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Responses of soil microarthropods to inorganic and organic fertilizers in a poplar plantation in a coastal area of eastern China

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ABSTRACT

Soil microarthropod community is an essential functional unit of soil food webs. Fertilizers can induce an alteration of quantity and quality of food for soil fauna and trigger profound changes in soil faunal communities. We initiated this study to examine the influence of organic and inorganic fertilizers on soil microarthropods in poplar plantations (*Populus deltoides*) in a coastal region of northern Jiangsu, eastern China. We established a control and four fertilizer application treatments: low and high levels of organic fertilizers, low and high levels of inorganic fertilizers. Organic fertilizer amendments increased both soil organic carbon (C) and total nitrogen (N), whereas inorganic fertilizer had a positive significant effect on soil total N. The application of both inorganic and organic fertilizers resulted in significantly reduced soil pH. We found that both inorganic and organic fertilizers increased the abundance of all soil microarthropods, bacterivorous Acari, and hemiedaphic and epedaphic Collembola, but had no influence on the total taxonomic richness, Shannon diversity index and DG diversity index of the microarthropod community. The abundance of soil microarthropods was positively correlated with soil C and N, and negatively with pH. Our results indicate that changes in the quality and quantity of soil organic matter and other immediate chemical properties after fertilizer application can increase the abundance of soil microarthropods, but have a limited influence on their diversity in the coastal alkaline soils of eastern China.

1. Introduction

Poplars (*Populus*), a genus of commercially important plantation species suited for cultivation in a vast area of coastal China, are of growing economic importance. They grow rapidly, have a short rotation cycle, and have multiple industrial uses in plywood and hardboard as well as use in the pulp and paper industries (Biswas et al., 2012; Wang et al., 2013). Moreover, the biomass production and C fixation potential of poplar plantations can also be used to mediate global climate change (Liberloo et al., 2006; Werner et al., 2012). China grows more than 7 million ha of poplar plantations (Fang et al., 2008), leading to a huge demand for genetic varieties with rapid growth potential, and excellent timber quality in man-made board and fiber material.

Improvement of soil fertility and maintenance of soil nutrients equilibrium are important for enhancing soil productivity (Selim et al., 2010; Demirsoy et al., 2012; Memon et al., 2012). Both organic and inorganic fertilizers were widely applied to sustain forest productivity in tree plantations (Cakmak, 2002; Chapagain and Gurung, 2010). Most researchers dealing with the application of fertilizers are interested in how fertilizers effect timber production and soil chemistry (Pavlou et al., 2007), but few studies have examined the effects of fertilizers on soil biota in managed tree plantations.

Soil fauna in ecosystems can serve as key components required for the functioning of soil and the maintenance of soil quality (de Vries et al., 2013). The contributions of soil fauna to soil fertility and health can be divided into several functional roles. These roles include participation in biogeochemical cycles and nutrient cycling, regulation of the decomposition of organic matter, improvement on soil aggregation and detoxification of pollutants (Shishido et al., 2008; Postma-Blaauw et al., 2010; de Vries et al., 2013).

Soil fauna are sensitive to the amendment of soil C and N and to disturbance of soil structure (Zhu and Zhu, 2015). However, whether the application of fertilizers will elevate or suppress the abundance of soil fauna in poplar plantations remains unclear,

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because previous studies identified both positive and negative effects of fertilizer application (Okada and Harada, 2007; Cheng et al., 2008; Liang et al., 2009). The effects of fertilization on biodiversity in soils are even less clear and fertilization may even pose a threat to soil biodiversity. Understanding the effects of fertilization on tree plantations can aid in the development of management plans designed to address growing concerns related to the sustainability of intensive tree farming practices and the maintenance of soil biodiversity (Hole et al., 2005).

Fertilizers can affect soil fauna either directly or indirectly. Direct effects, which cause responses occurring in the first season after the application of the fertilizers, include harm to soil organisms that encounter the chemicals. Indirect effects, typically taking more than one season to develop, include changes caused by the chemicals to the soil environment and/or food source of the organisms being consumed. The direct toxicity of metal contaminants and salts contained in inorganic fertilizers may result in the decrease in abundance or activity of soil organisms after fertilizer application (Bunemann et al., 2006; Roberts, 2014). Gomiero (2013) observed toxic effects of ammonia on soil organisms only in the zone/band where fertilizers were applied and those effects were usually short-term. Furthermore, the application of inorganic and organic fertilizers can increase the population and diversity of soil fauna (Liang et al., 2009). Long-term application of organic fertilizers has resulted in a resource-mediated increase in faunal populations via residue and organic matter inputs (Birkhofer et al., 2008; Li et al., 2010). In addition, the application of inorganic fertilizers has been reported to improve soil properties, which may exert an indirect and positive influence on faunal populations and microbial activity (Okada and Harada, 2007; Zhu and Zhu, 2015).

