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REGULAR ARTICLE

Management practices amplify the effects of N deposition on leaf litter decomposition of the Moso bamboo forest

Xinzhang Song · Guomo Zhou · Honghao Gu ·
Lianghua Qi

Abstract

Aims The litter decomposition effects of N deposition in combination with management practices are still unclear. The aims of this study were to test the individual and interactive effects of the two factors on Moso bamboo leaf litter decomposition.

Methods The experiment was conducted in Moso bamboo forests over a 24-month period and included three N addition treatments (low N, 30 kg N ha^{-1} yr^{-1}; medium N, 60 kg N ha^{-1} yr^{-1}; and high N, 90 kg N ha^{-1} yr^{-1}) and two management practices (conventional management and intensive management).

Results The low-N treatment significantly increased the annual decomposition rate, whereas the high-N treatment significantly decreased the annual decomposition rate ($P<0.05$). Intensive management alone did not significantly influence decomposition, but it amplified both the positive effects of the low-N treatment and the negative effects of the high-N treatment on litter decomposition. Intensive management weakened the positive effects of N addition on N loss but enhanced the positive effects on P loss during the early stage.

Conclusions The effects of increasing N deposition in a plantation ecosystem were altered by the management practices, and these changes should be considered when estimating the biological effects of N deposition at regional and global scales.

Keywords Litter decay · Plantation · Nutrient turnover · Lignin degradation · *Phyllostachys pubescens*

X. Song (✉) · G. Zhou · H. Gu
The Nurturing Station for the State Key Laboratory of
Subtropical Silviculture, Zhejiang Provincial Key Laboratory
of Carbon Cycling and Carbon Sequestration in Forest
Ecosystems, Zhejiang A&F University, Lin'an 311300, China
e-mail: songxinzhang@gmail.com

X. Song
e-mail: xzsong@126.com

G. Zhou
e-mail: zhougm@zafu.edu.cn

H. Gu
e-mail: 775753531@qq.com

L. Qi
International Centre for Bamboo and Rattan, Beijing 100102,
China
e-mail: qilianghua2008@aliyun.com

Introduction

Atmospheric nitrogen (N) deposition is an important driver of global environmental change. Reactive N production has increased from approximately 15 Tg N in 1860 to 187 Tg N yr^{-1} in 2005 and is expected to continue to increase by 50–100 % by 2030 (relative to 2000 figures) as a result of human activity (Galloway et al. 2008; Reay et al. 2008). The average bulk deposition of N has increased from 13.2 kg N ha^{-1} yr^{-1} in the 1980s to 21.1 kg N ha^{-1} yr^{-1} in the 2000s across China (Liu et al. 2013). Subtropical China, with a maximum annual N deposition rate of 63.53 kg N ha^{-1} yr^{-1} (Lü and Tian 2007), is predicted to become the region with

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the greatest N deposition in the world by 2030 (Reay et al. 2008).

Nitrogen deposition can profoundly influence litter decomposition, a crucial ecosystem process controlling the cycling of nutrients and carbon. Nitrogen deposition may either positively, neutrally, or negatively affect litter decomposition by altering soil N availability and soil microbial decomposers (Micks et al. 2004; Knorr et al. 2005; Fang et al. 2007; Hobbie et al. 2006; Keeler et al. 2009). However, forest management practices in plantations, such as thinning, ploughing, and fertilization, can also impact litter decomposition by altering the physicochemical and biological properties of the soil (Balesdent et al. 1998; Xu et al. 1998; Pandey et al. 2007). However, little information is available regarding the interactive effects of N deposition and management practices on litter decomposition and subsequent nutrient release.

Because of a rapid growth rate and a high annual regrowth rate after harvesting, Moso bamboo (*Phyllostachys heterocycla* (*Carr.*) *Mitford cv. Pubescens*) forests are highly representative of plantation forests in the subtropical region of China. Moso bamboo forests are the most important source of non-wood forest products in the current China, covering an area of 3.87 million ha, representing 70 % of the country's bamboo forested area and 80 % of the global distribution of *P. pubescens*(Li and Lei 2010; Song et al. 2011). Due to its enormous ecological and socioeconomic benefits and sustainable forest development policies, Moso bamboo forests have expanded rapidly in subtropical China, with an annual increase rate of 3 % in recent decades (Song et al. 2011).

