Effects of grassland management and stocking rate on plant dry matter production and mineral content in Inner Mongolia steppe, China

X.Y Gong[1], P. Schönbach[1], M. Gierus[1], S. Lin[2], K. Dittert[3], F. Taube[1]

[1] Institute of Crop Science and Plant Breeding - Grass and Forage Science/ Organic Agriculture, Hermann-Rodewald-Strasse 9, D-24118 Kiel, Germany;
Email: pschoenbach@email.uni-kiel.de

[2] Department of Plant Nutrition, China Agricultural University, Beijing, 100094, P. R. China

[3] Institute of Plant Nutrition and Soil Science, Christian-Albrechts-University, Hermann-Rodewald-Str. 2, D-24118, Kiel, Germany

Introduction

Xilingole grassland is a typical semiarid steppe in northern China, which plays an important role on ecological sustainability and social economics. Due to the increasing grazing pressure and irrational land use, the fragmentation and degradation of this environment has rapidly advanced in the recent decay (Tong et al., 2004). In a large area of Inner Mongolia, overgrazing has already led to a sharp decrease grassland primary productivity (Liu et al., 1998; Bai et al., 2004; Zhong et al., 2005) and severe losses of soil nutrients (Liu et al., 1998). In the Inner Mongolian steppe, cases of nutrient element deficiency were found (Yu, 1995). Cu content of pasture in eastern Inner Mongolia was found to range from marginal to deficient (Wu, 1986). Some experiments also proved that more than 80% of plants in Inner Mongolia steppe were deficient in S (Wang et al. 2001).

Considering the severe problems of degradation and nutrient deficiency in Inner Mongolia, a grazing experiment was carried out, which aimed at investigating the dry matter yield and nutrient element content of steppe vegetation as influenced by grassland management and stocking rate.

Material and methods

A grazing experiment with two grazing systems (mix and traditional systems) and seven stocking rate (0, 1.5, 3, 4.5, 6, 7.5, 9 sheep/ha) was initiated in 2005. The experiment was a split-block design with two replicates. Each system included grazing area and haymaking area, which represented the main local grassland management. In the mix system (MS) annual shift between grazing and hay making plots was carried out, whereas the traditional system (TS) indicates permanent land use as haymaking and grazing areas without shift. Plant samples were collected at beginning of July 2006 by cutting plant at soil surface within a 0.5×1 m quadrate. Plant material was separated into litter and aboveground standing biomass (ASB), a subsample of ASB was sorted into green biomass and standing dead material. Afterwards all plant material was ovendried and weighted. Samples of ASB was milled and digested with HNO_3, then afterward analyzed by ICP for nutrient element concentration, including P, S, K, Mg, Ca, Fe, Mn, Zn, Cu, and Na. Analysis of variance was performed by using the general linear model of SPSS 11.5.

Results and discussion

Based on comparing the ASB of sampling 2006 (Fig. 1), ASB significantly decreased along the grazing intensities from 194 g/m^2 to 38 g/m^2 ($p<0.001$), whereas grazing system has no effect on ASB ($p=0.35$). Considering the proportion of standing dead material, the relative aboveground green biomass (RAGB) was calculated as the percentage of aboveground green biomass relative to ASB. RAGB was significantly increased by grazing rate ($p<0.01$), grazing system has no effect on RAGB ($p=0.11$).

