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Impact of nitrogen addition on plant litter decomposition in a sheepgrass meadow steppe

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In order to examine the effect of species (S) and nitrogen (N) on litter decomposition rate and the cumulative CO_2 emissions, litter from three species and soil samples subjected to different N-addition treatments (CK, LD, MD, HD) were collected from a sheepgrass (*Leymus chinensis* Tzvel) meadow steppe. We found litter of *L. chinensis* had higher initial nitrogen content and lower carbon to nitrogen ratios and decomposed faster than that of *A. hirta* while each species decomposing in isolation. Moreover, N addition significantly enhanced litter decomposition rate of each species. Estimated litter decay rate constant (k) under N-free treatments was significantly lower than expected based on N-added soils results, while the k was affected by nitrogen addition and increased by amount of nitrogen addition, indicating exogenous N additions could positive effects, and the positive effects of N additions on litter decomposition could influence litter decomposition and, therefore, Carbon as well as nutrient cycling in sheepgrass meadow steppe.

Key words: Nitrogen addition, Litter decomposition, CO_2 emissions, Sheepgrass meadow steppe**.**

INTRODUCTION

Litter decomposition is very important process in most land ecosystems. The procedure offers soil nutrients for vegetative cover development and affects land net primary production [1-2]. A lot of carbon (C) may go down into belowground for soil organic matter [3]. Besides, litter decomposition often affects the fluxes of soil C [4,5]. This means a key function in the carbon budget of land ecosystems [8]. Litter decomposition processes relate to C shift between plant litter and the soil ecosystem at the litter-soil interface [9].A lot of studies have been done to *in situ* examine what soil CO_2 emissions are affected by litter form [10], especially N-deficient grasslands in China. To research this issue in Songnen grassland with nitrogen limitation, the present study selected three plant species in Songnen grassland of China and studied its litter decomposition in a sheepgrass steppe ecosystem. We addressed the issues as follows: 1) to examine the effect of species (S) and nitrogen (N) on litter decomposition rate; 2) to examine the inference of S and N, and their interactions on the cumulative CO_2 emissions.

EXPERIMENTAL

Experimental site

The experiments were carried out in Lanxi County in Northeast China, which is run by the Heilongjiang Academy of Agricultural Sciences (HASS). The station has longitude of 125°58' E and latitude of 46°32' N. The climate is classified as a typically steppe environment.

Experimental design and sampling

There were 4 nitrogen addition treatments with four replicates at four levels: CK, LD, MD, HD; the area of each block was 10 × 10 m with a 2 m buffer between plots. Nitrogen was added as urea from 2010 to 2013. Then the soil samples were sieved and segmented into two parts. One part was used to monitor soil ammonium-nitrogen (ANsoil) and nitrate-nitrogen (NNsoil) concentrations and to do incubation experiments; the rest part was used to monitor soil pH, Csoil (soil organic C), Nsoil (soil N), Psoil (soil P), APsoil (soil available P) in the laboratory. The chemical properties were analyzed by a CNS elemental analyzer.

Soil CO_2 emission measurements

We calculated the CO_2 that was evolved from the plant litter by incubating soils without litter. We performed an incubation experiment using the first-order kinetic model following equation (1) [11]:

$$C_m = C_0 (1 - e^{-kt}) \qquad (1)$$

where C_m refers to the cumulative CO_2-C emissions; C_0 is the potentially mineralizable C (mg g^{-1}); k is the decomposition rate constant (day^{-1}), and t is the time of incubation (days).

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Statistics

All data were assessed by ANOVA with LSD using SPSS 20.0 (SPSS Inc., Chicago, USA). The decomposition kinetics was fitted by OriginPro 7.5 (OriginLab Corporation, USA).

RESULTS AND DISCUSSION

Litter chemical properties

The litter from each species had a different initial chemical composition. *Arundinella hirta* litter had the lowest N_{litter} and P_{litter} concentrations and the highest C_{litter} to N_{litter} ratio, while the opposite was found for *Leymus chinensis* litter. Although no significant differences were found between the N concentrations and C_{litter} to N_{litter} ratios for *L. chinensis* litter and *Carex duriuscula* litter, the initial N concentrations in *Carex duriuscula* litter were lower than those in *Leymus chinensis* litter but larger than those in *Arundinella hirta* litter. No significant differences in initial C_{litter} concentrations were found between the three species (Table 1). *Soil physicochemical property*

When soils from N addition treatments were tested before the incubation, soil total C_{soil}, N_{soil}, P_{soil} and AP_{soil} were not remarkably affected by the N-addition treatment (Table 2). However, N-addition treatment increased NN_{soil} and AN_{soil} concentrations (Table 2). It is seen from Table 2 that soil pH with N-addition treatment is significantly lower than that without N-addition treatment, and the highest pH value is for soil with HD treatment, while the lowest pH is registered in the soil without N-addition after N addition treatment (P < 0.05).

Effect of species and N addition on litter decomposition rate

Taking into consideration the total litter decomposition during incubation presented in Table 3, it follows that litter decomposition rate and nitrogen addition are significantly different for the four incubation periods (all P < 0.001). For each species, the decay rate constant (k) estimated by the first-order exponential model varied from 0.017 day^{-1} for litter of *A. hirta* in no N-added soils to 0.068 day^{-1} for litter of *C. duriuscula* in HD soils. Among the three species, *A. hirta* had the minimum attenuation rate (k) under all N-added conditions (P < 0.001), while k was affected by nitrogen addition and increased with the amount of nitrogen addition to soils mixed with the same litter type.