To maintain high productivity in Moso bamboo plantations and achieve the maximal economic benefits, increasing numbers of farmers are adopting intensive management practices, such as the regular removal of understory vegetation, ploughing, and fertilization (Liu et al. 2011; Song et al. 2011). Typically, conventional management regularly harvests bamboo stems and shoots, without any of the other management practices mentioned above (Liu et al. 2011). The intensive management practices increase bamboo production but reduce soil microbial functional diversity (Xu et al. 2008; Zhou et al. 2009), accelerate soil organic carbon mineralization (Zhou et al. 2006; Jiang et al. 2009), and may influence litter decomposition. Litter decomposition is controlled by multiple factors. Our previous studies found that the interactive effects of N deposition and

UV-B radiation on litter decomposition far exceed the effects of each factor individually (Song et al. 2014a,b). The area of Moso bamboo plantations is the region with greatest N deposition in China, both currently and in future predictions. The effects of N deposition on litter decomposition and nutrient turnover, both solely and combined with management practices, still remain unknown, limiting our understanding of the responses of Moso bamboo plantations to global environmental changes and human management practices.

In this study, a 24-month field-based experiment was conducted to test the following hypotheses: (1) N deposition accelerates *P. pubescens* litter decomposition; (2) intensive management practices also accelerate *P. pubescens* litter decomposition; and (3) the combination of N deposition and management practices has stronger effects on litter decomposition than each practice separately.

Materials and methods

Study site

The study site was located in Qingshan Town, Lin'an city (30°14′N, 119°42′E), Zhejiang Province, China. The area has a monsoonal subtropical climate with four distinct seasons. The mean annual precipitation is 1420 mm, and the mean annual temperature is 15.6 °C, with maximum and minimum temperatures of 41.7 °C and-13.3 °C, respectively. The area receives an average of approximately 1847 h of sunshine per year and features an average of 230 frost-free days per year. The monthly mean air temperatures and precipitation quantities during the study period are shown in Fig. 1.

The conventionally managed Moso bamboo plantations (CM) were originally established in the late 1970s from native evergreen broadleaf forest in sites of similar topography (southwest slope of approximately 6°) and soil type. The soils are classified as Ferrisols derived from granite (Liu et al. 2011). The intensive management practices, including annual fertilization, ploughing, and weeding with herbicide, have been conducted since 2001. In September of each year, fertilizers are distributed and followed with a deep plough to 0.3 m. Urea (450 kg ha^{-1}), single super phosphate (450 kg ha^{-1}) and potassium chloride (150 kg ha^{-1}) were applied annually before 2010, and nitrate of S-based compound fertilizer (N-P$_2$O$_5$-K$_2$O: 15-6-20 %,
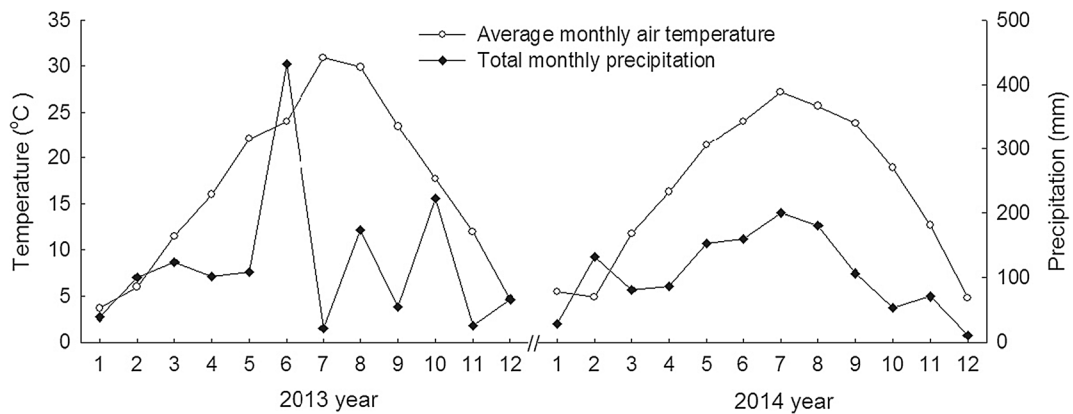
Fig. 1 Average monthly climatic data of the study site during litter decomposition experiment periods in 2013 and 2014

