Short-term effects of phosphorus application on phosphorus content in soil and dominant species under ungrazed and grazed conditions in the Tibetan Plateau

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Introduction

Phosphorus (P) availability in soils is an important indicator for health and growth in plants. The available phosphorus (AP) content of alpine meadow soil in northern China is low. Previous studies of alpine meadow have reported that soil nutrient levels have been significantly improved after a 9-year enclosure (Wu *et al.* 2010b) whereas continuous grazing over 19 years reduced total P (TP) by 25% in a *Leymus chinensis* steppe (Li 2001). Many studies have shown that the application of P fertilizer can improve dry matter production and forage quality in cultivated grasslands (Shi *et al.* 2007). However, the benefits of applying P fertiliser to alpine meadow in terms of increases in soil AP content and P concentrations in plants in both grazed and ungrazed meadows are less well known. The objective of this study was to investigate the short-term effects of P application on the AP content in top soil and total P content in the foliage of dominant meadow plant species.

Methods

Study sites and experimental design

A field experiment was conducted in an alpine meadow at Xiahe, Gansu, PRC, located at the eastern region of the Qinghai-Tibetan Plateau (35°07'52"N; 102°24'35"E; 3105 m a.s.l). The climate is cold and humid with an average annual temperature of 2.6°C (with the lowest daily temperature averaging−8. 9°C and concentrated in December, January and February), precipitation of 516 mm concentrated in July, August and September, and a frost-free period of only 20 days. The soil is classified as brown calcic soil with sand texture and its pH is 7.8, which is characterised by a thin humus layer and calcification. The SOC, total N and total P content is 48.7, 2.25, 0.56 g/kg, respectively. The vegetation was dominated by *Kobresia capillifolia* and *Elymus* spp. and the main associate species are *Poa* spp, *Saussurea* spp., *Anemone* spp. (Sun *et al.* 2011) which produce 70~100 g DM/m^2/year (Wu *et al.* 2010a).

A 64 m x 40 m area was fenced off within a grazing meadow and a similar adjacent area was selected for the ungrazed treatment. The 21 treatment plots (each 8 m x 5 m in area) were randomly allocated within the ungrazing and grazing meadows and were fertilized with P at differing concentrations, with three replicates per treatment. Fertilizer was applied to plots at 0 (control), 118 (P_1) and 197 (P_2) kg P/ha in the ungrazed meadow, and at 0 (control), 118 (P_1), 197 (P_2) and 299 (P_3) kg P /ha in the grazed meadow. Single superphosphate with a P content of 5.2% applied to the treatment plots in May 2012. Yaks were grazed at a rate of 10 yak/ha for the growing season (April to October) which followed the grazing intensity and grazing period used by local herders for grazing alpine meadow.

Soil samples were collected at 0-10 cm (topsoil), 10-20 cm and 20-30 cm depth increments. After drying soil was crush, sieved through a 2 mm screen, and the analysed for P. Lyme grass (*Elymus nutans*) was randomly harvested for plant samples in September, dried at 60 °C for 48h and analysed for P. Soil AP and plant P concentrations were measured by colorimetric using Molybdenum-Antimony Spectrophotometry. Statistical analyses were performed using SPSS, ver.17.0 (SPSS Inc., Chicago, IL, USA).

Results and Discussion

Under the P_1 (12 kg P/ha) treatment, soil AP content decreased slightly in top soil layer for both ungrazing and grazing meadows, with the reduction in the ungrazing meadow being lower than that in grazing meadow (Fig. 1-right). Under P_2 (20 kg P/ha) treatment, the AP content in the ungrazed meadow was increased (P<0.05) within the 0-10 cm soil layer, but AP content below 10 cm was not significantly affected (Fig. 1-left). In the grazed meadow, the trends of soil AP content under P_2 were consistent with that of the ungrazed meadow, indicating that the AP content were not significantly different among different P treatments although the AP in subsoils was low. Under P_3 (30 kg P/ha) treatment, soil AP content was increased slightly but the differences are not significant in the grazing meadow, indicating that the supply of P was at saturation (Fig. 1) because P is very slow moving due to fixation by Ca and Al (Chen 2005).

Application of phosphorus increased the P concentration in plants under ungrazing and grazing conditions, particularly in August. Dominant plant from the grazing meadow had a higher P concentration than that from the ungrazed, suggesting that grazing was beneficial to plant P uptake. The P concentration in plants firstly increased and

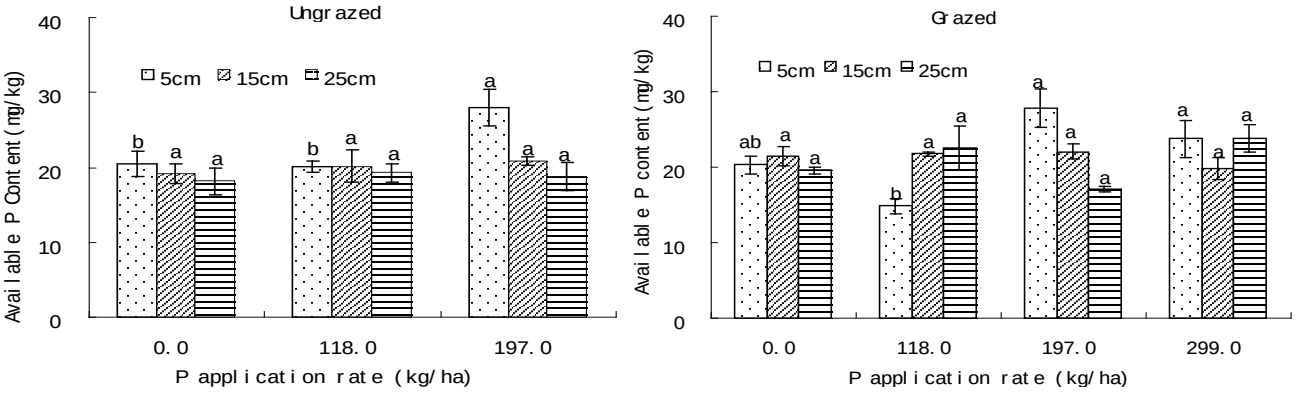

Figure 1. Soil available phosphorus content changes after P application on alpine meadow in the Tibetan Plateau. (The same bar with the different letter means significant differences at *P*<0.05).

Table 1. Effects of P rates on total P in lyme grass concentration under ungrazed and grazing conditions, at the beginning of August and September. Asterisks (*) are used to indicate it has significant difference with control at the same column (LSD test at *P* =0.05).

P application (kg/ha)	P concentration(mg/kg) in August		P concentration in September (mg/kg)	
	ungrazing	grazing	ungrazing	grazing
0	0.189	0.213	0.144	0.125
12	0.213	0.219	0.184*	0.127
20	0.216	0.279*	0.151*	0.144
30		0.256*		0.157*

then decreased as application of phosphorus increased, peaking at 20 kg P/ha under both grazing and ungrazing plot during growing season. Maximum efficiency appeared under 12 kg P/ha application rate. The P concentration in plants during August was higher than during September because the plant in late September has stoped growth in the study area (Table 1).

Conclusion

At a short term scale, the responses of meadow plants and top soil to P addition under ungrazed and grazed management conditions shows that soil in the study area is deficient in AP (Liebisch *et al*. 2013). This was especially the case in the grazing meadow, indicating that P application provides a means to improve alpine meadow fertility. The P concentration in Lyme grass is highly regulated by the application of fertilizer, with P concentration being more sensitive to low P application than higher P application, permitting the improvement of plant quality (Ji and Zhou 2009).

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