放牧密度の違いが羊草(シバムギモドキ)シュートの出生率と死亡率に及ぼす影響

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Short Report

Effects of Stocking Density on the Rates of Appearance and Death of *Aneurolepidium chinense* Shoots

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Introduction

The shoot density of grassland clonal plants alters with varying grazing severity[4]. Such changes in shoot density are determined by changes in the rates of appearance and death of shoots[13]. However, with the exception of a few type of grasses[7], the effects of grazing severity on changes in the rates of appearance and death of shoots are not actually known. Considering the mechanisms of these rate changes may aid the development of grazing management systems that could maintain the shoot density of clonal plants, an important source of nourishment for animals.

Aneurolepidium chinense (Trin.) Kitagawa is a clonal plant that is dominant in meadow steppe regions ranging from the northeastern part of China to Inner Mongolia[15]. The nutritive value of *A. chinense* and its palatability for domestic animals are both relatively high[1,3]. However, in recent years, *A. chinense* growth has been decreasing in overgrazed areas[6,8,12]. Replacing *A. chinense*, unpalatable plants such as *Artemisia frigida* have gradually become dominant in these areas[8,14]. To prevent a decrease in the shoot density of *A. chinense*, we need to be able to determine the rates of appearance and death of the shoots as these rates relate to grazing severity. In the present study, we examined how these aspects of plant growth and death change under different stocking densities.

Materials and Methods

The study site was located on the Baiyinxile Livestock Farm (43°26′-44°08′N, 116°04′-117°05′E), Xilin Gol League, Inner Mongolia Autonomous Region, P. R. China. A semi-arid continental temperate steppe climate predominates in this region, known for its dry spring and moist summer[5]. The annual mean temperature is −0.4℃ and there are 150-180 plant-growing days per year[5]. The annual precipitation amounts to 320-400 mm and is concentrated in the months of July, August and September[5]. The combination of high temperature with high humidity in the summer provides suitable conditions for the growth of steppe plants.

A. chinense, which is one of the most dominant

A portion of this study was presented at the 51st meeting (March 1996) of the Japanese Society of Grassland Science.

species in this area[5], is a rhizomatous plant and mainly propagates in an asexual manner. The shoot (vegetative stem) stands individually and does not form tufts. Ear emergence of *A. chinense* is rare in years with much precipitation[2]. In dry years, however, ear emergence occurs in the middle of July[2]. Grazing effects on *A. chinense* shoots were examined by an experimental stand in which *A. chinense* was dominant. The experimental stand was constructed in 1989 by the Inner Mongolia Grassland Ecosystem Research Station of the Chinese Academy of Sciences. The stand was composed of various plots with the following variety of stocking densities : non-, light-, moderate-, and heavy-grazing[9]. Each plot was 1 ha in size and was enclosed by a fence. On all of the plots except for the non-grazing plot, sheep (Jargalant sheep ; 40 kg in weight on average) grazed for the following periods : from 5 June to 20 June, 20 July to 5 August, and 5 September to 20 September. The stocking density (per ha) of sheep on the non-, light-, moderate-, and heavy-grazing plots was 0, 4, 12, and 20, respectively, during each grazing period. Thus, the total grazing heads (per ha · year) were 0, 180, 540, and 900, respectively. The experimental grazing period extended for 7 years from 1989 to 1995.

We randomly placed three quadrats (50 cm×50 cm/quadrat) in each plot on 3 July 1995 and marked all shoots of *A. chinense* found in each quadrat by burying a numbered stick near the base of each shoot. The height of the marked shoots was also measured at that time. At about 10-day intervals thereafter (until 5 September 1995), each quadrat was examined and the number of surviving shoots was counted. Non-marked shoots (new shoots) were then also marked and the shoot heights were measured. Here, a vegetative stem that existed independently with live leaves at the above-ground level was defined as a shoot. A shoot counted as an "appearance" when it emerged at the ground level. Shoots were considered to be dead when they no longer supported live leaves and when the stem was showing obvious signs of decay. The number of leaves per shoot was also recorded during the same period. In early September, we measured the plant cover of each species in each of the research quadrats.

The appearance and death rates (one shoot^{-1} day^{-1} 0.25 m^{-2}) of *A. chinense* shoots in each quadrat were calculated for the following three periods. The 1st period was the rest period beginning after the 1st grazing period and extending to just before the 2nd grazing period. The 2nd period was identical to the 2nd grazing period. The 3rd period was a next rest period extending from after the 2nd grazing period to the day before the 3rd grazing period. These rates were calculated by using the following equations.

Appearance rate (one shoot^{-1} day^{-1} 0.25 m^{-2})$=N_n/N_t/T$

Death rate (one shoot^{-1} day^{-1} 0.25 m^{-2})$=N_d/N_t/T$

N_n : Number of new shoots observed during each period.

N_d : Number of dead shoots observed during each period.

N_t : Number of shoots on the first day of each period.

