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Responses to N and P fertilization in a young *Eucalyptus dunnii* plantation: Microbial properties, enzyme activities and dissolved organic matter

Q.K. Wang [a], S.L. Wang [a,b,*], Y.X. Liu [a,c]

[a] Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, China
[b] Huitong National Research Station of Forest Ecosystem, Huitong 418307, China
[c] Graduate University of Chinese Academy of Sciences, Beijing 100039, China

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ABSTRACT

The short-term effects of nitrogen (N) and phosphorus (P) fertilizer application on soil microbial properties, dissolved organic matter and enzyme activity were examined in a young *Eucalyptus dunnii* Maiden plantation at Huitong county, southern China. The objectives of the study were to understand how N and P addition impacts microbial activity and dissolved organic matter in subtropical plantation forest ecosystems. Treatments in this study included 100 kg N ha^{-1} (N1), 200 kg N ha^{-1} (N2), 75 kg P ha^{-1} (P1), 150 kg P ha^{-1} (P2) and the control without any fertilizer application (CK). N application significantly increased soil microbial biomass N, mineralized N, dissolved organic N, and invertase, urease and acid phosphatase activities, but decreased microbial biomass carbon (C) and P, basal respiration, metabolic quotient and dissolved organic P in comparison with the control. P application decreased microbial biomass N, mineralized N, urease and acid phosphatase activities, whereas it increased dissolved organic P, microbial biomass P and metabolic quotient. We conclude that the influences of N and P addition on microbial activity, soil enzyme activities and dissolved organic matter were different in the studied *E. dunnii* plantation.

1. Introduction

Microbes play a critical role in carbon (C) and nutrient transformation in forest soil. Any changes in the microbial biomass or community structure may affect the cycling of nitrogen (N) and phosphorus (P) and their availability to plants (Saffigna et al., 1989). Therefore, soil microbial properties have been proposed to be potential indicators of impacts of forest management practices on soil (Li et al., 2004; Rudrappa et al., 2006). In recent years, numerous studies on effects of fertilization on microbial properties have been conducted. However, most of these studies were conducted in boreal and temperate forest ecosystems, and they have not shown consistent effects of fertilization on microbial properties, with positive, negative, and neutral effects being reported (Chen et al., 2002; Thirukkumaran and Parkinson, 2002; Bowden et al., 2004; Compton et al., 2004; Manna et al., 2005; Rudrappa et al., 2006). For example, Thirukkumaran and Parkinson (2002) found that microbial respiration and metabolic quotient were not affected by N addition in lodgepole pine forest soil, but Chen et al. (2002) reported that in a hoop pine plantation N application decreased microbial respiration, and increased the metabolic quotient in 0–10 cm soil. There is little available information on the influence of fertilizer application on microbial biomass and activities in subtropical forest ecosystems.

* *Corresponding author at*: Huitong National Research Station of Forest Ecosystem, Huitong 418307, China. Tel.: +86 24 8397 0344.
E-mail addresses: wqkui@163.com (Q.K. Wang), slwang@iae.ac.cn (S.L. Wang).

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Soil enzyme activities are also used as sensors in studies on the influence of soil treatments on microbial activity and soil fertility (Aon and Colaneri, 2001; Chen, 2003) and have been reported to be greatly affected by changes in soil management practices (Olander and Vitousek, 2000; Saiya-Cork et al., 2002; Frey et al., 2004; Allison et al., 2006). These studies were mainly conducted in boreal, temperate and tropical forest ecosystems with conflicting results. For example, Lucas et al. (2007) found that N addition increased phenol oxidase activity in the New Jersey Pinelands, but Frey et al. (2004) found that phenol oxidase activity decreased with increasing inorganic N availability. However, there is little information on the effects of N and P fertilization on soil enzyme activities in subtropical forest ecosystems.

Dissolved organic matter is an important labile fraction which can respond rapidly to changes in management practices compared with total soil organic matter (Liang et al., 1998). Several studies on the impacts of N fertilization on dissolved organic matter have been conducted in recent decades (Currie et al., 1996; McDowell et al., 1998; Neff et al., 2000; Adams et al., 2005), but these results are inconsistent. Additionally, these studies mainly addressed the effects of fertilization on dissolved organic C and N, with very few considering dissolved organic P. McDowell et al. (1998) observed that dissolved organic C concentrations in soil solution with inorganic N addition increased by 10–30% and dissolved organic N concentrations significantly increased in the Harvard Forest hardwood plots. In contrast, Yano et al. (2000) did not find a significant effect of repeated application of inorganic N on the amount of dissolved organic matter in forest soil. However, the effects of fertilizer addition on dissolved organic matter, especially dissolved organic N and P, in subtropical forest ecosystems are not clearly understood.

