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Comparisons of litterfall, litter decomposition and nutrient return in a monoculture *Cunninghamia lanceolata* and a mixed stand in southern China

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Abstract

Litter production, leaf litter decomposition and nutrient return were compared in a monoculture *Cunninghamia lanceolata* and a mixed stand in southern China. The mean annual litter production was significantly higher 24% in the mixed stand than the monoculture *C. lanceolata* stand. Within the mixed stand, about 38% of the total litterfall was from broadleaved tree *Michelia macclurei*. The litterfall was concentrated during the cool and dry period (November–March) and about 65% of total litterfall occurred during this period. The mass loss of leaf litter was positively correlated with N and P content and negatively correlated with C/N ratio. The decomposition rate of leaf litter in the pure stand was increased in the order: *C. lanceolata* < mixture of *C. lanceolata* and *M. macclurei* < *M. macclurei*. Soil conditions also affected litter decomposition. The decomposition rate of mixed litter was slightly, but not significantly, faster in the mixed stand than the pure stand. N concentration in all leaf litters increased over time during decomposition, whereas the remaining amount of N decreased. The returns of N, P and K via leaf litter were significantly higher in mixed stand than pure stand, but the returns of C, Ca and Mg between both stands did not differ significantly. The percent contribution of *M. macclurei* leaf litter to total nutrient return varied from 23% to 79% in the mixed stand. Our results indicated that introduction of broadleaved tree into monoculture coniferous stand could increase litter production, nutrient return and thus it had advantages in degraded soil restoration and sustainable land management.

Keywords: Litter production; Litter decomposition; Nitrogen release; Monoculture plantation; Soil restoration

1. Introduction

Cunninghamia lanceolata, an important coniferous timber species, has been widely planted for more than 1000 years in southern China due to its fast growth and good timber quality (Wu, 1984). Planting area has reached 12 million ha, accounting for about 24% of all forested area in China, and the system of successive cropping has been widely used (Chen and Wang, 2004). In recent decades, however, this practice has led to remarkably decline in soil fertility and timber productivity because of nutrient depletion and deterioration of physical, chemical and biochemical activity (Feng et al., 1988; Chen et al., 1990) which resulted from successive cropping, a short-rotation time of about 20 years, whole-tree harvest and site preparation. Fortunately, some scientists have found that planting mixed forest of *C. lanceolata* and broadleaved tree could improve the quality of forest land and the productivity of *C. lanceolata* stands (Feng et al., 1988; Chen et al., 1990). However, little information is known about the ecological properties of these ecosystems to avoid failures and optimize the use of soil and other resources in subtropical China.

The litter on the forest floor acts as input–output system of nutrient and the rates at which forest litter falls and subsequently, decomposes contribute to the regulation of nutrient cycling and primary productivity, and to the maintenance of soil fertility in forest ecosystems (Olson, 1963; Singh et al., 1999; Fioretto et al., 2003; Onyekwelu et al., 2006; Pandey et al., 2007). Therefore, it is critical to understand the

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amount and pattern of litterfall in these forest ecosystems. Although numerous studies on amount and pattern of litterfall in plantations has been conducted in subtropical region (Zhang et al., 1993; Parrotta, 1999; Liao et al., 2006; Pandey et al., 2007), few attempts have been made to comparatively measure litter in pure and mixed plantations under similar climatic and edaphic conditions in subtropical China.

Litter decomposition is a major pathway for providing organic and inorganic elements for the nutrient cycling processes and controls nutrient return to the forest ecosystem. The decomposition of litter is primarily influenced by the environmental conditions in which decay takes place, the chemical quality of leaf litter, and the nature and abundance of decomposing organisms present (Swift et al., 1979; Polyakova and Billor, 2007). Despite many studies carried out on litter decomposition, most of them have considered the decomposition of litter of a given species in isolation from other species in one forest stand in subtropical forest ecosystems (Rai and Proctor, 1986; Adams and Angradi, 1996; Sundarapandian and Swamy, 1999). Litter decay of each species present has the potential to be affected by the presence of litters from coexisting plant species. In recent years, researchers have only specifically begun to examine potential interactions among leaves of different species during decomposition. However, these studies have not shown consistent effects of litter mixing on decomposition rates, which are positive, negative, or neutral (Hansen, 2000; Hector et al., 2000; Wardle et al., 2003; Polyakova and Billor, 2007). Information is urgently needed about litter mixing effects of *C. lanceolata* and broadleaved tree on decomposition rates in different forest stands.

