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羊草(*Leymus chinensis*)草地雨天放牧与非雨天放牧的绵羊采食特征

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摘要:通过受控实验,比较了雨天和非雨天放牧在采食方式、采食损失量、践踏折损率以及土壤含水量和容重的差异。得出雨天放牧条件下,羊草各种采食方式的比例降低,去顶量依旧随放牧压升高而增加,但与非雨天放牧不同的是不再占主要比例。羊草采食损失量与非雨天差异不大,对于适口性更高的植物,如芦苇和全叶马兰,雨天放牧时损失更高。绵羊在冷湿环境中活动明显减少,羊草的践踏折损率各放牧压下差异不大,但芦苇的折损率依旧表现为随放牧压增强而增加。放牧后土壤15cm的含水量都低于对照小区,表明绵羊践踏加速了土壤水分的蒸发。放牧后土壤容重与放牧前和非牧区差异显著,并且容重随放牧压增强而增加。

关键词:绵羊;采食方式;践踏;羊草草地

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The grazing sheep characters in rainy day and rainless day on *Leymus chinensis* grassland

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Abstract: One of the disturbance factors of human on the grassland is grazing. Livestock grazing affects grasslands through defoliation and trampling and there have been many reports about the effect of grazing on grasslands under normal weather conditions. However, animal behavior may change in the situation of rainy days and the impacts on grasslands may be different. This is especially relevant in China where the herd persists in grazing as of old even after a drencher.

A study was conducted to determine differences in grazing effects between rainy and rainless days. The experimental design was as follows: a pasture of 2800m^2 was divided into three parts, the first part with 1200 m^2 was further divided into three plots of 400 m^2 each for the rainy day grazing treatment, the second part with 1200 m^2 was also divided into three plots of 400 m^2 each for the rainless day treatment, and the last part with 400 m^2 was used as the control without grazing for the rain day treatment. Each plot was grazed by 80 sheep for different time levels (30, 60 minutes and 90 minutes) with grazing rates of 10, 20 and 30 sheep·h/100m^2, respectively. In this paper we adopted the special parameter of ingestion type to describe sheep intake in the plant modulars. Two new indices, ingestion loss and trampling breaking rate, were proposed for the first time. The ingestion loss of sheep was used to indicate the waste mass during sheep foraging and the trampling breaking rate of plant was to measure activity intensity of sheep.

We compared changes such as ingestion type, ingestion loss, trampling loss, water content and bulk density in a rainy day

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and in a rainless day. We concluded that (a) the proportion of ingestion type for *Leymus chinensis* decreased, and the proportion of top-clipping, a major ingestion type, increased with increasing grazing intensity although it didn't occupy the most proportion any longer in a rainless day, (b) the difference in ingestion loss mass for *L. chinensis* under between grazing intensity was not significant, but for the preferred plants such as *Phragmites communis* and *Kalimeris interifolia*, it was much higher than that in a rainless day, (c) sheep reduced their movement in a rainy day, and trampling breaking rate for *L. chinensis* was similar between grazing rate while it increased with increasing grazing intensity for *P. communis*, similar to that in a rainless day, (d) soil moisture in three layers (0 ~ 5cm, 5 ~ 10cm, and 10 ~ 15cm) after grazing was less than that of control, indicating that trampling could reduce water availability in the soil, and (e) bulk density was significantly reduced by grazing($p < 0.05$) and increased with increasing grazing intensity.

