Fe and Mn concentrations in plants correlated negatively with air temperature precipitation in three types of grassland

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Keywords: alpine meadow; typical steppe; desert, trace element, climate.

Abstract. Alpine meadows, typical steppe, and deserts are globally important grassland ecosystems. We investigated the seasonal trends in Fe and Mn concentrations in the dominant species and community of plants from diverse grassland types in northwest China. It was found that seasonal Fe and Mn concentrations in most plant species were negatively correlated with seasonal precipitation, biomass, and temperature. Additionally, seasonal Cu concentrations in *Reaumuria soongorica* was significantly correlated with seasonal precipitation. The seasonal mean temperature explained more of the seasonal variation of the Fe and Mn concentrations in the plant community of these grasslands than precipitation, except for the concentrations of Mn in typical steppe vegetation. However, there was almost no significant correlation between these factors and the seasonal Cu and Zn concentrations. These results provided a scientific basis for the assessment of plant trace elements in alpine meadows, typical steppes, and deserts around the world.

Introduction

The concentrations of trace elements have a large temporal variability, both in the same plant species and between plant species, and the uptake of trace elements from soils by plants varies significantly with seasonal changes in precipitation and temperature (Zhang et al., 2014). Information on the seasonal changes in the characteristics of trace elements in plant species will allow an assessment of the temporal distribution and dynamics of trace element deficiencies or excesses in the forage used by grazing livestock in grasslands (Wang et al., 2014; Nedjimi, 2018).

Plant growth in the arid and semi-arid grasslands of northern China is often co-limited by the availability of different mineral nutrients and water (Xu et al., 2012). These ecosystems are sensitive to altered precipitation regimes (Niu et al., 2008). However, air temperature is the main factor restricting plant function and production in alpine meadows (Hou et al., 2016). , Therefore, it is hypothesized that the seasonal concentrations of trace elements in plants in alpine meadows are more correlated with the seasonal temperature than with precipitation, whereas, in typical steppe and desert grasslands, they are more correlated with the seasonal precipitation than the temperature.

Materials and methods

This research was conducted on three types of natural grassland in China: the alpine meadow of the eastern Tibetan Plateau; the typical steppe of the western Loess Plateau; and desert of the Northwest Inland Arid Region.To determine the above-ground biomass and the concentrations of trace elements in the vegetation, three blocks (5 ha/block), treated as three

replications, were set at each grassland site, with the distances between the nearest blocks in each grassland >10 km. Before plant sampling,, 30 quadrats in each block were randomly selected for subsequent sampling. The above-ground biomasses were collected from these quadrats on 20–30 April 2013 (spring), 15–25 July 2013 (summer), 20–30 September 2013 (autumn), and 20–30 December 2013 (winter). Each quadrat at the alpine meadow and typical steppe sites was 2 m × 2 m, whereas each quadrat at the desert site was 5 m × 5 m. The plants in each quadrat were manually classified by species and washed before calculating the biomass and determining the concentrations of trace elements. All samples were oven-dried at 65°C to a constant weight and then passed through a 0.5-mm plastic sieve. Plant Cu, Fe, Mn, and Zn concentrations in the plant were determined by atomic absorption spectrometry (Harlyk et al., 1997).

Results and Discussions

The seasonal Fe and Mn concentrations in most plant species were negatively correlated with seasonal precipitation, biomass, and temperature (Fig.1). There was a trend of no significant correlation between these factors and the seasonal Cu and Zn concentrations.There was a significantly negative correlation between the seasonal precipitation and the Cu concentration in *R. soongorica*. *R. soongorica* is generally found in saline lowlands in desert grasslands, so the effect of precipitation should be more obvious than in species growing on flat or high land (Zhuang et al., 2021). The concentrations of Cu in plants from the alpine meadow were very variable and the concentrations were lower than the recommended levels for feeding sheep and cattle in summer, autumn, and winter (NRC 2007). It is therefore necessary to supplement grazing livestock with a Cu lick block in these seasons. *K. capillifolia* and *K. humilis* contained significantly higher Cu concentrations than the other dominant plant species in summer and autumn.