T : Number of days included in each period.

The rate of increase in shoot density was obtained by subtracting the death rates from the appearance rates.

Increase rate (one shoot^{-1} day^{-1} 0.25 m^{-2})=(Appearance rate)−(Death rate)

An ANOVA was performed in order to determine differences among the grazing plots on the shoot height, the number of leaves per shoot, the appearance rate, the death rate, and the shoot density. As regards changes in every investigate day on the shoot height and the number of leaves, a repeated measures ANOVA was performed in each grazing plot. Stat View 5.0 software (SAS institute) was used for these calculations.

Results and Discussion

1. The cumulative effects of 6 years of grazing

The vegetation of the plots was as follows. In the non-grazing plot, *A. chinense, Artemisia frigida*, and *Carex korshinskyi* were dominant. In the light-grazing plot, *A. chinense, A. frigida, C. korshinskyi*, and *Cleistogenes squarrosa* were dominant. In the moderate- and heavy-grazing plots, *Potentilla acaulis* were dominant and *A. chinense, A. frigida, C. korshinskyi, C. squarrosa*, and *Kochia prostrata* were subdominant. The shoot density of *A. chinense* on 3 July tended to decrease with an increase in grazing severity (Table 1). Nakamura *et al.*[11,12] reported that *P. acaulis, C. korshinskyi*, and *C. squarrosa* were species with increased growth rates that correlated with intensifying grazing pressure, and *K. prostrata* was a species that grew irrespective of grazing pressure. On the other hand, *A. chinense* was classified as a "decreaser" under heavy grazing conditions[8,11,12]. In the moderate- and heavy-grazing plots used in this study, the grazing-tolerant species such as *P. acaulis* were in the process of becoming dominant.

Significant differences were observed on the shoot height in each investigate day among grazing plots (ex. 3 July ; $F=54.0$, $p<0.01$). The shoot height was ranked as follows : non-grazing>light-grazinging>moderate-grazing>heavy-grazing (Fig. 1a). The difference among plots seems to be due to both effects of cumulative grazing of 6 years and first grazing in 1995. On the other hand, no effects of long-term grazing were found on the number of

Table 1. The plant cover and shoot population characteristics of *Aneurolepidium chinense* under different stocking densities during the period from 3 July to 5 September 1995.

Grazing plot	*A. chinense* cover (%)	Shoot density on 3 July (0.25 m^{-2})	Shoot density on 5 Sept. (0.25 m^{-2})	Shoot appearance rate (10^{-3} one shoot^{-1} day^{-1} 0.25 m^{-2})			Shoot death rate (10^{-3} one shoot^{-1} day^{-1} 0.25 m^{-2})			Shoot increase rate (10^{-3} one shoot^{-1} day^{-1} 0.25 m^{-2})		
				Ⅰ [a]	Ⅱ [b]	Ⅲ [c]	Ⅰ	Ⅱ	Ⅲ	Ⅰ	Ⅱ	Ⅲ
Light-grazing	23	38	43	3.02	2.63	9.17	1.10	2.98	3.97	1.92	−0.34	5.20
Moderate-grazing	18	26	24	2.85	0	1.70	2.22	11.29	0	0.63	−11.29	1.70
Heavy-grazing	10	21	17	2.04	2.53	0.72	2.16	15.38	6.15	−0.12	−12.86	−5.43
Non-grazing	34	50	52	0.19	0	5.00	2.38	3.22	0.69	−2.19	−3.22	4.31

[a] Ⅰ : During the period following the 1st grazing period to just before the 2nd grazing period.
[b] Ⅱ : During the 2nd grazing period.
[c] Ⅲ : During the period following the 2nd grazing period to just before the 3rd grazing period.

