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The effect of altitudinal gradient on soil microbial community activity and structure in moso bamboo plantations

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ABSTRACT

Moso bamboo (*Phyllostachys edulis*) is the fastest growing vegetation in the world, and it is widely distributed from low- to medium-elevation mountains in Taiwan. To understand how microbial activity and microbial community change with the elevation in bamboo plantations, we investigated soil microbial biomass, enzymes, and composition of bacteria and fungi in five moso bamboo plantations along an elevation gradient (600, 800, 1000, 1200 and 1400 m asl) in central Taiwan. The soil microbial community structure was determined by analysis of the phospholipid-derived fatty acid (PLFA) and denaturing gradient gel electrophoresis (DGGE) profiles. The soil microbial biomass C (C_{mic}) and biomass N (N_{mic}) increased along the elevation gradient. Similarly, the activities of soil enzymes, such as cellulase, xylanase and urease, increased along the elevation gradient. The proportion of PLFAs that were attributed to total bacteria, Gram-positive (G+) bacteria, and Gram-negative (G-) bacteria also increased with the increase in elevation. However, the ratio of G+/G- bacteria decreased along the elevation increase, indicating that bamboo plantations at low elevations (600 m, 800 m and 1000 m) contained less active soil organic matter than those at high elevations (1200 m and 1400 m). The results coincided with the availability of labile organic matter in bamboo plantation soils with lower C_{mic}/C_{org} and N_{mic}/N_{tot} in lower compared to higher elevations. Principle component analysis of PLFA content separated the low-elevation plantations from the high-elevation plantations. The DGGE analysis revealed that changes in both bacterial and fungal community structures were associated with the elevation gradient. Temperature changes along the elevation gradient contributed to variations in the soil microbial community in the bamboo plantations.

1. Introduction

Soil microorganisms play a major role in soil organic carbon turnover and nutrient cycling. Soil microbial activity and community structure are influenced by abiotic and biotic factors, such as soil types, temperature and vegetation (Frostegård et al., 1993; Lipson et al., 2000; Batten et al., 2006). Altitudinal change is very common in forest ecosystems in the Southeast Asia due to the wide spread of mountains, and this change can influence the microclimate, such as the temperature and moisture. Increases in elevation tend to lead to decreases in the annual temperature, which can affect microbial activity. Some studies have indicated that there are shifts in the microbial community structure and changes in microbial activity with elevation. Margesin et al. (2009) found a significant increase in the populations of fungi and Gram-negative bacteria with increasing elevation. Chen et al. (2010) reported soil enzyme activities, such as alkaline phosphatase, invertase, and urease, to slightly increase with increasing elevation.

Trumbore et al. (1996) indicated that the mean annual temperature decreased with the increase in elevation, leading to a slow rate of soil organic matter (SOM) decomposition (Singh and Gupta, 1977), which thereby affected soil carbon and nitrogen stock (Garten, 2004; Garten and Hanson, 2006). Some studies indicated that SOM played a major role in determining soil enzymatic activities and microbial community structure (Insam and Domsch, 1988; Waldrop and Firestone, 2004; Chang et al., 2014). As soil microbial communities and activities are related to

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soil organic C and N, the control of altitudinal change on soil organic C (SOC) and soil organic N (SON) stocks will be reflected in the microbial community and its activity. However, it is still unclear how the soil microbial community and its activity respond to the altitudinal change.

Bamboos are distributed all over the world; however, most bamboo populations are found in the South and Southeast Asia (Tripathi and Singh, 1994). Bamboo is an economic crop because culms are used for building materials and shoots are adapted as a food source (Tripathi and Singh, 1994; Yang et al., 2004). Moso bamboo (*Phyllostachys edulis*) is suitable for growth in mountains and has widely spread from foothills to high-altitude mountainsides (approximately 500–1500 m asl) in central Taiwan for more than 100 years. Without the confounding effect of vegetation shift on soil microbes due to the elevation change in many ecosystems, this bamboo plantation is an ideal site to study how the soil microbial community structure and its activity changes with the elevation gradient. Our previous study showed that the soil total organic C and N, soluble organic C and N, and microbial biomass of bamboo plantations increased with increasing elevation (Huang et al., 2014), and the bacterial diversity showed a hump-backed trend with increasing elevation (Lin et al., 2015). However, little is known about how microbial activity and the microbial community structure relates to SOM in long-term bamboo plantations across elevations. We hypothesized that an altitudinal increase will cause an increase in the SOM due to the decreasing mean annual temperature, and this result would support a higher microbial biomass and higher abundance of microbial communities.