Key words: sheep; ingestion types; trampling; *Leymus chinensis* grassland

放牧作为人类对草地的主要利用手段之一,其放牧方式和效果一直受到学者和生产管理者的关注、并展开了大量研究[1-8]。放牧家畜主要通过采食与践踏对草地施加影响。不同家畜由于食性的不同,其采食方式迥异[9-14];由于体重和行走方式的不同,对草地的践踏作用也各异[15-19]。而在雨天,受冷湿的环境影响,家畜的采食行为会发生何种变化和对草地的影响又会产生如何变化,研究者通常对此只有感性上的认识,而事实上牧民在具体实践过程中是不加分别的。因此,关于家畜采食与践踏对草地影响的研究需要进一步深入。

本研究旨在探讨不同放牧强度下,东北细毛羊在雨天环境下的采食方式和践踏对草地的影响。通过雨天放牧和非雨天放牧的比较研究,弄清雨天放牧的影响和破坏程度,首次提出了践踏折损率(Trampling breaking rate)和采食损失量(Ingestion loss)概念,用以描述绵羊放牧过程的两种结果,从而在理论上为生产实践提供参考依据。

1　自然概况与研究方法

1.1　自然概况

研究地区位于吉林省长岭种马场东北师范大学松嫩草地生态系统研究站(N 44°45′,E 123°45′)。该地区为松嫩平原南部,地势平坦,海拔高度在 137.8 ~ 144.8m 之间,属于半干旱、半湿润温带季风气候。年平均气温 4.9℃,无霜期为 136 ~ 163d。年平均降水为 400 ~ 500mm,主要集中于 6 ~ 8 月份,占全年降水量的 60% 以上,年蒸发量为降水量的 2 ~ 3 倍,主要土壤类型是盐化草甸土与碱化草甸土。实验样地的草地植被以羊草(*Leymus chinensis*)为优势种,芦苇(*Phragmites communis*)为亚优势种,其它伴生种有全叶马兰(*Kalimeris interifolia*)、小花碱茅(*Puccinellia tenuiflora*)、寸草苔(*Carex duriuscula*)、蔓委陵菜(*Potentilla flagellaris*)、蒙古蒿(*Artemisia anethoides*)、线叶旋复花(*Inula linariaefolia*)、箭头唐松草(*Thalictrum simplex*)、女菀(*Turczaninowia fastigiatus*)等。

1.2　实验设计和方法

在平坦的羊草 + 杂类草群落地段,设置固定样地 2800m^2,划分成 7 块面积皆为 400 m^2 小区,其中有 3 块进行雨天放牧实验(用 R1、R2 和 R3 表示),3 块进行非雨天放牧实验(用 P1、P2 和 P3 表示),1 块为对照(R0)。用 80 只 2 ~ 4 岁的东北细毛羊(体重(37.88 ± 3.37)kg)在放牧小区分别放牧 30、60min 和 90min,则各放牧小区梯度为 10、20sheep·h/100m^2 和 30sheep·h/100m^2,对照小区禁牧。该实验利用天然降水(表 1),于 2003 年 6 月进行。

表 1　天然降水和蒸发情况

Table 1　Natural precipitation and evaporation

项目 Item	月-日 Month-day							
	06-09	06-10	06-11	06-12	06-13	06-14	06-15	06-16
降水 Precipitation(mm)	42	17.4	0	38.1	0	1.5	0	0
蒸发 Evaporation(mm)	4.4	4.4	5.8	5.1	2.9	5.5	7.5	7.7

绵羊对羊草的采食方式的划分在已有研究中已述及[13]。采用对角线法,放牧后各取 0.25×0.25 m^2 的样方7个,齐地面刈割,带回实验室分种类统计各种采食方式的比例、密度,然后于65℃烘干至恒重,称量干物质量。绵羊采食过程中,一方面对植物的践踏会造成植物的机械损伤。把由于家畜的践踏导致折损的植物占该植物总数的百分比称为践踏折损率。按照对角线法用 0.50×0.50m^2 样方取样5个,统计样方内羊草的总数和折损的数量;另一方面,会有部分植物从绵羊的口中掉落,这部分植物有的是被绵羊故意弃食的,也有的是绵羊遗落的,但都没有被绵羊利用,故称之为采食损失量,放牧后按对角线法取5个 1m^2 大小的样方,收集各样方内损落的新鲜茎叶,回到实验室称量干物质量。放牧前和放牧后分别对土壤的容重和含水量以"S"形分3层(5、10cm 和 15cm)配对取样。容重取样 7~9 点,在每个容重取样点附近再取样3点,测量含水量,共计 21~27 点。数据处理采用 SPSS 中的单因素方差分析和 T 检验。

