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Interactive effects of elevated UV-B radiation and N deposition on decomposition of Moso bamboo litter

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ABSTRACT

Being two important agents of global environmental change, elevated ultraviolet-B (UV-B) radiation derived from anthropogenic driven ozone depletion and enhanced nitrogen (N) deposition may strongly affect litter decomposition, a crucial factor in biogeochemical cycling. However, the interactive effects of both agents together on litter decomposition are still unclear even though each has been well-documented independently. We conducted a field-based experiment in subtropical China to investigate the combined effects UV-B radiation and N deposition on the decomposition of Moso bamboo (*Phyllostachys pubescens*) leaf litter over a 20 months period. It was found that the combined effect significantly accelerated litter decomposition, C loss, and lignin degradation as well as facilitating phosphorous (P) release, although it had no measurable effect on N release. Moreover, the interactive effects of both agents together far exceeded the effects of each separately. Results indicated that the positive combined effect of UV-B radiation and N deposition on litter decomposition and C loss could potentially impact Moso bamboo forest ecosystem C cycling. These findings provide a new perspective to further understand the interactive effects of global environmental changes on terrestrial ecosystem processes.

1. Introduction

Elevated ultraviolet-B (UV-B, wavelength 280–320 nm) radiation and nitrogen (N) deposition are two important drivers of global environmental change. Due to ozone depletion, UV-B reaching the earth's surface has increased by approximately 5% over northern mid-latitudes throughout the last 30 years and is expected to continue to increase until the mid twenty-first century (Herman, 2010). Reactive N production also increased from ~15 Tg N in 1860 to 187 Tg N yr^{-1} in 2005 and is expected to continue to increase from 50% to 100% by 2030 (relative to 2000 figures) as a result of human activity (Galloway et al., 2008; Reay et al., 2008).

These increases in UV-B radiation and N deposition could profoundly influence terrestrial ecosystem processes, such as litter decomposition, a crucial factor of biogeochemical cycling. UV-B may increase litter decomposition by enhancing lignin photodegradation (Rozema et al., 1997; Austin and Vivanco, 2006; Song et al., 2012) or decrease litter decomposition by its impact on the abundance and community composition of microbial decomposers (Pancotto et al., 2003). N deposition also showed positive (Limpens and Berendse, 2003; Manning et al., 2008) and negative (Micks et al., 2004; Fang et al., 2007) effects on litter decomposition by altering soil N availability and soil enzymatic activity. To date, effects of enhanced UV-B (Newsham et al., 2001; Flint et al., 2003; Pancotto et al., 2003, 2005; Brandt et al., 2007; Smith et al., 2010; Kirschbaum et al., 2011) and N deposition (Knorr et al., 2005; Mo et al., 2006; Hobbie et al., 2012) on plant litter decomposition have primarily been investigated as effects of a single factor. However, the interactive effects of these two environmental agents together on litter decomposition have never been reported. It is therefore necessary to estimate the potential combined effects of both elevated UV-B and N deposition on litter decomposition.

These issues are of particular relevance in subtropical China, where UV-B radiation has increased with an annual ozone depletion rate of 0.27% (Liao et al., 2007; Zhou and Chen, 2008) and

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annual N deposition rate was recorded with a maximum value of 64 kg N ha^{-1} yr^{-1} (Lü and Tian, 2007). This region was predicted to become the region in the world to receive the greatest N deposition rates by 2030 (Reay et al., 2008). Moso bamboo (*Phyllostachys pubescens*) forests, primarily distributed throughout subtropical China, cover an area of 3.37 million ha, which is 70% of the country's bamboo forested area and 80% of *P. pubescens* global distribution (Song et al., 2011a). With its fast growth rate and high annual regrowth rate after harvesting, annual tree layer C fixation for a typical *P. pubescens* forest is c. 5 t ha^{-1}, which is some 1.3 orders-of-magnitude compared to a typical tropical mountain rain forest (Zhou and Jiang, 2004). Owing to its enormous C sequestration potential as well as their other ecological benefits, such as water and soil conservation, moisture retention, rainfall interception, Moso bamboo forests play an increasingly important role in climate change mitigation and environmental protection (Song et al., 2011a). All of the listed ecological benefits are related to litter decomposition as this affects the realised growth rate of *P. pubescens* via its effects on nutrient availability. Under conditions of increasing UV-B and N deposition, it remains unclear how *P. pubescens* litter decomposition and nutrient release will respond to either single or combined factors. For this study, a 20 month field-based experiment was carried out to test the following hypotheses: (1) elevated UV-B radiation accelerates *P. pubescens* litter decomposition; (2) elevated N deposition also accelerates *P. pubescens* litter decomposition; and (3) the interactive effects of both factors combined on litter decomposition is stronger than each separately.

2. Materials and methods

2.1. Leaf litter collection

In March 2010, *P. pubescens* (Carrière) Lehaie leaf litter was collected at Zhejiang A & F University's experimental field (long 119°44′ E, lat 30°16′ N). Samples were air-dried for a period of one month in a laboratory. Subsamples of air-dried samples were oven-dried at 65 °C to a constant weight to determine water content of air-dried samples. Oven-dried samples were then used to determine initial litter chemistry using the methods described below.