450 kg ha^{-1}) has been applied annually since 2010, which is equivalent to the annual addition of 67.5 kg N, 11.8 kg P, and 74.7 kg K per hectare. With the exception of bamboo stems and shoots being selectively and regularly harvested as required, the conventionally managed Moso bamboo plantations did not experience any other management practices. In the CM plantations, 32 understory species, dominated by *Loropetalum chinensis* (R. Br.) Oliv., *Cyclobalanopsis glauca* (Thunb.) Oerst., and *Vaccinium bracteatum* Thunb., cover 80 % of the forest floor, have a mean height of 0.7 m, and form a total shrub and herbal biomass of 2183 kg ha^{-1}. In the intensively managed Moso bamboo plantations (IM), 11 understory species, dominated by *Viola prionantha*, achieve a mean height of 0.1 m, a forest floor coverage of 5 %, and a total herbal biomass of 14.6 kg ha^{-1}.

Experimental design and measurement

In November 2012, 24 measurement plots of 20×20 m were established, with 12 in both the CM plantation area and the IM plantation area. The initial stand and soil characteristics of both the CM and IM are summarized in Table 1. Briefly, compared with CM, IM had significantly lower soil organic C (SOC) but higher soil total N (TN) and available nitrogen (AN). Each plot was surrounded by a 20 m-wide buffer zone to avoid disturbing nearby plots. Three N addition treatments (low-N, medium-N, high-N) and a control (no added N) with three replicate plots per treatment were established randomly in each Moso bamboo plantation management type. According to the widely used method in the previous studies simulating N deposition (Mo et al. 2006; Fang et al. 2007) and the local N deposition of 30.9 kg N ha^{-1} yr^{-1}(Xie et al. 2008), the N addition treatments were conducted with a low-N addition of 30 kg N ha^{-1} yr^{-1} (N30), a medium-N addition of 60 kg N ha^{-1} yr^{-1}(N60), and a high-N addition of 90 kg N ha^{-1} yr^{-1}(N90). Starting in January 2013, quantitative NH$_4$NO$_3$ was weighed, mixed with 10 L of water and sprayed evenly onto the forest floor of each plot using an electric sprayer at the beginning of every month for a total of 12 equal applications over the entire

Table 1 The initial stand and soil characteristics of the study sites in the Moso bamboo forest (mean±SD, $n=4$)

Management type	Stand density (trees ha^{-1})	DBH (cm)	SBD (g cm^{-3})	SOC (mg g^{-1})	TN (mg g^{-1})	AN (mg g^{-1})	TP (mg g^{-1})	AP (mg g^{-1})	Soil pH
CM	3106±386a	10.08±0.38a	1.06±0.07a	27.8±0.3a	0.9±0.03b	0.06±0.001b	0.4±0.01a	0.002±0.000a	4.53±0.01a
IM	3362±309a	10.16±0.13a	0.97±0.07a	23.7±0.2b	1.1±0.04a	0.09±0.002a	0.5±0.01a	0.002±0.000a	4.46±0.02a

CM conventional management, *IM* intensive management, *DBH* diameter at breast height, *SBD* soil bulk density, *SOC* soil organic C, *TN* soil total N, *AN* available nitrogen, *TP* soil total P, *AP* available phosphorus. Different lowercase letters in the same column indicate significant differences (*P*<0.05)

year throughout the experiment period. These water-based additions amounted to an increase of 0.3 mm of rainfall per year (Mo et al. 2006; Fang et al. 2007). Each control treatment plot received 10 L of N-free water to control for the effects of the added water.

Leaf litter collection, decomposition and chemical analysis

In June 2012, freshly fallen leaf litter of *P. pubescens* was collected from the CM plantation's floor. The samples were air-dried for a period of several months in a laboratory. Subsamples of the air-dried samples were oven-dried at 65 °C to a constant weight to determine the water content of the air-dried samples and were then ground for initial litter chemistry analysis using the methods described below.