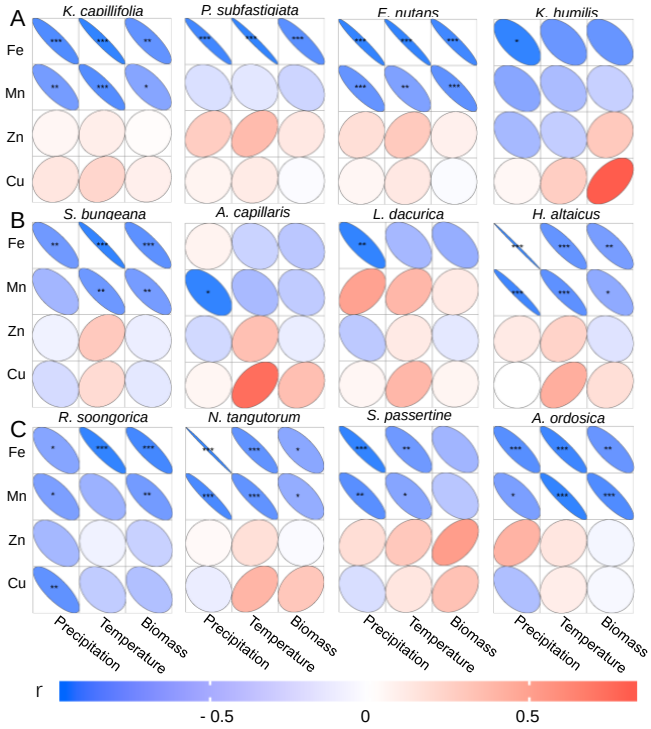

Figure 1. Correlation between seasonal precipitation, biomass, mean temperature, and seasonal TE

concentrations of the top four dominant species in the alpine meadow (A), typical steppe (B), and desert (C). Asterisk means significantly correlated (*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$).

Multiple linear regression was used to calculate the specific contribution of each factor to the Fe and Mn concentrations in the three types of grassland and showed that the seasonal temperature contributed more to the seasonal changes in Mn and Fe than the seasonal precipitation and biomass, except for Mn in typical steppe and desert grassland.Consistent with our hypothesis, the seasonal temperature explained more of the seasonal changes in Fe and Mn concentrations in the alpine meadow than the seasonal precipitation, whereas the seasonal precipitation explained more of the seasonal changes in Mn concentrations in the typical steppe and desert grassland than the seasonal temperature. However, the results that seasonal temperature explained more of the seasonal changes in Fe concentrations than precipitation in the typical steppe and desert grassland were inconsistent with our hypothesis. In agreement with previous research (Yang et al., 2019; Cai et al., 2017), the Fe concentration was much greater than the Mn concentration in the soils and plants in these grasslands, which may be why the low precipitation in arid and semi-arid grasslands hardly cause any change in the Fe concentration in plants. Compared with precipitation, dramatic changes in seasonal temperature directly affected soil water availability and indirectly affected Fe availability (Khan et al., 2006; Nedjimi, 2018).

Table 1. Contribution of the seasonal temperature, seasonal precipitation, and seasonal above-ground biomass with the concentrations of different trace elements in the three types of grassland.

Element	Factor	df	Type I SS	Contribution (%)	*F*	*P*
Alpine meadow						
Fe	Temperature	1	471154.9	94.09	213.37	<0.0001
	Precipitation	1	11375.9	2.27	5.15	0.0529
	Biomass	1	529.3	0.11	0.24	0.6376
	Error	8	17665.3	3.53		
Mn	Temperature	1	6796.2	87.39	238.75	<0.0001
	Precipitation	1	673.1	8.66	23.65	0.0013
	Biomass	1	80.1	1.03	2.81	0.132
	Error	8	227.7	2.93		
Typical steppe						
Fe	Temperature	1	1109.1	98.92	1482.74	<0.0001
	Precipitation	1	5.9	0.52	7.84	0.0232
	Biomass	1	0.2	0.02	0.30	0.5992
	Error	8	6.0	0.53		
Mn	Temperature	1	35050.54	4.23	6.76	0.0288
	Precipitation	1	746444.98	90.13	104.98	<0.0001
	Error	9	46696.58	5.64		
Desert						
Fe	Temperature	1	428000.3	94.06	145.57	<0.0001
	Precipitation	1	2862.5	0.63	0.97	0.3527
	Biomass	1	664.6	0.15	0.23	0.6472
	Error	8	23520.8	5.17		
Mn	Temperature	1	268.3	21.33	9.87	0.0138
	Precipitation	1	452.9	36.00	16.67	0.0035
	Biomass	1	339.5	26.99	12.49	0.0077
	Error	8	197.3	15.68		

Conclusions

A higher soil moisture content caused by higher precipitation resulted in a lower relative bioavailability of Cu, Fe, and Zn in alpine meadows than in the two rangeland types located in arid or semi-arid regions. There were antagonistic interactions of Fe and Mn in the typical steppe rangeland. High temperatures and low precipitation in the desert rangeland jointly resulted in lower availability of water and restricted the uptake of soil Fe and Zn by plants. The temperature had a greater impact than precipitation on the seasonal Fe and Mn concentrations in the alpine meadow. Precipitation may weaken the effect of temperature on the concentration of Mn in plants on typical steppe and desert rangelands.

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