eight plots, with four plots of *C. lanceolata* seedlings and four plots of *M. laosensis* seedlings. In July 2012, one 2×3 m plot was established in each plantation species plot and two 1×1 m subplots were established in each of the 2×3 m plots. Nine *M. laosensis* litterbags were affixed to the surface of the litter layer in one subplot by stainless steel pins and nine *C. lanceolata* litterbags were similarly affixed in the other subplot, the subplots being randomly allocated to litter species.

2.2. Litterbags and soil sampling

Recently senesced litter was collected fresh from *M. laosensis* and *C. lanceolata* forest in litter traps between January and March 2012. The litter samples of individual species were air-dried and homogenized. Approximately 18 g of air-dried litter was sealed in 15×15 cm litterbags constructed with 1-mm mesh fiberglass screen. Twelve 0.25 cm $\times$ 0.25 cm holes were cut, evenly distributed on the upper side of each litterbag to minimize the isolation effect on large soil fauna. For the *M. laosensis* litter, the foliage, twigs and bark accounted for 70%, 15% and 15% of total litter biomass in the litterbags, respectively. For *C. lanceolata*, the foliage, twigs and bark accounted for 50%, 40% and 10% of total litter biomass in the litterbags, respectively. Additional litter samples were dried at 60 °C for four days, weighed to determine dry mass,