



Incipient changes of lignin and substituted fatty acids under N addition in a Chinese forest soil



Nana Wu^{a,b}, Timothy R. Filley^c, Edith Bai^{a,*}, Shijie Han^a, Ping Jiang^a

^aState Key Laboratory of Forest and Soil Ecology, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110164, China

^bUniversity of Chinese Academy of Sciences, Beijing 100049, China

^cDepartment of Earth, Atmospheric, and Planetary Science and The Purdue Climate Change Research Center, Purdue University, West Lafayette, IN 47907, USA

ARTICLE INFO

Article history:

Received 21 July 2014

Received in revised form 19 November 2014

Accepted 3 December 2014

Available online 16 December 2014

Keywords:

Atmospheric nitrogen deposition

Broad-leaf Korean pine mixed forest

Cutin

Soil carbon

Suberin

ABSTRACT

Elevated nitrogen (N) deposition has the potential to increase litter and soil carbon (C) storage by suppressing lignolytic activity, but reports of the response of forest floor and soil have shown inconsistent responses. We investigated organic carbon and nitrogen as well as lignin phenols and substituted fatty acids (SFA) in forest floor litter and organic horizons, and mineral soil profiles from a mixed broad-leaf Korean pine (*Pinus koraiensis*) forest, China after 6 years of N addition treatment at double the current N deposition rate. Total C and N were not influenced by experimental N deposition. However, incipient changes in extractable lignin phenol concentration were seen for degraded litter ($P = 0.100$) exhibiting increases of about 5% while mineral soil, surface litter and O-horizon showed no change. The degree of lignin oxidation was not substantially influenced in any layer although a significant decrease in vanillyl lignin phenol oxidation was measured in the degraded litter under elevated N. Extractable substituted fatty acids in the forest floor and mineral soil horizons were also, essentially, insensitive to N addition with the minor exception of the O-horizon showing a small but significant ($\sim 16\%$, $P = 0.041$) increase. Our results are consistent with one group of literature showing little change in overall soil and litter character under short term, 5–10 years, of N addition. Minor changes in molecular C dynamics, such as those observed for lignin phenols and substituted fatty acids could possibly be attributed to the suppression of microbial decay under N addition.

© 2014 Elsevier Ltd. All rights reserved.

1. Introduction

Since the beginning of the industrial revolution, the anthropogenic emissions of nitrogen (N) from agriculture and fossil fuel use has increased upwards of 200% resulting in large increases in N deposition above the natural background of approximately $0.5 \text{ kg N ha}^{-1} \text{ yr}^{-1}$; in many industrialized regions, such as the eastern regions of China, N deposition rates now exceed $50 \text{ kg N ha}^{-1} \text{ yr}^{-1}$ (Galloway et al., 2004; Liu et al., 2013). Elevated N deposition affects terrestrial carbon (C) cycles through changes in net primary productivity (NPP), plant and microbial community composition, and enzymatic regulation such that there is the potential to alter terrestrial ecosystem C stocks (Knorr et al., 2005). In temperate forests where plant growth is generally N limited, increased N availability has been found to promote tree biomass and NPP, and hence enhance C storage in plants (Oren

et al., 2001; Nordin et al., 2005; Pregitzer et al., 2008). In fact, recent experimental studies and meta-analyses of experimental N addition studies revealed elevated N also increases soil C storage by decreasing the extent of litter decay through alteration of biochemical decay dynamics (Liu and Greaver, 2010; Whittinghill et al., 2012; Frey et al., 2014).

Soil contains more than three times as much C as either the atmosphere or terrigenous vegetation (Fischlin et al., 2007), thus minor changes of soil C storage may significantly affect the atmospheric CO_2 concentration. Soil organic carbon (SOC) is a complex mixture, composed of material derived from plant and microbial sources with different degrees of chemical (mineral) and physical (structural) protection depending on the environment, input and edaphic properties (Sollins et al., 1996, 2006). Chronic N addition has the potential to alter the soil and litter protection dynamics resulting in distinct pathways of C accumulation that are reflected in the selective build up of specific types of chemical components (i.e., lignin, carbohydrates, substituted fatty acids, etc.) in more or less protected soil C pools (Frey et al., 2014).