The litterbag method was used to determine the rate of leaf litter decomposition. The litterbags were 15×15 cm in size and constructed from polypropylene fabric with a 0.5×1.0 mm mesh-size. Each litterbag was filled with 10 g of air-dried leaf litter. The starting weight of air-dried litter was converted to oven-dried weight according to the water content of air-dried samples. In December 2012, a total of 360 litterbags were positioned on the surface of the organic horizon in the 24 treatment plots. Each plot contained 15 litterbags that were divided into three equal groups, with each group including 5 litterbags for five sampling events. Three litterbags were retrieved from each plot after periods of 4, 8, 12, 18, and 24 months. After collection, any adhering soil particles were removed by gentle washing and brushing. The litter was then oven-dried at 65 °C to a constant weight and weighed. The three samples from each plot per sampling event were averaged as the value per plot. Differences between the mass at the start of the experiment and the 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., China). The total carbon (C) and N values were determined using a Sumigraph NC-80 high-sensitivity CN analyzer (Shimadzu, Japan). The phosphorus (P) concentration was determined using a modified Kjeldahl method followed by photometric analysis (Xuluc-Tolosa et al. 2003). The lignin concentration was determined using acid-detergent fiber methods (Rowland and Roberts 1994; Song et al. 2014a).

Data and statistical analysis

The remaining dry weight of the litter in each retrieved litterbag was expressed as a percentage of the initial litter dry weight of each litterbag. The first-order exponential decay model (Olson 1963) of the form $X_t/X_0 = e^{-kt}$ 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}).

The nutrient release via litter decomposition was expressed as a percentage of the initial nutrient content, which was calculated by determining the nutrient content at each sampling time 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 the 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; and C_t is the nutrient concentration at time t.

One-way analysis of variance (ANOVA) and least significant difference (LSD) tests were used to determine the statistical significance of differences between the annual decomposition rate, litter mass loss, and nutrient release of each sampling event among the four experimental treatments in the two plantation management types. A two-way ANOVA method was used to test the interaction of N deposition and management practices on annual litter decomposition rates. These analyses were conducted using SPSS (Statistical Package for the Social Sciences) 18.0 for Windows (SPSS Inc., Chicago, Illinois).

Results

Litter mass loss and annual decomposition rate

In the CM plots (Fig. 2, Table 2), both the litter mass loss and the annual decomposition rate were fastest under the N30 treatment and slowest under the N90 treatment. No significant difference in litter mass loss or annual decomposition rate was observed between the control and N60 treatments ($P > 0.05$). In the IM plots, the litter mass loss under the four treatments was similar to that in the CM plots but tended to slow after 18 months of decomposition (Fig. 2). Similar to the CM plots, the decomposition rates in the IM plots also showed the same trends, with the highest decomposition rate under the
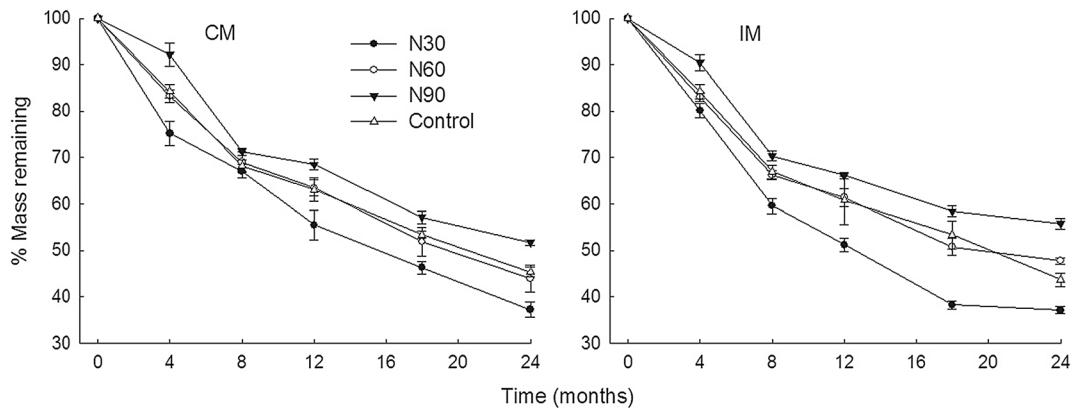
Fig. 2 Mean ($n=3$) with standard deviation of remaining leaf litter mass, as a percentage of the initial mass, during a 24-month leaf litter decomposition experiment of *Phyllostachys pubescens* under four treatments: low-N addition (N30, 30 kg N ha^{-1} yr^{-1}), medium-N addition (N60, 60 kg N ha^{-1} yr^{-1}), high-N addition (N90, 90 kg N ha^{-1} yr^{-1}), and a control in Moso bamboo forest with conventional management (CM) and intensive management (IM)

N30 treatment and the lowest under the N90 treatment (Table 2).

