Effect of long-term nitrogen fertilization on composition and carbon utilization of soil microbial communities in a northern grassland, China

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INTRODUCTION

Background

Nitrogen (N) is one of the limiting factors on ecosystem productivity, the ever-increasing N deposition caused by human activities had a profound impact on ecosystems at global scale. Soil microorganisms modify carbon (C) decomposition, thus understanding how microbial communities reacts to nutrient additions will improve predictions of terrestrial C dynamics.

However, the responses of soil microorganisms to N fertilization have been inconsistent among studies, and the impacting mechanism of N on soil C by regulating microbial C utilization remains an open question, especially for cellulose-dominated grassland soils.

Objectives

This study tried to explore the alteration of the grassland soil microbial communities and the dynamics of their labile C utilization under a long-term N addition scenario.

There were 3 questions to be discussed:

- ❖ Impacts of N fertilization on microbial composition and their contributions to glucose utilization;
- ❖ Effects of N fertilization on the dynamics of glucose utilization by microbial communities during decomposition;
- ❖ Changes in the soil C components for microbial C and thus the change of soil C accumulation utilization by N fertilization.

METHODS

Study site

Duolun County, Inner Mongolia, China (42.02°N, 116.17°E).
Dry urea ($CO(NH_2)_2$) has been spread on the surface of the plots (15m × 10m each) in mid-July of each year since July 2003.

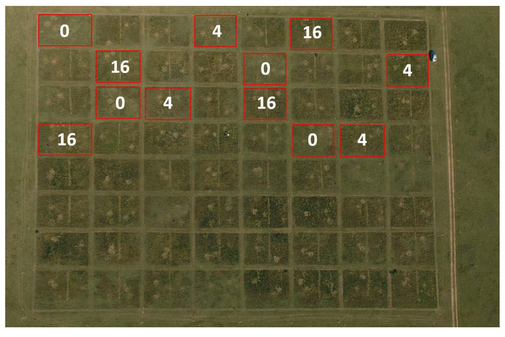


Table 1 Baseline soil properties.

N levels (g N m^{-2} yr^{-1})	Total C (%)	Total N (%)	Inorganic N (mg kg^{-1})	Soil pH
0	2.12(0.12)	0.21(0.01)	7.45(0.73)a	7.26(0.58)a
4	1.91(0.23)	0.19(0.03)	18.03(5.54)a	7.08(0.80)a
16	1.96(0.10)	0.20(0.01)	44.02(8.66)b	5.78(0.10)b

Different small letters indicates significant differences among N levels in the same sampling day ($p<0.05$).

Experimental design

3 × 2 factorial design

3: soil samples from N fertilization sites with 0, 4 or 16 N m^{-2} yr^{-1}
2: treatments of control or 0.4 mg ^{13}C labeled glucose g^{-1} soil

Soil samples incubated for 35 days at 20℃ and 70% water holding capacity. Destructively sampling conducted on day 7, 21 and 35 after glucose addition.

^{13}C-phospholipid fatty acid (PLFA) extraction followed by gas chromatograph combustion isotope ratio mass spectrometer for each destructively sampling.
Soil respiration, soil inorganic nitrogen for each sampling.
^{13}C in soil, soil total carbon and nitrogen for the last sampling.

RESULTS

Long-term N fertilization effects on microbial composition and their glucose utilization

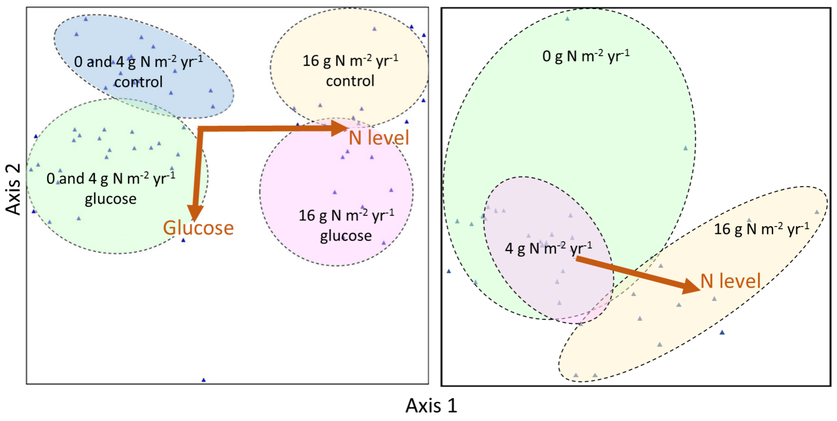


Figure 1 Non-metric multidimensional (NMS) scaling ordination plots of PLFA biomarkers (in %, left) and incorporated ^{13}C in PLFAs (in %, right) on day 7, 21 and 35. Dotted circles represent the clusters of samples, and red arrows indicate the factors associated to the groupings in samples.