In forest ecosystems, N addition experiments have demonstrated complicated and seemingly contradictory responses

* Corresponding author at: State Key Laboratory of Forest and Soil Ecology, Institute of Applied Ecology, Chinese Academy of Sciences, No. 72 Wenhua Road, Shenyang 110164, China. Tel.: +86 24 83970570; fax: +86 24 83970300.

E-mail address: baie@iae.ac.cn (E. Bai).

(Gallo et al., 2005) with some studies showing an acceleration of the degradation of labile plant litter (i.e., cellulose rich) and a slowing of decay of the purportedly recalcitrant plant components such as lignin (Neff et al., 2002; Knorr et al., 2005; Grandy et al., 2008). In contrast, N addition has also been found to promote lignin oxidation in mineral soil (Feng et al., 2010; Gillespie et al., 2014), while other studies found no apparent changes in forest floor lignin decomposition under chronic N fertilization even though soil C contents increased (Thomas et al., 2012). A recent review and report of new finding from a 20 year study at Harvard forest demonstrated that N addition resulted in a shift in organic matter chemistry and the microbial community with pine and hardwoods showing distinct responses that were driven by plant species mortality effects (Frey et al., 2014). They also showed that level of N availability is important for soil C pools (Frey et al., 2014), which means both N addition level and ambient N deposition should be considered while evaluating N-induced soil C storage. However, current studies are mostly carried out in North America and Europe where ambient N deposition rate is relatively low. Whether forest soils under high ambient N addition rate such as in China respond similarly to high N addition level still needs to be explored.

In this study, we sought to investigate the hypothesis that elevated N deposition could potentially enhance soil C storage in forest soils and litter, evidenced in part through accumulation of undegraded lignin phenols and substituted fatty acids, derived from complex polyesters such as cutin and suberin. To test these hypotheses, we measured carbon and nitrogen contents, and alkaline cupric-oxide (CuO) extractable phenols and substituted fatty acids (Hedges and Mann, 1979; Goñi and Hedges, 1990) in forest floor and soil organic matter from a temperate forest in northeastern China after a 6 year N addition experiment.

2. Materials and methods

2.1. Site description and sample collection

The study was conducted in a mixed deciduous, broad-leaf Korean pine forest (*Pinus koraiensis* Siebold & Zucc) located at the Changbai Mountain (42°24'N, 128°5'E, 738 m elevation), north-eastern China (Dai et al., 2013). The 200 year old forest stand is the typical vegetation assemblage in this temperate zone of China. The dominant tree species are *P. koraiensis*, Tuan linden (*Tilia amurensis*), Mono maple (*Acer mono*), Manchurian ash (*Fraxinus mandshurica*), Mongolian oak (*Quercus mongolica*), elm (*Ulmus glabra*) and other interspersed deciduous species (Guan et al., 2006). The mean annual temperature and precipitation are 3.5 °C and 700 mm, respectively (Wang et al., 2012). The soil originates from volcanic ash and is termed a mountain dark brown forest soil in the Chinese soil classification scheme (Han et al., 2000; Zhang et al., 2006) and Mollisols in the American Soil Taxonomy classification scheme (Wu et al., 2006). Specifically, the soil is clay loam and slightly acidic (pH = 5.47, unpublished data).

Current ambient N deposition rates (wet and dry) in this area is 23 kg N ha⁻¹ yr⁻¹ (Wang et al., 2012). The N addition experiment was established in June 2006, consisting of four control and four N addition plots, 25 m × 25 m. The plots were randomly assigned to control and nitrogen addition treatments. All plots have been sampled for similarity before the treatment began (Wang et al., 2012). Ammonium nitrate (NH₄NO₃) was applied at a rate of 50 kg N ha⁻¹ yr⁻¹ during the growing season (from May to October) with a sprayer in the N addition plots. The rate was about two times the current N inputs in this area. The same amount of deionized water was sprayed in control plots. Iron plates were inserted in the soil to the depth of 1.5 m between N addition and control plots to minimize N leaching and exchange between plots.

