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Fine root dynamics and turnover rate in an Asia white birch forest of Donglingshan Mountain, China

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Abstract

Fine root dynamics and turnover rate were studied by sequential soil coring method in a 60-year-old Asia white birch (*Betula platyphylla*) forest of Donglingshan Mountain, China. Biomass and necromass of both the finest (<1 mm) and very fine (1–2 mm) roots in 0–55 cm soil layer were determined every month from April to October 2006. The ratio of necromass to biomass, production, mortality, disappearance and turnover rate of both the finest and very fine roots in 0–55 cm soil layer were estimated. Some dynamics of biomass and production of both the finest and very fine roots were explained by meteorological conditions. Biomass, necromass, ratio of necromass to biomass, production, mortality and disappearance of both the finest and very fine roots greatly varied during the growing season. Biomass and production of both the finest and very fine roots decreased from May to June, probably due to the greater carbon investment in the aboveground parts of the trees in the period. Production of both the finest and very fine roots, and precipitation and air temperature were the highest in July, suggesting that the precipitation and air temperature in July are very propitious to root growth of Asia white birch and the plant has a highest potential for water and nutrient uptake in the period. Biomass, necromass, production, mortality, disappearance and turnover rate of the finest roots were significantly higher than those of very fine roots, whereas the ratio of necromass to biomass of the finest roots was significantly lower than that of very fine roots. Fine root mass, production, mortality, disappearance and turnover rate decreased, but ratio of necromass to biomass increased along soil depth for both the finest and very fine roots. The mean turnover rate of the finest roots, very fine roots and fine roots of the two size classes in the 0–55 cm soil layer were 0.63, 0.39 and 0.51 $year^{-1}$, respectively.

Keywords: Fine root mass; Production; Mortality; Turnover rate; *Betula platyphylla*

1. Introduction

As the increase in global temperatures coincides with rise in atmospheric CO_2 concentrations, the interest of scientific and political communities in the global carbon cycle continues to grow (Janssens et al., 2002). Therefore, the increasing interest in a better understanding and quantification of the carbon cycle of forest ecosystems has resulted in a number of recent reviews on biomass and production (Vogt et al., 1996; Gower et al., 2001; Nakane, 2001; Roy et al., 2001). However, the accuracy of energy and nutrient budgets of forest ecosystems has been limited by the difficulty of obtaining reliable estimates of the production and turnover of fine roots (Steen, 1985; Eissenstat and Yanai, 1997; Vogt et al., 1998).

Fine roots perform a variety of functions, including water and nutrient uptake and production of plant growth regulators, and also are an important sink of carbon from the shoot and a source of carbon input for the soil (Matamala et al., 2003; Trumbore and Gaudinski, 2003). Understanding temporal and spatial dynamics of fine roots and turnover rate is critical to evaluating productivity of the whole terrestrial ecosystems and the impacts of disturbance on ecosystem processes. However, quantifying the fine root dynamics and turnover is more time consuming than other compartments of the tree body, and the methods are usually less precise (Persson, 1990). At present, soil coring has often been used as a method for estimating fine root biomass (e.g., Vogt et al., 1981). However, fine root production and turnover are estimated by several direct and indirect methods, such as sequential soil coring (Nadelhoffer

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and Raich, 1992; Makkonen and Helmisaari, 2001; Ostonen et al., 2005), ingrowth core (Janssens et al., 2002; Lukac et al., 2003; Ostonen et al., 2005), minirhizotrons (Hendrick and Pregitzer, 1993; Tingey et al., 2003), nitrogen budget approaches (Nadelhoffer et al., 1985), and isotopic approaches (Gaudinski et al., 2001; Joslin et al., 2006). The merits and limits of the direct and indirect methods for measuring fine root production and turnover have been reviewed (e.g. Vogt et al., 1998; Majdi et al., 2005), and further improvement and standardization of these methods are still needed.

The importance of fine roots for carbon cycling has been confirmed by the findings that fine root production contributes from 33 to 67% of the annual NPP in forest ecosystems (Grier et al., 1981; Santantonio and Grace, 1987; Jackson et al., 1997). Fine roots can fluctuate considerably in biomass, production, and turnover throughout the season or between years, according to different sites (Olsthoorn, 1991; Persson, 1983; Gill and Jackson, 2000; Janssens et al., 2002). Therefore, the studies of fine root dynamics and turnover rate for principal forests are still needed. Asia white birch (*Betula platyphylla*) is widely distributed in temperate and sub-tropical zone of China, and is an important forest type in China (Chen, 1997). The importance of Asia white birch forest for carbon budgets of east Asian forests has also been pointed out by Fang et al. (2007). However, only a few studies reported fine root biomass of Asia white birch forest (e.g., Guo et al., 2006), and fine root production, mortality, disappearance and turnover rate have not been reported for this kind of forest.