The litter in the IM plots decomposed faster than in the CM plots under both the control and N30 treatments but slower under both the N60 and N90 treatments. Under the N30 and N90 treatments, this difference was significant ($P<0.05$). A two-way ANOVA showed that N addition alone and N addition combined with management practices significantly affected the litter decomposition rates ($P<0.01$) (Table 3).

N and P loss dynamics

In the CM plots (Fig. 3), N exhibited a fast net loss in the early 8 months of decomposition, with the fastest rate under the N60 treatment and the slowest rate under the control. The N net loss tended to slow after 12 months, and this deceleration occurred more rapidly under the N60 and N90 treatment than under the control and N30 treatments. In the IM plots, rapid N net loss also occurred in the early 8 months under all four treatments and also slowed after 12 months, with the fastest loss under the control and the slowest under the N90 treatment.

The P loss exhibited similar dynamics in both the CM and IM plots with a fast net loss in the early 8 months of decomposition that tended to slow after 8 months and especially after 18 months. P loss was fastest under the N30 treatment, followed by the control, and the slowest under the N90 treatment (Fig. 4).

Table 2 The annual decomposition rate (k-value) calculated using the first-order exponential decay model ($X_t/X_0=e^{-kt}$) and the correlation coefficient (R^2) for leaf litter of *Phyllostachys pubescens* under four treatments in Moso bamboo forests with conventional and intensive management

Treatment	CM		IM	
	k-value	R^2	k-value	R^2
N30	0.47±0.02Ba	0.98	0.51±0.01Aa	0.94
N60	0.40±0.03Ab	0.98	0.37±0.01Ac	0.94
N90	0.34±0.01Ac	0.95	0.30±0.01 Bd	0.91
Control	0.38±0.02Ab	0.97	0.40±0.02Ab	0.97

The values are expressed as the mean±SD ($n=3$). Different lowercase letters in the same column indicate significant differences ($P<0.05$) among the N addition treatments. Different capital letters in the same row indicate significant differences between management types under the same N addition treatment ($P<0.05$)

Table 3 The two-way ANOVA of the effects of N addition and management type on leaf litter decomposition of *Phyllostachys pubescens*

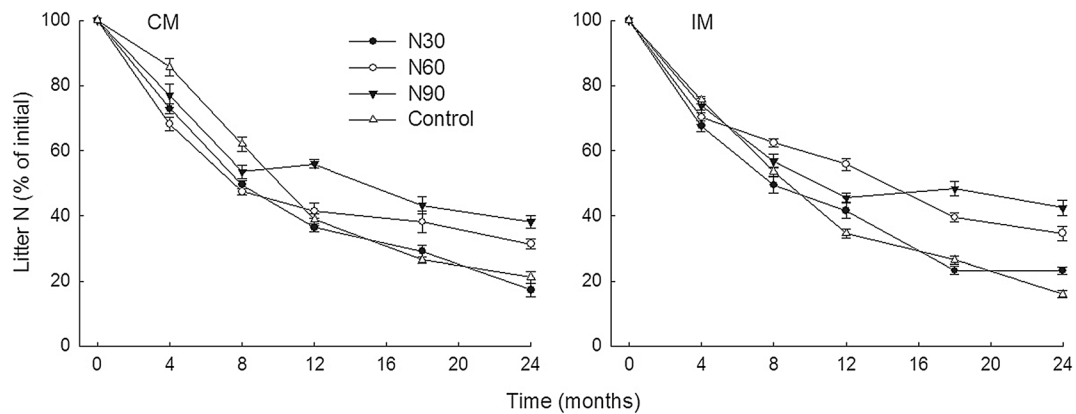| Source of variation	SS	df	MS	F	P-value
N addition	0.0972	3	0.0324	95	<0.0001
Management type	0.00002	1	0.00002	0.0488	0.8280
Interaction	0.0066	3	0.0022	6.3902	0.0047
Within	0.0055	16	0.0003		
Total	0.1092	23			