表2 雨天放牧地和非雨天放牧地植被情况

Table 2 The comparisons of vegetation on two pastures

植被情况 Vegetation		对照 CK	雨天放牧地 Pastures in rainy day			非雨天放牧地 Pastures in rainless day		
		R0	R1	R2	R3	P1	P2	P3
生物量 Biomass(g/m^2)	羊草①	127.32a	133.28a	134.67a	132.03a	131.09a	132.66a	132.50a
	芦苇②	26.95a	24.89a	24.50a	25.64a	28.28a	28.35a	26.35a
	全叶马兰③	7.96a	5.32a	6.10a	5.64a	8.64a	5.67a	10.76a
	总量 total	181.71	193.58	180.03	188	192.25	190.08	190.51
主要植物密度 Density of main species ($No./m^2$)	羊草①	846a	857a	834a	894a	880a	903a	889a
	芦苇②	45a	52a	57a	50a	53a	53a	50a
	全叶马兰③	37a	34a	32a	41a	38a	48a	48a

不同字母表示差异显著 $p<0.05$ The different letters in the same line mean significantly different($p<0.05$); ①*L. chinensis*; ②*P. communis*; ③*K. interifolia*

2 结果与分析

2.1 采食方式的变化

雨天放牧条件下,绵羊的牧食活动与非雨天放牧相比主要有3方面变化(图1)。

首先,绵羊减少了对植物的采食,对羊草的未采食比例明显增加($p<0.05$),平均是非雨天放牧2倍。这是由于绵羊减少了活动范围,由图3雨天践踏情况可以反映。

第2方面变化体现于对羊草的采食方式。绵羊对羊草的主要采食方式,包括去顶和摘叶,其比例明显减少,大约是非雨天放牧情况下的一半。

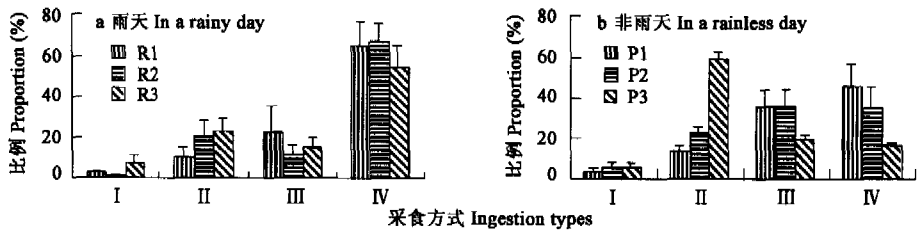

图1 雨天和非雨天绵羊对羊草的采食方式

Fig.1 Sheep ingestion types of *L. chinensis* in a rainy/rainless day

I 拔芯 Stem-drawing; II 去顶 Tops-clipping; III 摘叶 Defoliating; IV 未采食 Untouched

最后,绵羊在雨天放牧条件下仍然受放牧压影响,如去顶和摘叶的比例随放牧压减轻而增加。具体变化为:去顶量依旧随放牧压升高而增加,表明这一指标的变化趋势受牧压控制,而大小变化受环境影响,如雨天的冷湿环境。摘叶量在放牧压较低的小区维持较高,在放牧压较大的小区,如大于 20 sheep·h/100m^2 的小区,绵羊对羊草的采食方式将以去顶为主。牧草的叶子中含有较丰富的蛋白质、粗脂肪和可溶性碳水化合物,在

放牧压较低或者牧草现存量较丰富时,绵羊则增加叶片的选食而不愿采食茎部[20]。但在放牧压较大或者地上现存量有限时,绵羊会加大对茎部的采食,故增加了去顶量。无论在雨天还是在晴天,绵羊的拔芯量都维持较低水平,这表明绵羊选择拔芯的采食方式是随机性的。