In this paper, we hypothesized that litterfall, litter decomposition rate and nutrient cycling could increase in ecosystems when broadleaved tree species (e.g. *Michelia macclurei*) is added to pure *C. lanceolata* stands, and that litter could decompose more rapidly in the mixed stand than the pure coniferous stand. Therefore, in the study covering a 6-year period, litterfall, leaf litter decomposition and nutrient return were investigated in a monoculture *C. lanceolata* and a mixed stand in subtropical China. In addition, soil chemical and biochemical characteristics were also investigated in both stands. The aims of the present investigation were conducted: (a) to investigate the impact of broadleaved tree species on the amount and pattern of litterfall, litter decomposition and nutrient return in *C. lanceolata* plantations and (b) to determine effects of litter mixing and stand quality on decomposition rate.

2. Materials and methods

2.1. Study area

This study was conducted at Huitong Experimental Station of Forest Ecology, Chinese Academy of Sciences (latitude 26°40′–27°09′N and longitude 109°26′–110°08′E), Hunan Province, China. This experimental Station lies at the transition zone from the Yunnan-Guizhou plateau to the low mountains and hills on the southern side of the Yangtze River at an altitude of 300–1100 m above mean sea level. The climate of this region is humid mid-subtropical monsoon with mean annual temperature of 15.8 °C with a mean minimum of 1.9 °C in January and a mean maximum of 29 °C in July. Therefore, four seasons are divided as follows, spring (March–May), summer (June–August), autumn (September–November) and winter (December–February). The mean annual precipitation was 1200 mm of which about 67% occurred between April and August. The mean relative humidity varied from 34% to 93% during the study period (Fig. 1).

The native vegetation being evergreen broadleaved forest typical of the subtropics, with the major species component of *Castanopsis* spp. and *Lithocarpus* spp., has almost been extirpated by human activities, and *C. lanceolata* has become the major forest community. After clear-cutting of native broadleaved forest at an altitude of 480–560 m above mean sea level in autumn of 1982 and slash burning in winter, a pure *C. lanceolata* stand and a mixed stand of *C. lanceolata* and *M. macclurei* in total 10 ha were established in early spring of 1983. Planting density was 2000 trees ha^{-1} in the both stands. The ratio of *C. lanceolata* to *M. macclurei* in the mixed stand was 4:1. Tree density was 940 stems ha^{-1} *C. lanceolata* in pure stand, and 657 stems ha^{-1} *C. lanceolata* and 265 stems ha^{-1} *M. macclurei* in mixed stand at the investigation. Five replicate plots were selected in each of the stands giving 10 permanent plots of 15 m × 20 m in size. Chen et al. (2000) documented that the background values, including soil profile characteristics, textures and mineral composition, were almost identical in the different plots. All the plots were situated in areas of similar soil moisture class, topography, aspect, slope position. The common management practices used in the early stage was: weeding and chemical fertilizer in surface soil around 1 m^2 area of tree trunk.

According to US Taxonomy, the soil is Oxisol developed from slate and shale. The soils in both stands have developed from the same parent material. Forest soil is 50–70 cm deep and

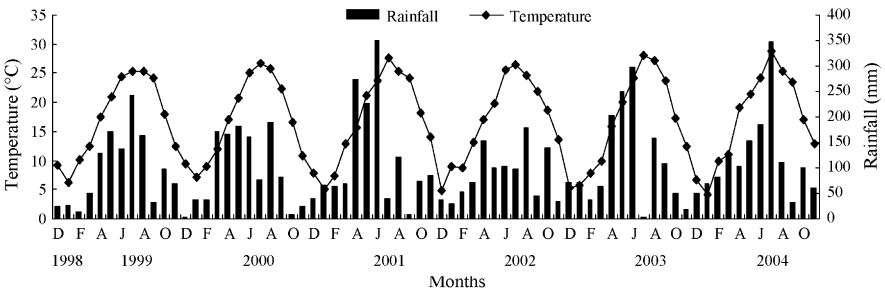

Fig. 1. Rainfall and temperature from December 1998 to November 2004 in Huitong Experimental Station of Forest Ecology, in Hunan Province, China.