Fig. 3 Mean litter nitrogen (N,% of initial) with the standard deviation over time for the leaf litter decomposition of *Phyllostachys pubescens* under four treatments: low-N addition (N30, 30 kg N ha^{-1} yr^{-1}), medium-N addition (N60, 60 kg N ha^{-1} yr^{-1}), high-N addition (N90, 90 kg N ha^{-1} yr^{-1}), and a control in Moso bamboo forest with conventional management (CM) and intensive management (IM)

Lignin degradation

Compared to N and P loss, lignin degradation was slow and did not show a significant difference between treatments after the first 4 months of decomposition in both the CM and IM plots ($P>0.05$). Lignin degradation became rapid after 4 months and tended to slow again after 18 months (Fig. 5). The fastest and slowest degradation rates occurred under the N30 and N90 treatments, respectively, in both the CM and IM plots, but lignin degradation did not feature a significant difference between the N60 and control treatments throughout the entire experiment ($P>0.05$).

Discussion

Effects of N deposition and management practices on litter decomposition

In the CM plots, the N30 treatment significantly increased the annual litter decomposition rate, but the N90 treatment significantly decreased the decomposition rate, and the N60 treatment did not significantly influence the decomposition rate (Table 2), which to some extent supports our first hypothesis. In a previous field-based experiment investigating the interactive effects of UV-B radiation and N deposition on litter
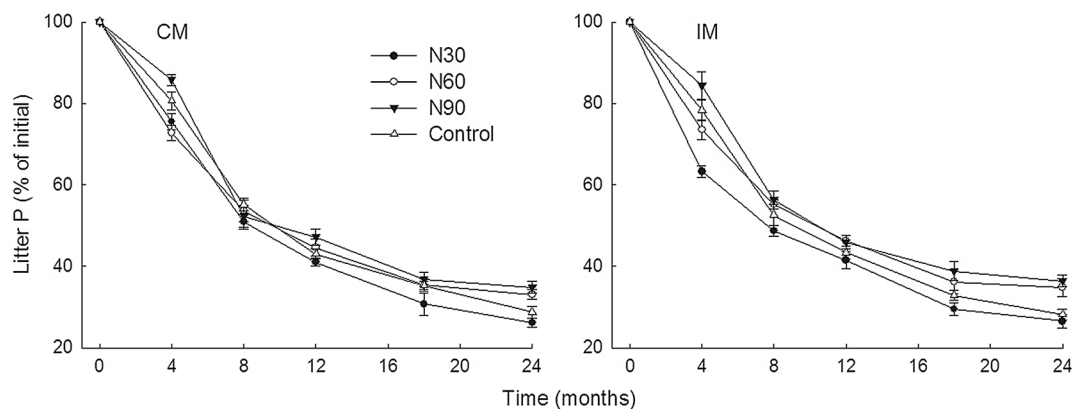

Fig. 4 Mean litter phosphorus (P,% of initial) with the standard deviation over time in the leaf litter decomposition of *Phyllostachys pubescens* under four treatments: low-N addition (N30, 30 kg N ha^{-1} yr^{-1}), medium-N addition (N60, 60 kg N ha^{-1} yr^{-1}), high-N addition (N90, 90 kg N ha^{-1} yr^{-1}), and a control in Moso bamboo forest with conventional management (CM) and intensive management (IM)
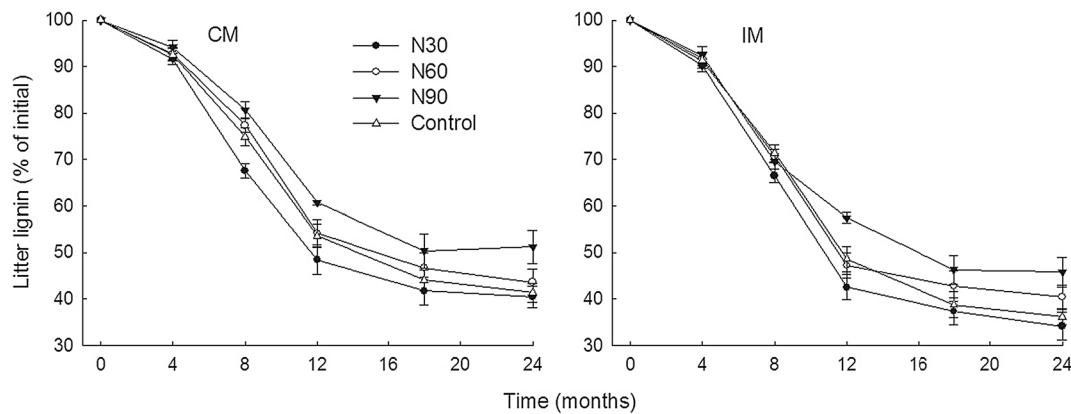
Fig. 5 Mean litter lignin (lignin,% of initial) with the standard deviation over time in the leaf litter decomposition of *Phyllostachys pubescens* under four treatments: low-N addition (N30, 30 kg N ha^{-1} yr^{-1}), medium-N addition (N60, 60 kg N ha^{-1} yr^{-1}), high-N addition (N90, 90 kg N ha^{-1} yr^{-1}), and a control in Moso bamboo forest with conventional management (CM) and intensive management (IM)