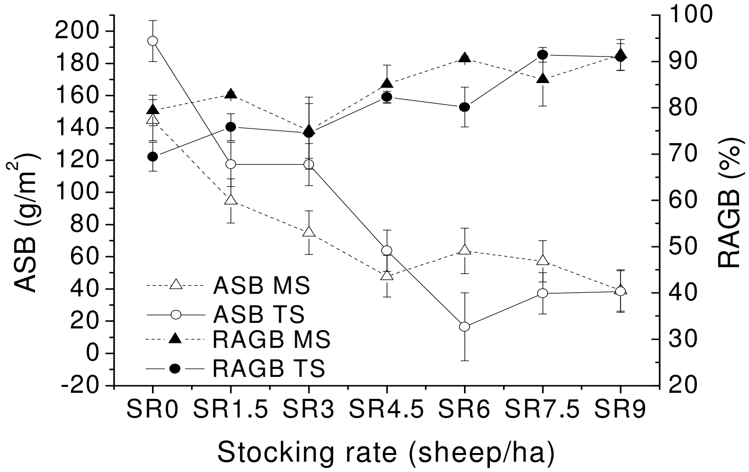

Figure 1: Plant aboveground standing biomass (ASB) and relative aboveground green biomass (RAGB) as influenced by grazing systems and stocking rates.

As shown in Table 1, the highest concentration of nutrient element in shoot of plant is K, followed by Ca ≥ P ≥ Mg ≥ S ≥ Fe ≥ Na ≥ Mn ≥ Zn ≥ Cu. Compared with the critical level for growth of perennial ryegrass (Whitehead, 2000), Ca, Fe, Zn content were quite high, which will not lead to nutrient deficiency. Mg, Mn, and Cu content were in a moderate level, nutrient deficiency may occur in some plots. P, S, and K content were in a quite low level, which will not fulfill the need of plant growth. Compared with the critical level of sheep (Underwood *et al*, 1999), K, Fe, and Mn were in a high level, which should be sufficient for sheep of all ages. P, Mg, Ca, S and Zn were in a moderate level, which may cause nutrient deficiency for certain age of sheep. Cu and Na content were extremely lower than the critical level.

Table 1: Plant nutrient element content under treatments of grazing systems and stocking rates (Level 1 means critical level for perennial ryegrass, Level 2 means critical level for sheep with different ages)

		P	S	K	Mg	Ca	Fe	Mn	Zn	Cu	Na
		mg/g	mg/g	mg/g	mg/g	mg/g	mg/g	mg/kg	mg/kg	mg/kg	mg/g
MS	SR0	1.1	0.91	9.7	1.2	4.9	0.45	22	20	4.7	0.17
	SR1.5	1.3	0.94	11	1.2	5.0	0.63	26	23	4.7	0.21
	SR3	1.2	0.89	9.2	1.2	5.6	0.57	23	23	5.4	0.21
	SR4.5	1.3	1.1	9.0	1.4	6.3	1.0	38	26	7.4	0.22
	SR6	1.3	1.1	11	1.9	5.8	0.72	30	26	6.1	0.27
	SR7.5	1.2	0.97	8.7	1.2	5.1	1.3	32	20	5.5	0.30
	SR9	1.5	1.2	10	1.7	5.7	0.73	29	23	5.8	0.30
TS	SR0	1.1	0.94	8.0	1.0	4.7	0.56	17	17	3.7	0.21
	SR1.5	1.3	0.88	9.6	1.1	4.8	0.56	22	17	3.1	0.31
	SR3	1.1	0.81	6.0	0.97	4.2	0.74	23	17	2.9	0.17
	SR4.5	1.3	0.87	8.2	1.0	4.4	0.67	26	19	3.2	0.14
	SR6	1.4	0.92	9.4	1.1	4.7	0.55	24	21	7.2	0.22
	SR7.5	1.8	1.1	11	1.5	5.4	0.87	39	29	5.9	0.30
	SR9	1.6	1.1	11	1.5	5.2	0.83	37	26	6.5	0.30
Level 1		2.8-3.0	1.8-2.5	18-20	0.6-1.3	1.0-3.0	0.05	20	10-14	4.0	-
Level 2		1.0-3.9	1.0-1.5	3	0.7-1.4	1.4-7.0	0.025-0.040	13-16	9.0-27	9.0-14	0.6-1.3

Grazing system and stocking rate affect the concentration of some elements. S content of plant was higher in mix system than in traditional system ($p<0.05$), and it increased along stocking rate ($p<0.05$). Grazing system has significant effect on plant Ca ($p<0.05$) and Zn ($p<0.05$) content, it shows that mix system have higher Ca and Zn content. For the other elements, a slight trend of increasing along stocking rates was found, but no significant effect of grazing system and stocking rate was detected.