Forest growth is most limited by N and P in subtropical regions (Fisher and Binkley, 2000; Chen, 2003). Therefore, fertilization is a common practice to improve forest productivity in plantation management. In this study, based on expectations arising from previous studies of effects of fertilization on soil microbial properties, enzyme activity and dissolved organic matter, we hypothesized that N and P application would impact soil microbial dynamics, and increase enzyme activities and dissolved organic matter. Therefore, soil microbial biomass C (MBC), microbial biomass N (MBN) and microbial biomass P (MBP), basal respiration, mineralized N, invertase, urease and acid phosphatase activities, and dissolved organic C, N and P were examined in a young *Eucalyptus dunnii* Maiden plantation with N and P added separately at different rates in southern China. The objectives of the study were to understand how N and P addition impacts microbial properties, enzyme activities and dissolved organic matter in subtropical plantation forest ecosystems.

2. Materials and methods

2.1. Experimental site and soil sampling

The experimental site was located in a first rotation *E. dunnii* plantation with a density of 975 stems ha^{-1}, at Huitong county in the southwest Hunan province (26°31′N, 109°47′E), China, and established in April 2006 after clear-cutting of *Cunninghamia lanceolata* Hook. The mean annual precipitation is about 1300 mm with 60–72% occurring from April to August, and the mean annual temperature is 15.8 °C. The soil is predominantly derived from slate and shale, and classified as Oxisol with reference to U.S. Soil Taxonomy and its major physico-chemical properties are presented in Table 1. The experiment included five treatments with four replicates for each treatments: (1) control (without any fertilizer applied, CK); (2) 100 kg N ha^{-1} (N1); (3) 200 kg N ha^{-1} (N2); (4) 75 kg P ha^{-1} (P1); (5) 150 kg P ha^{-1} (P2). The middle rates of N (100 kg N ha^{-1}) and P (75 kg P ha^{-1}) are the typical amounts applied to Eucalyptus in subtropical China. For each treatment, there were four plots. Each plot was 800 m^2 and consisted of 100 trees (10 rows × 10 trees), with 5 m wide buffer strips between plots to avoid edge effects. N fertilizer (urea) or plus P fertilizer (triple super phosphate) was applied in April 2007. Six soil cores (5 cm in diameter, 0–20 cm depth) were randomly taken from each plot in August 2007 and bulked. Field moist soil samples were passed through a 2 mm sieve and stored at 3 °C prior to analysis for microbial properties, available nutrients, dissolved organic matter and enzyme activity. A subsample of each soil was air-dried and ground (<250 μm) prior to determination of total C, N and P.

2.2. Soil analyses

Soil organic C and total N were measured with a C/N analyzer, and total P was determined in digested samples colorimetrically using the ammonium molybdate stannus chloride method (Olsen and Sommers, 1982). Available N (ammonium- and nitrate-N) was extracted with a 2 M KCl extracting water solution. Ammonium- and nitrate-N (NH_4^+-N and NO_3^--N) in the extract was measured by colorimetry. Available P was determined according to Olsen and Sommers (1982) after acid extraction with 1 M NH_4F. The pH was measured in a 1:2.5 soil–water solution using a glass electrode.

The chloroform fumigation–extraction method was used to estimate microbial biomass (Wu et al., 2006). Microbial biomass C was calculated by applying the factor of Wu et al. (2006) and microbial biomass N by applying that of Brookes et al. (1985). Microbial biomass P was extracted using 0.5 M $NaHCO_3$ at pH 8.5. The correction for chloroform released P that was absorbed by soil during extraction was made by

Table 1 – Soil C, N and P concentrations, pH, cation exchange capacity (CEC), bulk density and texture in the eucalyptus plantation study site

Total C ($g\ kg^{-1}$)	Total N ($g\ kg^{-1}$)	Total P ($g\ kg^{-1}$)	pH (H_2O)	CEC ($cmol^+\ kg^{-1}$)	Bulk density ($g\ cm^{-3}$)	Texture (%)		
						Sand	Silt	Clay
15.47	1.82	0.33	4.51	11.8	1.25	30.5	29.8	39.7