The objectives of this study were: (1) to examine the effects of inorganic (NPK compound fertilizer) and organic fertilization (soybean cake fertilizer) on soil microarthropods in a coastal soil under poplar plantation; and (2) to evaluate the relationships between the soil properties and the abundance and diversity of soil microarthropods communities. We ask questions related to whether the application of organic and inorganic fertilizer can increase the abundance of total soil microarthropods, especially Acari and Collembola, and how fertilizer regimes can affect the diversity of the soil microarthropod communities in poplar plantations.

2. Materials and methods

2.1. Site description

The study was conducted near the Yellow Sea State Forest Park in a coastal area of Yellow Sea in Dongtai County, northern Jiangsu Province, eastern China (32°33–57′N, 102°07′E). The monsoon climate influences the study area. It is located in the transition zone from a north subtropical to warm temperate climate. Annual mean temperature, rainfall and relative humidity are 13.7 °C, 1051 mm and 88.3%, respectively. The 220 d yr^{-1} frost-free period compliments the average sunshine hours of 2169.6 h yr^{-1}. The study site lies along the lower reaches of the alluvial plain of the Yangtze River and has desalted meadow sandy loam soil with 1.4% soil organic matter. Dongtai County sits at the center of the distribution of poplar forests and supports 3000 ha of plantations. A 4-yr-old stand of pure poplar plantations (*Populus deltoides*) with undergrowth vegetation mainly comprised of *Humulus scandens* and *Pteris biaurita* was selected as the study site. The afforestation density of poplar was 3 m × 5 m. In the study area, the forest canopy coverage was 72%, and the mean tree height was 18.1 m with a mean diameter at breast height (DBH) of 16.2 cm.

3. Experimental design

The experiment followed a randomized block design with five treatments in three replicate blocks, for a total of fifteen 2 m × 2 m plots established in June 2012. The treatments were: (1) unfertilized control (CK), (2 and 3) low (OM1) and high (OM2) levels of organic fertilizer application (1875 kg ha^{-1} and 3750 kg ha^{-1}), respectively, and (4 and 5) low (NPK1) and high (NPK2) levels of compound fertilizer (NPK1, 750 kg ha^{-1} and NPK2, 1500 kg ha^{-1}), respectively. Soybean cake served as the organic fertilizer, measured on a dry weight basis, and was applied to a depth of 0–20 cm. The inorganic NPK compound fertilizer (8:4:3) was applied to a depth of 0–20 cm by trenching (Xiao and Fang, 2007). Trenching was applied to ensure the efficiency of organic and inorganic fertilizers in the fertilizer plots. Two trenches (0.5 × 0.5 × 0.2 m) were created in the center of the fertilizer plots. Although we did not apply fertilizers in the CK plots, the identical pattern of ditch was dug to guarantee the comparison effect.

4. Soil analysis and fauna identification

Soil samples were taken once every three months from the 0–20 cm soil layer in each of the 15 plots from September 2012 to September 2013. Soil samples in each of fifteen plots consisted of 4–5 soil cores (2.5 cm diameter) during each sampling period. Total organic carbon (TOC) and total nitrogen (TN) of soil was measured using an element analyzer (Elementar, Vario ELIII, Elementar Analysen Systeme GmbH, Hanau, Germany). Soil pH was determined with a glass electrode in 1:2.5 soil:water solution (w/v).

Soil microarthropods were extracted from 100 g of soil (fresh weight) by modified Tullgren extractors (Wallwork, 1976). The soil samples were collected from 0–20 cm soil layer in 4 sampling points per plot using self-regulating geotome. The individuals of soil microarthropods were calculated as number per 100 g dry soil. The collection strategy of soil and fauna is dependent upon the efficiency of the extraction technique. All extracted faunal samples were preserved in 75% ethanol and then sorted under a dissecting microscope (LeicaMZ 125). The biodiversity of soil microarthropod community was estimated using taxonomic groups, e.g., Acari, Oribatid, Mesostigmatid, and Prostigmata, Collembola, and Hymenoptera (Yin, 1998). The feeding structure of Acari was grouped by fungivorous, bacteriovores, saprophagous and omnivorus guilds (Bardgett et al., 1993; Moore et al., 1988); the habitat preference structure of Collembola was sorted into euedaphic, hemiedaphic and epedaphic types (Petersen, 2002).

5. Statistical analysis

The biodiversity of soil microarthropod community was estimated using the total abundance of soil microarthropods, total group number of soil fauna (Zhu and Zhu, 2015), the Shannon-Wiener index (H') (Whittaker, 1972), Simpson index (C) (Simpson, 1949) and Evenness index (E) (Pielou, 1975), the DG (density-group) diversity index (Zhu and Zhu, 2015). Functional trait index of Acari and Collembola was calculated as the mean trait category affinity (mT) (Hedde et al., 2012). Repeated measures ANOVA were used to identify the influence of fertilizer application on the abundance of soil microarthropods and soil chemical parameters. For the biodiversity of soil microarthropods, and the abundance of Acari and Collembola communities, significant differences between treatments were tested by ANOVA followed by Tukey-tests. Correlations between abundance and chemical parameters were analyzed by means of the Spearman Rank Order Correlation Coefficient. All statistical analyses were preformed using the software package SPSS version 11.5 (SPSS Inc., Chicago, IL, USA).