2. Materials and methods

2.1. Site description and soil sampling

The study area was located at Mt. Da-an in Jhushan Town, Nantou County, Central Taiwan (120°42′E, 23°42′N). The moso bamboo (*P. edulis*), a temperate bamboo species with delicious tasting shoots and beneficial long culms that are used for construction, was largely introduced from China to Mt. Da-an, Jhushan, 100 years ago. The bamboo production has been developed from broadleaved forest in low-elevation for more than 100 years and several decades in high-elevation (Lin, 2000). Moso bamboo is well adapted to a mild climate, and its plantations currently stretch from 500 m to as high as 1500 m asl in this area. The soils of the studied bamboo plantations were colluvial soils derived from sandstones and shales, which were classified as Entisols based on Soil Taxonomy (Soil Survey Staff, 2010). The studied soils were acidic, sandy loam to loam and with a shallow depth, ranging from 30 to 50 cm, as described by the Soil Survey Staff (2010).

Along a country road, five bamboo plantations at the altitude of 600, 800, 1000, 1200 and 1400 m asl were selected for soil sampling. Based on the record from weather stations at 84 m, 800 m, 1150 m, 1755 m and 2413 m asl, the annual mean air temperature was estimated as 20.3 °C at 600 m and 16.1 at 1400 m with a decrease 0.52 °C per 100 m altitudinal increase (Fig. 1). The mean annual precipitation at the study site ranged from 2210 to 2600 mm. Chen et al. (2014) indicated a positive altitudinal effect on diameters, height, height at crown base, and biomass in plantations of moso bamboo at altitudes from 600 m to 1400 asl in this area.

At each bamboo plantation, we set up 5 (replicates) sampling plots, each sized 50 m × 50 m. The distance between each plot was 50 m. The soil samples were collected in the winter (January 2012) by the use of a soil corer (8 cm in diameter and 10 cm deep). Human disturbance to the bamboo plantations mainly occurred in growing season because of activities related to bamboo management and the collection of bamboo shoots. We chose the early winter to collect soil samples as during this period, soil at the bamboo plantations was minimally disturbed. At the time of sampling, air temperature was 11.6 °C at 1150 m asl. Three soil cores were collected at each plot and combined as a composite sample in a plot. Visible root and litter residue and soil fauna in the soil samples were removed. Then, the soil samples were sieved through a 2-mm mesh size sieve and kept at 4 °C before analysis.

2.2. Soil chemical and biochemical analyses

The organic C and total N contents in the soil samples were determined using an NSC elemental analyzer (NA1500 Series 2, Fisons, Italy). The soil subsamples were weighed and oven-dried at

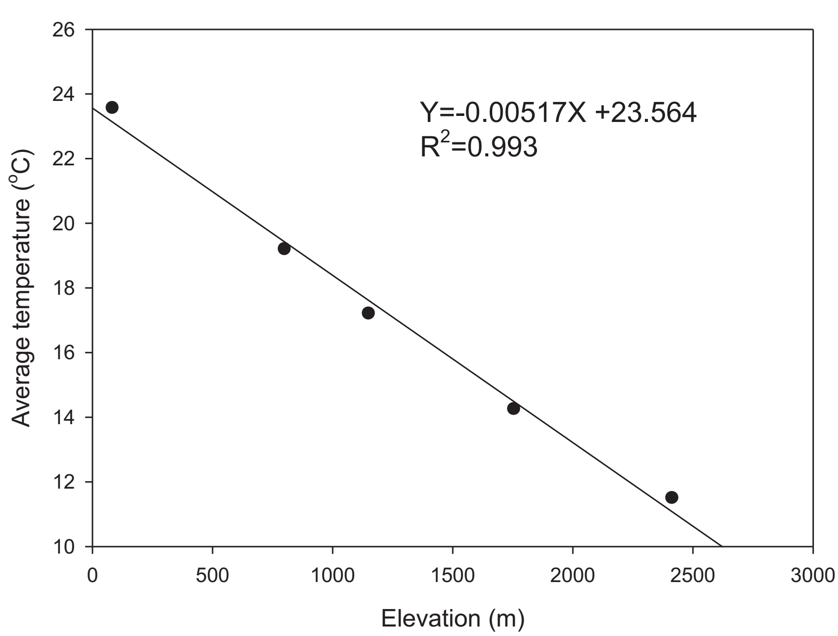

Fig. 1. Decrease in annual mean air temperature along with the increase in altitude in Daan Mountain.