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Short communication

Phosphorus additions have no impact on plant biomass or soil nitrogen in an alpine meadow on the Qinghai-Tibetan Plateau, China

Yongheng Gao[a,b,*], David J. Cooper[b], Xingxing Ma[a]

[a] Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, Chengdu, SC 610041, China
[b] Department of Forest and Rangeland Stewardship, Colorado State University, Fort Collins, CO 80523, USA

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ABSTRACT

Little is known about the effect of phosphorus (P) on plant biomass production or soil nitrogen (N) in alpine meadows. We conducted a four-year P addition experiment to assess the responses of plant biomass, plant N and P concentration, soil N availability, and microbial activities to a multi-level P enrichment (0, 2.5, 5, 10, 15 g P m^{-2} $year^{-1}$) in an alpine meadow on the Qinghai-Tibetan Plateau, China. The P treatments increased plant P and soil available P, but had no effect on plant biomass or plant N, soil available N, NH_4^+-N, NO_3^--N, and soil microbial activity during three consecutive sampling years. These results suggest that P is not a limiting nutrient for plant growth and not a key factor on regulating N cycling in this alpine meadow. Further research is needed to identify the role of P in driving vegetation biomass production and soil N dynamics and clarify whether vegetation and soil characteristics on alpine meadows are sensitive to P enrichment.

1. Introduction

The Qinghai-Tibetan Plateau is the largest and highest elevation plateau on earth, with abundant and widely distributed alpine meadows (Zheng, 2000). These meadows play a vital role in livestock forage production and husbandry, and also in climate regulation in Asia (Zheng, 2000; You et al., 2015). Due to the short growing season and low temperature in winter, soil available nitrogen (N) and phosphorus (P) for plant utilization are quite low and could limit plant growth in these meadows (Zhou, 2001). Several studies have demonstrated that N limits plant growth in alpine meadows and N additions increase soil inorganic N content (Li et al., 2014; Shen et al., 2002; Song et al., 2012), but little is known about P limitations on plant biomass production and soil N availability. The Qinghai-Tibetan Plateau is experiencing striking climate warming (Luo et al., 2010; Wu et al., 2015) that is expected to increase the decomposition rates of soil organic material. Thus, more inorganic P could be mineralized and released into the soil, potentially increasing soil P availability (Rui et al., 2012). Analyses of the effect of increased P could improve our understanding of how alpine meadow ecosystems may respond to global change.

We conducted a multi-level P addition experiment for four consecutive years in an alpine meadow on the Qinghai-Tibetan Plateau and measured the response of plant biomass, N and P concentration in plant biomass, soil N availability, and microbial activity. The objectives of our study were to: 1. Determine how above and belowground plant biomass and plant N and P content varied across the range of P addition levels; and 2. Determine if P additions influenced soil N availability, which could in turn feedback to influence plant biomass production.

2. Materials and methods

2.1. Study sites

This study was conducted in Hongyuan County, located on the eastern Qinghai-Tibetan Plateau, China (33°03′N, 102°36′E). It is 3500 m above sea level, with a harsh continental climate. Mean annual temperature is 1.1 °C. Annual precipitation averages 752 mm, with about 86% received from May to September (Gao et al., 2015). The soil is classified as Mat Crygelic Cambisol according to the Chinese national soil survey classification system (Chinese Soil Taxonomy Research Group 1995). The vegetation is a typical alpine meadow, dominated by *Kobresia setchwanensis* Hand.-Mazz. and *Elymus nutans* Griseb (Gao et al., 2011). Soil characteristic and vegetation productivity were showed in Table 1.

* Corresponding author.
E-mail address: yhgao@imde.ac.cn (Y. Gao).

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Table 1
Soil characteristics (0–20 cm) and vegetation productivity in the study site.

	Mean	SE	CV (%)
pH	6.05	0.02	0.65
Organic C ($g\,kg^{-1}$)	42.74	0.95	4.45
Total N ($g\,kg^{-1}$)	3.90	0.07	3.58
C/N	10.96	0.07	1.32
Total P ($g\,kg^{-1}$)	1.00	0.02	4.97
Available N ($mg\,kg^{-1}$)	334.7	6.58	3.93
Available P ($mg\,kg^{-1}$)	6.83	0.14	4.03
Vegetation biomass ($g\,m^{-2}$)	462.4	16.08	6.95

SE means standard error of the mean with 4 replicate measurements; CV, coefficient of variation.