2.2. Experimental treatments

The decomposition experiment was carried out at the Zhejiang A & F University's experimental field, located in the outskirts of Lin'an City, Zhejiang Province, China. The area has a monsoonal subtropical climate with four distinct seasons. Mean annual rainfall is 1420 mm. Mean annual temperature is 15.6 °C, with a 2696 °C average effective accumulated temperature above 10 °C. The site has an average of 1939 daylight hours and 234 frost-free days per year. The experiment used four treatments: elevated UV-B radiation (UV-B), elevated N deposition (N), elevated UV-B radiation and elevated N deposition (UV-B + N), and a control group. Three replicate plots were created for each treatment. All plots and treatments were designed in randomized complete blocks. Soil in all plots was homogenized local red soil sieved through a 4 mm grate to remove coarse material. To focus solely on decomposition effects related to UV-B and N deposition, the experiment was carried out on bare ground devoid of vegetation.

Enhanced UV-B was regulated using artificial irradiance (Song et al., 2012) using fluorescent UV-B lamps (UV-B313EL, Beijing Lighting Research Institute, Beijing, China). Lamps were wrapped in cellulose triacetate film that allowed transmission of both UV-B and UV-A (315–400 nm) while removing all UV-C. Like many previous UV-B experiments (Hoorens et al., 2004; Smith et al., 2010), UV-A was not controlled in this experiment. Lamps operated between 9:00 a.m. and 4:00 p.m. under cloudless conditions and were adjusted monthly for height from ground to maintain an approximate 10% increase above ambient levels, measured using a UV-297 radiometer (Photoelectric Instrument Factory of Beijing Normal University, China).

Local N deposition was calculated at 30.9 kg N ha^{-1} yr^{-1} (Xie et al., 2008). Accordingly, 30 kg N ha^{-1} yr^{-1} ammonium nitrate (NH_4NO_3) was applied to the N treatment. NH_4NO_3 was weighed and mixed with 100 ml water and distributed onto each plot using a sprayer at the start of every month. This made 12 equal applications over a one year period, equal to an annual increase of 0.6 mm rainfall (Mo et al., 2006; Fang et al., 2007). When NH_4NO_3 was applied to the N treatment plots, the remaining treatments were irrigated using 100 mL of N-free water to avoid effects of water N transfer.

The UV-B + N treatment was carried out under both a 10% UV-B increase and a 30 kg N ha^{-1} yr^{-1} N addition, using the above methods. Lamp arrays using dummy lamps were constructed over both control and N treatment plots, which provided the same degree of shading as lamp arrays underwent in the UV-B and UV-B + N treatments.

2.3. Litter decomposition and chemical analysis

The widely used litterbag method was employed to determine the rate of leaf litter decomposition. Litterbag size was 15 × 15 cm and constructed from 0.5 × 1.0 mm mesh-size polypropylene fabric. All were filled with 10 g air-dried leaf litter. In May 2010, a total of 144 litterbags were positioned on the soil surface of 12 homogenized decomposition treatment plots so they would be in contact with the organic layer. Each plot contained 12 litterbags for four sampling. Three samples from each plot per measurement duration were averaged as the value per plot. Plots were maintained to prevent weeds from growing into the litterbags.

Three litterbags were retrieved from each plot after a period of 4, 8, 14, and 20 months, after which adhering soil particles were removed by gentle washing and brushing. Litter was oven-dried at 65 °C and weighed. Differences between mass at the start of the experiment and mass at each sampling time were used to calculate the rate of leaf litter decomposition.

Oven-dried litter was ground with a grinder (DFT-50A, Wenling LINDA machinery co. ltd., Wenling, China). Total carbon (C) and N was determined using a Sumigraph NC-80 high-sensitivity CN analyser (Shimadzu, Japan). Phosphorus (P) concentration was determined using a modified Kjeldahl method. This was followed by photometric analysis. Finally, lignin concentration was determined using the ADF-sulphuric method (Song et al., 2011b).

2.4. Data and statistical analysis

Net plant litter dry weight for each retrieved litterbag was expressed as a percentage of the initial plant litter dry weight of each litterbag. The first-order exponential decay model (Olson, 1963) using the $X_t/X_0 = e^{-kt}$ form was fitted to the decomposition data where X_t is the net oven-dry weight remaining at time t; X_0 is the initial oven-dry weight; and k is the annual decomposition rate constant (yr^{-1}).

Nutrient release via litter decomposition was expressed as a percentage of initial nutrient content, which was calculated by determining nutrient content at each sampling and dividing it by the initial nutrient content (Pancotto et al., 2003; Brandt et al., 2010): $E = [(M_t \times C_t)/(M_0 \times C_0)] \times 100\%$ where E is nutrient release (%); M_0 is the initial oven-dry mass (g); C_0 is the initial nutrient concentration (mg g^{-1}); M_t is the oven-dry mass at time t;