decomposition over a 20-month period, we also observed that low-N additions (30 kg N ha^{-1} yr^{-1}) significantly accelerated litter decomposition of *P. pubescens* (Song et al. 2014a). Nitrogen addition can enhance N availability and soil enzyme activity, thereby accelerating litter decomposition (Knorr et al. 2005; Manning et al. 2008). Lignin is a key factor in the regulation of litter decomposition, especially during the later decay stage (Austin and Ballaré 2010). Excessive N inputs have been demonstrated to suppress ligninolytic enzyme activity in the long term and correspondingly reduce litter decomposition (Fog 1988; Carreiro et al. 2000; Thirukkumaran and Parkinson 2000; Hobbie et al. 2012), although a few studies have found no evidence of negative effects (Hobbie et al. 2006). In the present study, lignin degradation was faster under the N30 treatment and slower under the N90 treatment than the control and slowed after 18 months of decomposition under all four treatments (Fig. 5). Therefore, the low-N addition facilitated lignin degradation, whereas the high-N addition suppressed lignin degradation. Our findings suggest that certain rates of N deposition, such as 30 kg N ha^{-1} yr^{-1}, can accelerate leaf litter decomposition of *P. pubescens*, whereas excessive N deposition, such as 90 kg N ha^{-1} yr^{-1}, suppresses decomposition. We predict that the critical threshold of N addition is likely between 60 and 90 kg N ha^{-1} yr^{-1} for *P. pubescens* leaf litter decomposition.

No significant differences in the litter decomposition rate were observed between the IM and the CM plots under the control treatment (Table 2). A two-way ANOVA also showed management practices alone did not significantly affect litter decomposition (Table 3), which does not support our second hypothesis. Balesdent et al. (1998) reported that intensive management practices, such as fertilizer application and tillage, could enhance microbial activity and consequently promote soil organic C mineralization. Xu et al. (1998) also observed that intensive management practices enhanced soil enzyme activity in the Moso bamboo plantations. Our previous studies at this site also found that intensive management practices improved the activity of soil β-fructofuranosidase and cellulose (Xuan et al. 2014). Our results indicate that these positive effects on soil biological properties were still not enough to create a significant difference in litter decomposition, although they contributed to a higher decomposition rate in the IM plots than the CM plots without N addition.

A two-way ANOVA showed that management practices combined with N addition significantly influenced litter decomposition (Table 3). Moreover, when combined with a low-N addition of 30 kg N ha^{-1} yr^{-1}, the management practices significantly accelerated lignin degradation and litter decay. However, when combined with a high-N addition of 90 kg N ha^{-1} yr^{-1}, which significantly retarded litter decomposition, these management practices significantly decreased lignin degradation and litter decay even further (Table 2, Figs. 2 and 5). Thus, the management practices amplified both the positive effects of the low-N addition and the negative effects of the high-N addition on *P. pubescens* leaf litter decomposition. This pattern supports the third hypothesis, i.e., a combination of management practices and N

deposition has stronger effects on litter decomposition than either factor separately.