2.2　采食损失量的变化

雨天放牧条件下,受雨天冷湿环境影响,植物被丢弃的比例要比非雨天放牧条件下增加(如图2),这表明雨天放牧时绵羊采食选择性增强。放牧过程中,全叶马兰被丢弃的比例增加显著($p<0.05$)。除羊草以外,其它植物的丢弃比例是非雨天放牧情况的2倍,甚至更多。特别是植物体上被毛的种类,如芦苇和全叶马兰,这种植物体会吸附更多的雨水,影响了绵羊采食。无论是雨天还是非雨天,绵羊对羊草的采食选择性都不强,羊草的丢弃量也大致相近;而雨天的冷湿环境提高了绵羊的采食选择性,故增加了在轻牧时的丢弃比例。

雨天放牧下,采食损失量也受放牧压影响,其中羊草和全叶马兰随放牧压增强而增加。这表明随放牧压或者说采食量的增加,植物丢弃的比例也增加,而在非雨天环境下,对于适口性较高的全叶马兰则不会出现这种现象。芦苇在各放牧压下损失量差异不显著。可见,放牧压对绵羊采食芦苇的影响没有冷湿环境影响大。

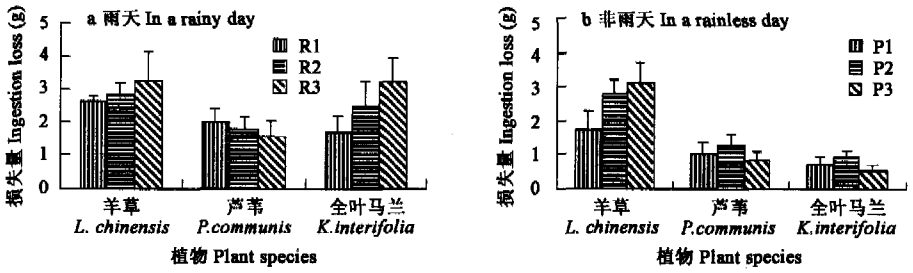

图2　雨天和非雨天绵羊采食损失量

Fig.2　Sheep ingestion loss in a rainy day and in a rainless day

2.3　践踏折损率的变化

雨天践踏折损比例明显降低(图3),羊草的折损比例几乎是平时的一半,芦苇也降低了近1/3。说明绵羊在雨天活动明显减少,践踏伤害减少;同时,由于植物体吸收较高水分,植物体弹性增加,也减少了植物体受折损的量。

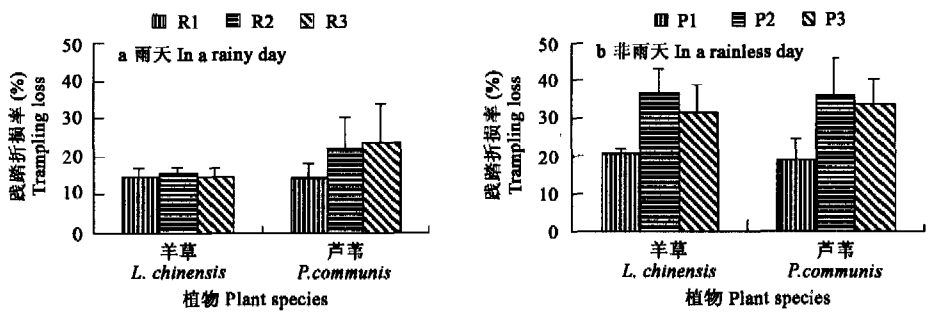

图3　雨天和非雨天绵羊践踏折损率

Fig.3　Trampling breaking rate of sheep in a rainy/rainless day

羊草践踏折损率在各放牧压下差异不大,说明在冷湿环境下绵羊在各放牧小区活动强度相近,践踏伤害减少。芦苇的践踏折损率依然随放牧压增强而升高。可见芦苇相对羊草更易受践踏伤害。同时说明践踏折损率是一个比较可靠的衡量家畜活动的指标,具有较高的灵敏性。