The primary objective of this study was to determine seasonal variations in fine roots of different root size classes along the soil profile of a 60-year-old Asia white birch forest in warm-temperature zone of China. The second objective was to estimate fine root production, mortality, disappearance and turnover rate of different root size classes to explain seasonal variations in the fine root system with respect to environmental conditions.

2. Materials and methods

2.1. Site description

This study was conducted in a 60-year-old Asia white birch forest at the Beijing Forest Ecosystem Station of the Institute of Botany of the Chinese Academy of Sciences, and about 120 km northwest of Beijing City, China. The field site was located in Southeast part of the Donglingshan Mountain (39°57′0.83″N, 115°25′6.70″E, elevation 1380 m a.s.l.). The mountain inclination of the site is 32°. The soil in this area is classified as Eutric cambisol (FAO-UNESCO, 1988) with a depth of some 60 cm. Primary Asia white birch forest has been intensely disturbed by human activities and completely destroyed, and the contemporary Asia white birch forest is secondary and currently is protected in natural regeneration (Chen, 1997). The Asia white birch forest mainly includes Asia white birch, and admixed with associated species (*Betula utilis* and *Populus alba*). There also are a lot of shrubs including *Sorbus pohuashanensis*, *Lonicera japonica*, *Prunus armeniaca*, *Corylus mandshurica*, *Acer mono*, *Abelia biflora*, *Leptodermis oblonga*, *Spiraea sargentiana*, and *Macrocarpium officinalis*. The current number of trees is 1234 ha^{-1}, with a mean diameter at breast height (DBH) of 13.17 cm and a mean tree height of 8.48 m. The spatial distribution pattern of Asia white birch population is random, and the important value (IV = relative dominance + relative density + relative frequency) of Asia white birch is some 53% in the Asia white birch forest (Yang et al., 2007). Usually, leaves expand in end April, litterfall occurs in early September, and end of litterfall is in end October in the Asia white birch forest.

2.2. Meteorological data measurements

The climate is semi-wet monsoon of warm-temperate zone in the Donglingshan Mountain (Sang et al., 2002). Monthly means air temperature and sums of precipitation were obtained from the meteorological station adjacent to our study site. The yearly patterns of air temperature and precipitation in 2006 were compared with those between the years 1993 and 2005.

2.3. Fine root measurements

Fine root (<2 mm) biomass (living fine root mass) and necromass (dead fine root mass) were determined by core sampling (Roberts, 1976) to a depth of 55 cm repeated approximately a monthly sampling period, i.e. the samples were collected on 24 April, 24 May, 22 June, 24 July, 25 August, 22 September, and 20 October 2006. At each sampling date, 10 sample columns were randomly excavated using a sharp-edged metal cylinder with an inner diameter of 10 cm. Samples from different depths (0–5, 5–15, 15–30, 30–45 and 45–55 cm) were labeled and fine roots were manually removed from the soil sample, washed and sorted into two diameter classes (<1 and 1–2 mm). We defined here the <1 mm roots as the finest roots and the 1–2 mm roots as very fine roots. Live and dead root fragments were subsequently separated by visual inspection. The xylem of dead roots looks darker and deteriorated, the degree of cohesion between the cortex and the periderm decreases, and root tips become brittle and less resilient. Dry biomass was determined after oven-drying at 75 °C for 1–2 days.

The production, mortality, and disappearance of fine roots between samplings were estimated using the decision matrix of Fairley and Alexander (1985) (Table 1).

Fine root turnover is defined here as the rate of the total amount of produced in this growing season over the mean standing biomass of fine roots (Aber et al., 1985). Mean fine root biomass was estimated as the average of live root biomass on 24 April, 24 May, 22 June, 24 July, 25 August, 22 September, and 20 October 2006. Total fine root production was estimated as the sum of the production by compartmental flow calculation method (Hertel and Leuschner, 2002) from 24 April to 20 October 2006.

2.4. Statistical analyses

Data management and statistical analyses were performed using SPSS software (SPSS, Chicago, IL). Three-way ANOVA