Based on the Kendall correlations between PLFA biomarkers and the first ordination axis of NMS:

PLFA	Relative abundance (%)	^{13}C incorporation in PLFA (%)
Gram-positive bacteria	↑	↑
Actinomycete	↑	↑
Gram-negative bacteria	--------	↓
Saprophytic fungi	↓	↓

Long-term N fertilization effects on ^{13}C distribution in microbial communities during the course of decomposition

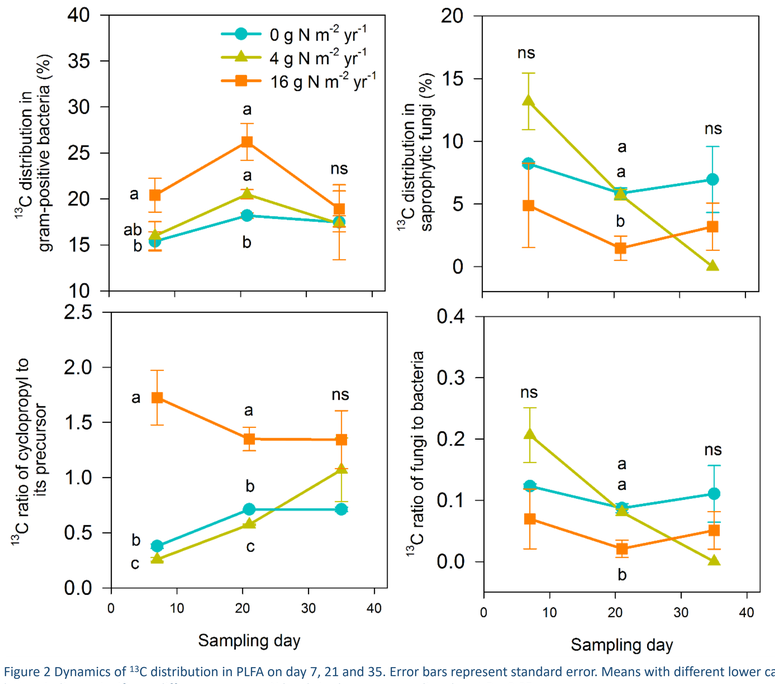


Figure 2 Dynamics of ^{13}C distribution in PLFA on day 7, 21 and 35. Error bars represent standard error. Means with different lower case letters indicate significant differences among N levels in the same sampling day at $P < 0.05$.

The ^{13}C distribution describes the proportion of ^{13}C incorporated in PLFA relative to the ^{13}C incorporated in total PLFAs.

- ➢ Competition for labile C indicated by the different dynamics of the ^{13}C distribution among microbial communities.
- ➢ High ^{13}C distribution in saprophytic fungi at the early stage of the incubation, and stable ^{13}C distribution in total bacteria during the process of decomposition .
- ➢ Stress on gram-negative bacteria indicated by the increased ratio of ^{13}C incorporated in cycloprophyl to its precursor under high N scenario.

Long-term N fertilization effects on soil C and N

Based on the differences between two substrate treatments:

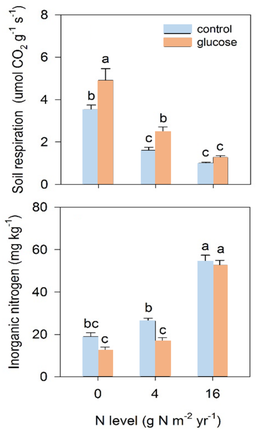


Figure 3 Averaged soil respiration rate (above) and averaged inorganic nitrogen (below) on day 7, 21 and 35. Error bars represent standard error. Means with different letters indicate significant differences at $P < 0.05$.

N mining theory, the highest positive priming effect on native SOM when N was most limited.

N level (g N m^{-2} yr^{-1})	Soil respiration (CO_2 g^{-1} s^{-1})	Inorganic nitrogen (mg kg^{-1})
0	**largest**	------
4	------	**largest**
16	**smallest**	**smallest**

Nutrient stoichiometry theory, an optimal nutrient ratio occurring when labile C was added with low N input.

Based on the different responses of soil microorganisms to low and high N fertilization:

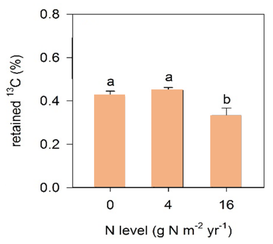
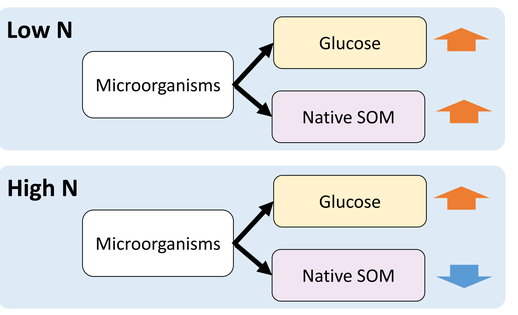


Figure 4 The difference of incorporated ^{13}C between phospholipid fatty acids and soil carbon on day 35. Error bars represent standard error. Different lower case letters indicate significant differences at $P < 0.05$.

The retained ^{13}C is the incorporated ^{13}C that passed through the microbial biomass and ended up in the SOM.



CONCLUSION

- ✓ N fertilization increased the proportion of gram-positive bacteria and enhanced its contribution to C utilization, but reduced the proportion of fungi and suppressed its contribution to C utilization.
- ✓ Decomposition theories such as 'nutrient stoichiometry' and 'N mining' were both supported in this study. N fertilization in this grassland might regulate the shift in labile C and SOM between soil microbial C utilization.

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Research interests: Responses of soil microorganisms to anthropogenic management, and soil carbon cycle regulated by soil microorganisms

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