2.4　土壤含水量的变化

雨天放牧前后,土壤表层5cm变化极大(图4)。一方面有自然蒸发的原因,另一方面绵羊践踏也促进了

这一自然过程,所以各放牧小区土壤5cm的含水量都低于对照小区。而对照小区由于没有践踏,5cm层含水量最高,而各放牧小区5cm层含水量则低于10cm层含水量,说明没有受到扰动的土层具有较好的保水能力。这也反过来说明践踏破坏了地表土层结构,促进了表层土壤雨水的蒸发。而在不同放牧强度的小区,各土层土壤含水量都低于对照,表明雨天放牧对土壤的影响可以达到15cm深度,因此,雨天放牧会对土壤的保水能力产生负面影响,即使是短时放牧。而在非雨天放牧时,短时放牧一般是不会产生明显作用的(表3)。

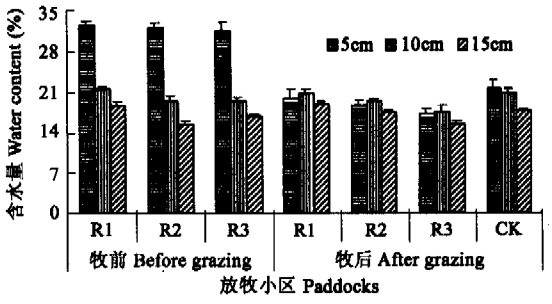

图4 雨天放牧前后土壤含水量

Fig.4 Contents of soil moisture before/after grazing in rainy day

表3 非雨天放牧前后土壤含水量变化

Table 3 Changes of soil moisture before/after grazing in rainless day

放牧区 Pastures	土层深度 Soil depth					
	5cm		10cm		15cm	
	①	②	①	②	①	②
CK	15.23 ± 1.24 a	15.61 ± 1.62 a	16.38 ± 1.87 a	15.77 ± 1.93 a	16.87 ± 1.56 a	16.60 ± 1.53 a
1	15.95 ± 0.84 a	16.01 ± 1.84 a	16.13 ± 0.90 a	16.04 ± 1.48 a	16.82 ± 1.44 a	16.85 ± 1.35 a
2	15.42 ± 1.31 a	15.41 ± 1.26 a	15.31 ± 1.17 a	15.45 ± 0.84 a	16.21 ± 1.11 a	16.09 ± 0.98 a
3	15.96 ± 1.62 a	15.29 ± 1.42 a	15.72 ± 1.28 a	15.19 ± 1.77 a	16.16 ± 1.91 a	16.49 ± 1.58 a

①放牧前 Before grazing; ②放牧后 After grazing; 不同字母间表示差异显著 The different letters mean significantly different ($p < 0.05$)

2.5 土壤容重的变化

雨天放牧对土壤含水量影响较大,对土壤容重的影响也十分强烈(表3)。

雨天放牧后土壤容重明显增加,与非牧区(CK)的土壤容重差异显著,与放牧前的土壤容重也呈现显著性差异。并且随放牧压增强,容重增加。表明绵羊雨天践踏对土壤会有强烈的踏实作用。而在非雨天环境下,仅一次放牧不会对土壤容重有明显影响。

表4 雨天与非雨天放牧前后土壤5cm层容重变化

Table 4 changes of soil 5cm bulk density in a rainy/rainless day before grazing and after grazing

	雨天 Rainy day		非雨天 Rainless day	
放牧区 Pasture plot	放牧前 Before grazing	放牧后 After grazing	放牧前 Before grazing	放牧后 After grazing
CK		1.2437 c		1.1212 a
1	1.1993 a	1.3523 b	1.1377 a	1.1288 a
2	1.2617 a	1.3945 d	1.1106 a	1.1208 a
3	1.2207 a	1.4409 de	1.1130 a	1.1292 a

不同字母表示差异显著 The different letters mean significantly different ($p < 0.05$)