Plant element yield was calculated by multiplying element concentration and ASB, the highest yield element is K (2 g/ m^2), followed by Ca (0.89 g/ m^2) ≥ P (227 mg/ m^2) ≥ Mg (226 mg/ m^2) ≥ S (169 mg/ m^2) ≥ Fe (128 mg/ m^2) ≥ Na (40.7 mg/ m^2) ≥ Mn (4.84 mg/ m^2) ≥ Zn (3.83 mg/ m^2) ≥ Cu (0.89 mg/ m^2) No significant effect of grazing system and stocking rate was found for all elements. It is mainly due to the buffering effect deriving from the decreasing of ASB and increasing of element concentration while grazing intensity increasing.

Since grazing was commonly considered to have effect of declining ASB and reducing standing dead biomass, and there is distinctively difference between nutrient content of green biomass and that of necrotic material, significant correlations were detected between plant dry matter production and nutrient content. The content of all elements negatively correlated to ASB (with the exception of Na), and positively correlated to the RAGB (table 2). Thus we conclude that the grazing effect on nutrient element content is mainly driven by changing of green biomass percentage under grazing.

Table 2: correlation analysis between element concentration and ASB and RAGB (* and ** mean correlation was significant at level of 0.05, 0.01, respectively).

		P	S	K	Mg	Ca	Fe	Mn	Zn	Cu	Na
ASB	r	-0.70	-0.75	-0.53	-0.66	-0.60	-0.47	-0.68	-0.76	-0.64	-0.34
	Sig.	**	**	**	**	**	*	**	**	**	ns
RAGB	r	0.67	0.73	0.53	0.65	0.55	0.53	0.59	0.60	0.41	0.47
	Sig.	**	**	**	**	**	**	**	**	*	*

Conclusion

Plant P, S, and K content were lower than the critical level for plant growth, and Cu, and Na content was extremely lower than the critical level of sheep requirement. After two years grazing, grazing treatments significantly influenced plant dry matter production, but distinctive effect on element content and yield wasn't detected.

Literature

BAI, Y., HAN X., WU J., CHEN Z., LI L. (2004): Ecosystem stability and compensatory effects in the Inner Mongolia grassland. *Nature* 431: 181-184.

LIU Z., WANG W., LIANG C., HAO D. (1998). The regressive succession pattern and its diagnostic of Inner Mongolia steppe in sustained and super-strong grazing. *Acta Agrestia Sinica* 6: 244-251.

TONG, C., WU, J., YONG, S., YANG, J., YONG, W. (2004): A landscape-scale assessment of steppe degradation in the Xilin River Basin, Inner Mongolia, China. *Journal of Arid Environment* 59, 133-149.

UNDERWOOD, E. J., SUTTLE, N., F. (1999): The mineral nutrition of livestock 3rd edition. *CABI,* New York.

WANG, S., WANG, Y., CHEN, Z., SCHNUG, E., HANEKLAUS, S. (2001): Sulphur concentration of soils and plants and its requirement for ruminants in the Inner Mongolia steppe of China. *Grass and Forage Science* 56, 418-422.

WHITEHEAD, D., C. (2000): Nutrient elements in grassland-soil plant animal relationships. *CABI*, New York

WU, L. (1986): Study on determination of copper content of pasture, feedstuffs and tissues of sheep and experiment of copper supplement to sheep. *Dissertation.* Inner Mongolia College of Agriculture and Animal Sciences.

YU, S. (1995): Review of mineral research in grazing sheep in China. *www.aciar.gov.au.*

ZHONG S., LI Y., CUI J., ZHAO W. (2005): Influence of continuous grazing and livestock exclusion on soil properties in a degraded sandy grassland, Inner Mongolia, northern China. *Catena* 59: 267-278.