Samples of forest floor and mineral soil profiles, including litter (L), decomposed litter (LD), O horizon (O) and mineral soil (MS), were collected separately in June 2012 after 6 years of N addition treatment. At each plot, four samples were randomly collected and pooled together to create a composite sample. The mineral soil (0–15 cm) was sampled using a 5 cm diameter impact corer. All samples were shipped back to the laboratory within 2 days. The L and LD samples were dried in a convection oven at 50 °C for 48 h and ground into powder using an automated grinder. O horizon and MS samples were passed through a 2 mm sieve to remove roots, rocks and other coarse debris, dried in a convection oven at 50 °C for 48 h and powdered to a flour consistency for later chemical analysis.

2.2. Elemental and biochemical analyses

Total C and N contents of L, LD, O and MS samples were determined in duplicate, using a Sercon GSL (Crewe, UK) elemental analyzer. The soils were tested to be carbonate free using acid digestion. Therefore, total C content was equivalent to organic carbon (OC) content.

Alkaline CuO oxidation method (Hedges and Mann, 1979; Filley et al., 2008a) was used to assess concentration of extractable lignin-derived phenols and estimate cutin- and suberin-derived substituted fatty acids (SFA). The samples were weighed to an equivalent of ~4 mg OC. The biopolymer extraction reactions utilized Monel reaction vessels (Prime Focus, Inc. Seattle, WA, USA). Ethyl vanillin and DL-12 hydroxystearic acid were added as internal standards post reaction and before extraction. Extracted compounds were analyzed by gas chromatography mass spectrometry (GCMS) using a Shimadzu (Kyoto, Japan) QP2010plus GCMS system (Kyoto, Japan) and internal calibration curves were used to quantify compound concentrations (Filley et al., 2008b). Lignin phenols were assessed as trimethylsilane derivatives of vanillyl (V)-based (i.e., vanillin, acetovanillone, vanillic acid), syringyl (S)-based (i.e., syringaldehyde, acetosyringone, syringic acid), and cinnamyl (Ci)-based (i.e., p-hydroxycinnamic and ferulic acids) monomers. Total yields of lignin phenols were expressed as SVC-lignin (the sum of S + V + Ci). The derivatives of eight SFA were quantified and their sum termed as Σ SFA which included 16-hydroxyhexadecanoic acid (ω -C₁₆), hexadecane-1,16-dioic acid (C₁₆DA), 18-hydroxyoctadec-9-enoic acid (ω -C_{18:1}), 9,16- and 10,16-dihydroxyhexadecanoic acid (9&10, ω -C₁₆), 9-octadecene-1,18-dioic acid (C_{18:1}DA), 7- and 8-hydroxyhexadecandioic acid (7&8-C_{16:1}DA), 9,10,18-trihydroxyoctadec-12-enoic acid (9,10, ω -C_{18:1}), 9,10,18-trihydroxyoctanoic acid (9,10, ω -C₁₈). Such SFA are primarily derived from cutin and suberin esters and are commonly extracted with organic solvents and base saponification (Riederer et al., 1993; Nierop et al., 2003; Otto and Simpson, 2006), however the alkaline CuO method has been used to assess their abundance in soils and plants, albeit with lower extraction efficiency, particularly for higher molecular weight isomers (Crow et al., 2009; Ma et al., 2013). Previous studies have demonstrated that the sum of 9&10, ω -C₁₆, 7&8-C_{16:1}DA and 9,10, ω -C₁₈ compounds (Σ cutin acids) was relatively higher in leaf tissue than root of the same plant while ω -C₁₆, C₁₆DA, ω -C_{18:1} and C_{18:1}DA compounds (Σ suberin acids) were relatively higher in roots than leaf tissue (e.g., Crow et al., 2009). Individual compound concentrations are given as mg compound/100 mg OC. Duplicate CuO analyses were performed for each sample.

2.3. Statistical analyses

Our null hypothesis is that N addition has no effect on lignin or cutin/suberin chemistry or concentration. Due to the low number of replicates ($n = 4$) for each treatment and control, three statistical

Download English Version:

<https://daneshyari.com/en/article/5161563>

Download Persian Version:

<https://daneshyari.com/article/5161563>

[Daneshyari.com](https://daneshyari.com)