3 结论与讨论

雨天放牧的负面影响一直以来都被国内外学者们所共识,但涉及具体的影响情况时,则缺乏相应的定量刻画。本研究发现绵羊雨天放牧不仅体现在对土壤的影响上,对植被的作用也与非雨天放牧有较大的差异。

在植被方面,雨天放牧绵羊的采食选择性增强,未采食植物比例大大增加,而且随放牧压减轻而增加,各种采食方式的比例都有降低的趋势。而在同时期非雨天放牧羊草是主要的采食牧草[9]。羊草的采食损失量与非雨天差异不大,但对于适口性更高的植物,诸如芦苇和全叶马兰,在低强度放牧时损失更高。绵羊在雨天对牧草采食策略的改变应该是本能和后天学习的结果,这可能是由于带有雨水的牧草不易被区分辨识,减少采食以避免误食毒草;同时,这所谓的"水草"在羊胃内容易发酵变质,诱发急性胃肠疾病。绵羊在冷湿环境中活动明显减少,羊草的践踏折损率各放牧压下差异不大,芦苇的折损率同非雨天放牧表现的趋势一致,随放牧压增强而增加。

对土壤的影响方面,绵羊践踏加速了土壤表层水分的蒸发。雨天放牧后土壤容重与放牧前和非牧区差异显著,并且随放牧压增强而增加。而在非雨天放牧时,仅一次放牧是不会对土壤物理性质产生强烈影响的。

References:

[1] Owens M K, Launchbaugh K L and Holloway J W. Pasture characteristics affecting spatial distribution of utilization by cattle in mixed brow communities. Journal of Range Management, 1991, 44(2): 118 ~ 123.

[2] Kemper J, Cowling R M and Richardson D M. Fragmentation of South African renosterveld shrub lands: effects on plant community structure and conservation implication. Biological Conservation, 1999, 90(2): 103 ~ 111.

[3] Maria F G and Barbara A D. Vegetation change along gradients from water sources in three grazed Mongolian ecosystems. Plant Ecology, 2001, 157(1): 101 ~ 118.

[4] Wang R Z. A study on the effects of grazing and mowing disturbances in *Leymus chinensis* grassland in Songnen Plain. Acta Ecologica Sinica, 1998, 18(5): 210 ~ 213.

[5] Wang Y F and Wang S P. Influence of different stocking rates on aboveground present biomass and herbage quality in Inner Mongolia Steppe. Acta Prataculturae Sinica, 1999, 8(1): 15 ~ 20.

[6] Bai Y F, Li D X, Xu Z X, *et al*. Growth and reproduction of *Stipa krylovii* population on a grazing gradient. Acta Ecologica Sinica, 1999, 19(4): 479 ~ 484.

[7] Wand S P, Li Y H, Wang Y F. Relationship between forage areas of sheep (wether) and spatial heterogeneity of grassland landscape. Acta Ecologica Sinica, 1999, 19(3): 431 ~ 434.

[8] Wang D L. Progress in the coadaptation and coevolution between plants and herbivores. Acta Ecologica Sinica, 2004, 24(11): 2641 ~ 2648.

[9] Wang S P. The dietary composition of fine wool sheep and plant diversity in Inner Mongolia steppe. Acta Ecologica Sinica, 2000, 20(6): 951 ~ 957.

[10] Liu J X, Hu Z Z and Ren J Z. The serial studies of ecological grazing and digestion and metabolism of sheep on alpine pasture Ⅰ. The study of forage preference index of grazing sheep. Acta Prataculturae Sinica, 1999, 8(3): 31 ~ 34.

[11] Zhao G, Xu Z X, Au T G, *et al*. Study on the grazing behavior of Mongolian cattle in spring. Grassland of China, 1998, 5: 50 ~ 55.

[12] Wang X, Wang D L, Liu Y, *et al*. Intake mass and diet selection for grazing goats on *Leymus chinensis* grassland. Acta Ecologica Sinica, 2002, 22(5): 361 ~ 667.