Effects of N deposition and management practices on litter nutrient loss

The accumulation or release of nutrients from decomposing litter is predominantly regulated by the initial N content and the stoichiometric requirements of the microbial decomposers (Xu and Hirata 2005; Parton et al. 2007; Manzoni et al. 2010). N release takes place generally when the initial N content is between 0.6 and 2.8 % (Berg and Staff 1981) or the C:N ratio drops below a critical threshold of 5 to 15 (Parton et al. 2007; Manzoni et al. 2008). However, decomposers may become adapted to substrates with low N concentration by decreasing their C use efficiency and thus elevating the required critical C/N ratios of the litter for net mineralization to occur (Manzoni et al. 2008). In the current study, the initial litter N content (1.13 %) (Table 4) was in the lower range of the threshold suggested by Berg and Staff (1981), thus resulting in N loss under all the treatments. Although the C:N ratio (36.5) was higher than the threshold of 15, net N loss still occurred. A possible reason may be that N deposition positively affected the adaptation of the decomposer communities to low-N substrates and altered the stoichiometric requirement of the decomposers, thus facilitating the occurrence of N release. A similar result was also observed in our previous study (Song et al. 2014a). This result may imply that the microbial decomposers in Moso bamboo plantations have a higher stoichiometric threshold in decaying litter.

The effects of N addition on the activity of the soil microbial decomposers varied with the decay stage (Hobbie et al. 2012; Tu et al. 2012). In the early stage, N addition may increase the decomposers' activity (Molina et al. 1983; Madritch and Hunter 2003) and promote N release. However, in the later stage, the cumulative N addition effect tends to induce C-based

limitation of microbial decomposer activity (Thirukkumaran and Parkinson 2000; Andersson et al. 2004), limiting N release. In the present study, N loss in the CM plots was faster under the three N addition treatments than the control group in the first 8 months of decomposition but became significantly slower under N60 and N90 treatments after 12 months (Fig. 3). This pattern can be explained by early positive effects and the cumulative negative effects of N addition over time. In the IM plots, management practices may have improved microbial activity, and N addition, as another source of N, did not create positive effects on N loss in the early several months of decomposition but was associated with stronger negative effects in the later stage. The management practices may weaken the positive effects of N addition on N loss in the early stage of litter decomposition but enhance the negative effects in the later stage.

The C:P ratio regulates P release from decomposing litter. The critical C:P ratio, with a typical range between 200 and 480 (Gosz et al. 1973; Manzoni et al. 2010), varies across climatic regions and ecosystems. Tropical regions generally have a higher C:P ratio due to the compound effects of increased decomposer respiration, a high decomposer C:P ratio, and strong leaching (Manzoni et al. 2010). In the current study, the litter C:P ratio was far less than 480 and showed net P release from the beginning of the decomposition experiment under all treatments. The accumulation or release of P and N generally occur simultaneously (Manzoni et al. 2008, 2010). Unlike the effects on N loss in the later stage, management practices strengthened both the positive effects of N addition on P loss in the early stage and the negative effects in the later stage. In addition, physical processes, such as leaching, play an important role during decomposition in humid conditions, especially at the early stage of decomposition (Manzoni et al. 2010). In the present study, the leaching resulted from local abundant rainfall (Fig. 1) can also influence the effects of N addition on litter mass loss and nutrients release, which remains unclear.

Table 4 Initial leaf litter chemistry (mean±SD, $n=6$) of *Phyllostachys pubescens*

C (mg g^{-1})	N (mg g^{-1})	P (mg g^{-1})	Lignin (mg g^{-1})	C:N	Lignin:N	C:P
412.3±7.9	11.3±0.4	1.2±0.05	205.0±2.7	36.5±1.3	18.2±0.6	334.5±13.1

Conclusions

Our *P. pubescens* leaf litter decomposition experiment over a 24-month period found that the low-N addition significantly accelerated leaf litter decomposition, whereas the high-N addition significantly retarded decomposition ($P<0.05$). IM practices, such as weeding, ploughing, and fertilization, did not significantly influence decomposition alone but did amplify both the positive litter decomposition effects of the low-N addition and the negative litter decomposition effects of the high-N addition. N addition accelerated N and P loss in the early stage but suppressed N and P loss in the later stage. IM practices weakened the positive effects on N loss but enhanced the positive effects on P loss in the early stage and strengthened the negative effects on N and P loss in the later stage. The findings from this study provide a new perspective to better understand and estimate the biological effects of environmental change accompanying human management practices.

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