2.2. Experimental setup and sampling

In early May of 2009, twenty 2 m × 2 m plots were laid out in a homogenous area of meadow sufficiently large to provide four replicates each of five P addition treatments (P0, P2.5, P5, P10, and P15 represent 0, 2.5, 5.0, 10, and 15.0 $g\,P\,m^{-2}\,year^{-1}$, respectively). These plots were arranged in a complete randomized block design and each plot was separated by a 1-m buffer zone. P was applied as a solution of NaH_2PO_4 dissolved in 2 L of water. Solutes were added evenly across the plots using a watering can in early May and July each year, during a period with little to no precipitation. The same volume of water was also applied to P0 plots designed as controls during each treatment event. Samples of plant and soil were collected in the middle of August during three consecutive years starting in the second year (2010) after P addition in 2009. Aboveground biomass was clipped at ground level in three random 0.25 m^2 quadrats within each plot, and was never collected in the same quadrat more than once. Root biomass was collected in three 5 cm diameter soil cores in each quadrat. The cores were washed through a 1-mm mesh screen to remove soil, and above ground material was also removed. All plant material was oven-dried at 70 °C to constant weight, and then weighed. All soil analyses were performed on five soil cores, each 5 cm in diameter and 20 cm deep, randomly collected in each plot and mixed into one composite sample.

2.3. Laboratory analyses

Soil organic C was tested by the Walkley-Black method (Lu, 1999). Soil and plant N was measured using the micro-Kjeldahl method (Lu, 1999). Soil and plant P was measured by spectrophotometer (Perkin Elmer Lambda 35, USA) after wet digestion with H_2SO_4 and $HClO_4$ (Lu, 1999). Available soil N was determined by the alkaline diffusion method (Lu, 1999). Soil NO_3^--N and NH_4^+-N was extracted with 2 M KCl for 1 h and the concentration was determined by continuous flow autoanalyser (Skalar San^{++} 8505, Netherlands). Available soil P was determined using Olsen method by extracting samples with 0.5 M $NaHCO_3$, and determining P colorimetrically using molybdate (Olsen and Sommers, 1982). Soil microbial biomass, C, N and P were measured using the chloroform fumigation extraction method (Wu et al., 2006). Fumigated and

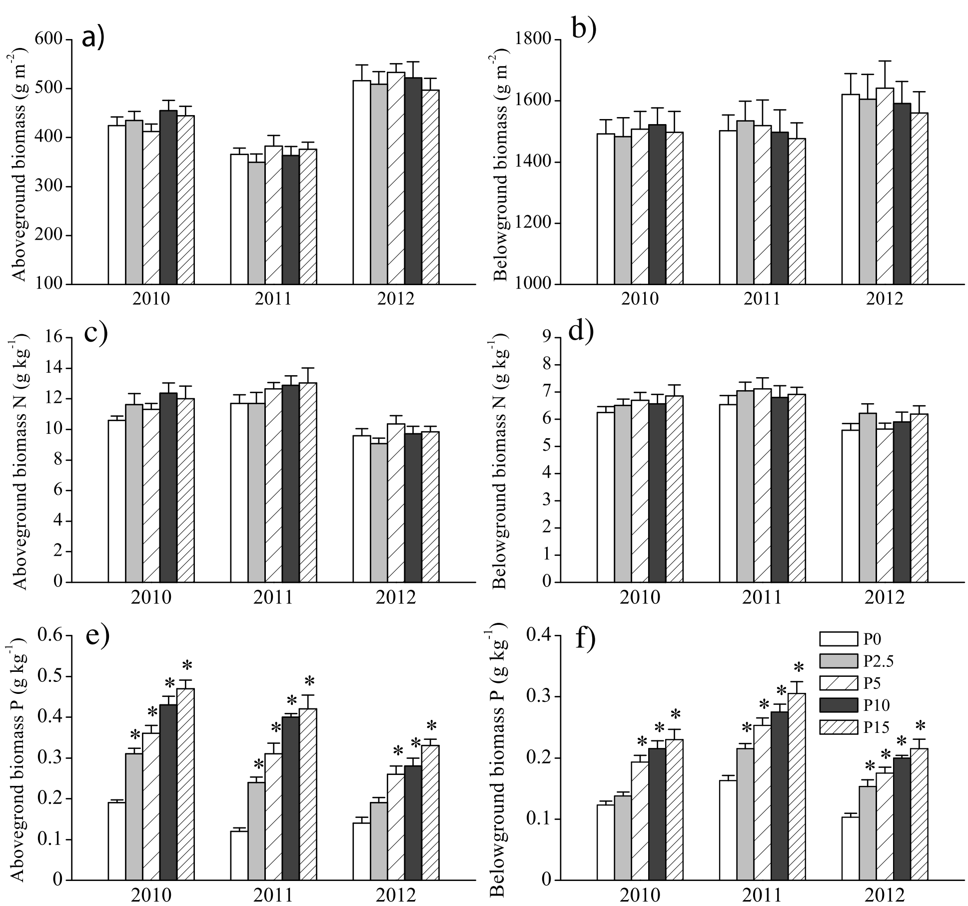

Fig. 1. Mean ± 1SE of plant above and belowground biomass, and N and P concentration in biomasses as affected by multi-level P addition. Asterisk indicates significant difference ($P < 0.05$) from P0 treatment.