[13] Teng X, Wang D L, Cheng Z R, *et al*. Ingestion behaviors changes of sheep under different grazing intensities. Acta Prataculturae Sinica, 2004, 13(2): 67 ~ 72.

[14] Teng X and Wang D L. The negative effects of the sheep on the *Leymus chinensis* grassland. Journal of Northeast Normal University, 2002, 34:34 ~ 38.

[15] Cole D N and Spildie D R. Hiker, horse and llama trampling effects on native vegetation in Montana, USA. Journal of Environmental Management, 1998, 53: 61 ~ 71.

[16] Cole D N. Experimental trampling of vegetation Ⅱ. Predictors of resistance and resilience. Journal of Applied Ecology, 1995, 32(1): 215 ~ 224.

[17] Cole D N and Bayfield N G. Recreational trampling of vegetation: standard experimental procedures. Biological Conservation, 1993, 63: 209 ~ 215.

[18] Hou F J and Ren J Z. Evaluation on trampling of grassland Gansu wapiti (*Cervus elaphus kansuensis* Pocock) and its effects on soil property in winter grazing land. Acta Ecologica Sinica, 2003, 23(3): 486 ~ 495.

[19] Yao A X, Wang P, Xia J X, *et al*. Effects of different grazing intensity for dairy cows on soil characteristics of perennial ryegrass/white clover sward. Acta Agrestia Sinica, 1995, 3(3): 187 ~ 189.

[20] Heady H.F and Torell D T. Forage preferences exhibited by sheep with esophageal fistulas. Journal of Range Management, 1959, 12: 28 ~ 34.

参考文献:

[4] 王仁忠. 放牧和刈割干扰对松嫩草原羊草草地影响的研究. 生态学报, 1998, 18(2): 210 ~ 213.

[5] 王艳芬, 汪诗平. 不同放牧率对内蒙古典型草原地地下生物量影响. 草地学报, 1999, 8(1): 21 ~ 26.

[6] 白永飞, 李德新, 许志信. 牧压梯度对克氏针茅生长和繁殖的影响. 生态学报, 1999, 19(4): 479 ~ 484.

[7] 汪诗平, 李永宏, 王艳芬. 绵羊的采食行为与草场空间异质性关系. 生态学报, 1999, 19(3): 431 ~ 434.

[8] 王德利.植物与草食动物之间的协同适应及进化. 生态学报, 2004, 24(11): 2641 ~ 2648.

[9] 汪诗平. 不同放牧季节绵羊的食性及食物多样性与草地植物多样性间的关系. 生态学报, 2000, 20(6): 951 ~ 957.

[10] 刘金祥, 胡自治, 任继周. 高山草原绵羊放牧生态及消化代谢的研究 Ⅰ.放牧绵羊嗜食性研究. 草业学报, 1999, 8(3): 31 ~ 34.

[11] 赵钢, 许志信, 敖特根,等. 蒙古牛春季牧食习性的观察研究. 中国草地, 1998, 5: 50 ~ 55.

[12] 王旭, 王德利, 刘颖,等. 羊草草地生长季放牧山羊的采食量和食性选择研究. 生态学报, 2002, 22(5): 661 ~ 667.

[13] 滕星, 王德利, 程志茹,等. 不同放牧强度下绵羊采食方式的变化特征. 草业学报, 2004,13(2): 67 ~ 72.

[14] 滕星, 王德利. 松嫩平原草地放牧绵羊的破坏作用. 东北师范大学学报, 2002,34:34 ~ 38.

[18] 侯扶江, 任继周. 甘肃马鹿冬季放牧践踏作用及其对土壤理化性质影响的评价. 生态学报, 2003, 23(3): 486 ~ 495.

[19] 姚爱兴, 王培, 夏景新,等. 不同放牧强度下奶牛对多年生黑麦草/白三叶草地土壤特性的影响. 草地学报, 1995, 3(3): 187 ~ 189.