Cumulative CO_2 emissions

The cumulative amount of CO_2 from N-added (MD) soil with *C. duriuscula* litter was generally the highest one compared to all treatments, and *A. hirta* litter without N addition was the lowest among all treatments. Based on the time of incubation (days), the cumulative amount of CO_2 from different N-added soils with different litter was generally estimated by 12 models (equations) included in Table 4.

Table 1. Mean initial C_{litter}, N_{litter}, P_{litter}, C_{litter} to N_{litter} ratio, and N_{litter} to P_{litter} ratio of litter from the three species

Species	C_{litter} (mg g^{-1})	N_{litter} (mg g^{-1})	P_{litter} (mg g^{-1})	C_{litter} to N_{litter} ratio	N_{litter} to P_{litter} ratio
Arundinella hirta	460.3±3.6^a	12.5±1.3^c	1.0±0.05^b	36.8±2.7^a	12.5±1.1^b
Carex duriuscula	464.3±3.5^a	15.6±1.4^b	1.4±0.04^a	29.8±2.6^b	11.1±0.9^b
Leymus chinensis	465.3±3.8^a	16.3±1.3^a	1.1±0.06^b	28.5±2.9^c	14.8±1.3^a

Table 2. Chemical properties of soils with different treatments before the incubation.

T	Csoil	Nsoil	Psoil	APsoil	NNsoil	ANsoil	pH
CK	3.59±1.0a	0.32±0.02a	0.11±0.01a	10.22±0.3a	3.20±0.26d	4.22±0.06d	8.1±0.20a
LD	3.56±1.2a	0.31±0.01a	0.12±0.02a	11.38±0.4a	7.14±0.22c	10.63±0.04c	7.8±0.10b
MD	3.60±1.3a	0.33±0.02a	0.15±0.01a	12.32±0.2a	8.36±0.24b	12.50±0.09b	7.6±0.05c
HD	3.58±1.1a	0.28±0.03a	0.10±0.02a	11.46±0.4a	8.92±0.19a	13.31±0.03a	7.2±0.20d

Table 3. Two-way ANOVA of the effect of species (S) and nitrogen (N) addition on rate of litter decomposition in six incubation periods (Ⅰ, Ⅱ, Ⅲ, Ⅳ, Ⅴ and Ⅵ).

V	Incubation periods					
	I (5 days)	II (10 days)	III (15 days)	IV (20 days)	V (25 days)	VI (30 days)
S	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	<0.001	<0.001	<0.001	<0.001	0.376	0.054
S *N	<0.001	<0.001	<0.001	0.169	0.461	0.039

Table 4. Models (equations) of cumulative CO2 emissions of soils with different litter types and N addition.

Treatment	Models	R^2
Litter of A. hirta + CK	C m= 896.2 (1 – e-0.017t)	0.978
Litter of A. hirta + LD	C m= 764.5 (1 – e-0.028t)	0.991
Litter of A. hirta + MD	C m= 548.3 (1 – e-0.035t)	0.992
Litter of A. hirta + HD	C m= 468.7 (1 – e-0.039t)	0.990
Litter of C. duriuscula + CK	C m= 546.5 (1 – e-0.055t)	0.991
Litter of C. duriuscula + LD	C m= 522.3 (1 – e-0.059t)	0.988
Litter of C. duriuscula + MD	C m= 508.7 (1 – e-0.062t)	0.982
Litter of C. duriuscula + HD	C m= 448.0 (1 – e-0.068t)	0.998
Litter of L. chinensis + CK	C m= 646.9 (1 – e-0.045t)	0.998
Litter of L. chinensis + LD	C m= 528.5 (1 – e-0.049t)	0.998
Litter of L. chinensis + MD	C m= 510.3 (1 – e-0.052t)	0.998
Litter of L. chinensis + HD	C m= 496.1 (1 – e-0.059t)	0.998

In our study, the mixtures of litter powder and soil samples were fixed to similar glass jars. As a result, litter contact area may be least different from soil. A well-known fact is that litter decay depends on the soil nutrient status [12, 13]. This outcome was consistent with previous research [14, 15]. However, others have shown that litter decomposition may decrease [16], or not change [1, 18] under N addition conditions. Our findings on the cumulative relationship between CO_2 emissions and soil characteristics showed that cumulative CO_2 emissions increased in response to three different soil nutrient supply responses. The addition of inorganic nitrogen can change the nutritional status of soil microorganisms, thereby affecting the growth and activity of microorganisms, thereby affecting the decomposition of carbon and nutrient release from litter decomposition.

CONCLUSIONS

Our study revealed that litter of *L. chinensis* had higher initial nitrogen content and lower carbon-to-nitrogen ratios and showed a marked increase over that of *A. hirta*. Estimated litter decay rate constant (k) under N-free treatments was significantly lower than expected based on the results for N-added soils, while k was affected by nitrogen addition and increased with the amount of nitrogen addition, indicating that exogenous N additions could have positive effects, and the positive effects of N additions on litter decomposition could influence litter decomposition and, therefore, carbon, as well as nutrient cycling in a sheepgrass meadow steppe.

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