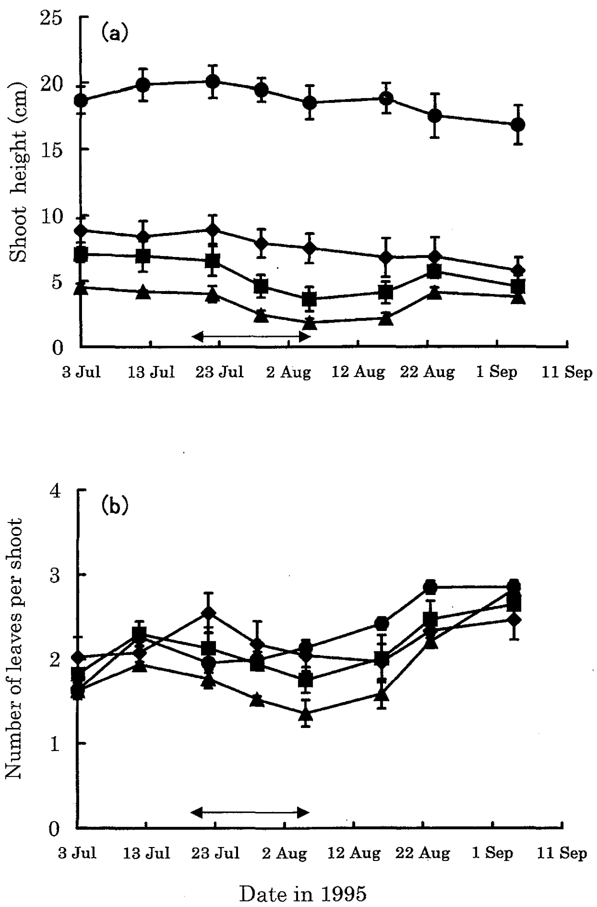

Fig. 1. Changes in the shoot height (a) and the numbe of leaves per shoot (b) of *Aneurolepidium chinense*.
◆ : Light-grazing plot, ■ : Moderate-grazing plot, ▲ : Heavy-grazing plot, and ● : Non-grazing plot.
Bars show standard errors. An arrow shows a grazing period.

leaves per *A. chinense* shoot (Fig. 1b). On 3 July and 12 July, almost no difference in the number of leaves per shoot among plots was observed (3 July ; $F=1.3$, NS. 12 July ; $F=2.1$, NS). The numbers of leaves per shoot ranged from 1.6 to 2.0 on 3 July, and from 1.9 to 2.3 on 12 July, on all of the plots. The effects of long-term grazing on *A. chinense* shoots seem to be manifest in the shoot density and the height, and not the number of leaves.

2. The effects of grazing in 1995

In all plots, ear emergence of *A. chinense* was rarely observed during the period from early July to early September. A significant difference among dates was shown on the shoot height in the moderate- and heavy- grazing plots (moderate-grazing ; $F=5.1$, $p<0.01$. heavy-grazing ; $F=14.8$, $p<0.01$), while it was not shown in the light- and non-grazing plots (light-grazing ; $F=2.2$, NS. Non-grazing ; $F=0.8$, NS). During the 2nd grazing period, shoot heights in the moderate- and heavy-grazing plots decreased remarkably (Fig. 1a). After the grazing period, shoot height in these plots recovered rapidly (Fig. 1a). As regards the number of leaves per shoot, a significant difference among dates was shown in the heavy- and non-grazing plots (heavy-grazing ; $F=18.1$, $p<0.01$. non-grazing ; $F=24.3$, $p<0.01$), while it was not shown in the light- and moderate-grazing plots (light-grazing ; $F=1.0$, NS. moderate-grazing ; $F=1.0$, NS). In the heavy-grazing plot, the change in the number of leaves per shoot was similar to that in the shoot height (Fig. 1b). On the other hand, the number of leaves in the non-grazing plot increased from earlier than those of the other plots (Fig. 1b).

The shoot density in the moderate- and heavy-grazing plots decreased during the study period from 3 July to 5 September (Table 1). The decrease in the shoot density in these plots was caused by both a decrease in the appearance rate and an increase in the death rate. In the first rest period, there were hardly any differences among plots as regards the appearance and death rates. The appearance rates in the period ranged from 0.19 to 3.02 (10^{-3} one shoot^{-1} day^{-1} 0.25 m^{-2}), and the death rates ranged from 1.10 to 2.38 (10^{-3} one shoot^{-1} day^{-1} 0.25 m^{-2}), on all of the plots. However, during the 2nd grazing period, the death rates in the moderate- and heavy-grazing plots increased rapidly ; the rates were 11.29 and 15.38 (10^{-3} one shoot^{-1} day^{-1} 0.25 m^{-2}), respectively. These results seem to be due to direct damage by grazing animals. Due to the increased death rate, the shoot density in these plots greatly fell during this period. Moreover, in the heavy-grazing plot, the decrease in shoot density continued until the rest period following the grazing period. In the 3rd period, the appearance rate in that plot was the lowest ; 0.72 (10^{-3} one shoot^{-1} day^{-1} 0.25 m^{-2}), and the death rate was the highest ; 6.15 (10^{-3} one shoot^{-1} day^{-1} 0.25 m^{-2}), among all of the plots. Conversely, in the light-grazing plot, the shoot density had recovered during the rest period due to an increase in the shoot appearance rate. The tendency toward significant difference among plots was shown only in the 3rd period (Appearance rate : $F=3.35$, $p=0.076$. Death rate : $F=3.49$, $p=0.058$). There was a significant difference among plots as regards the increased rate of shoot density ($F=5.08$, $p<0.05$).

Though the shoot height and leaf number per shoot had recovered after grazing in the heavy-grazing plot, the shoot density decreased due to a decrease in the appearance rate and an increase in the death rate. Among the *A. chinense* plants on the plot, priority was given to the production of new leaves or to the regrowth of old leaves instead of to the production of new shoots. On the other hand, in the light-grazing plot, the plants appeared able to produce not only new leaves but also new shoots. A decrease in the appearance rate under conditions of high stocking density was also reported in the vegetative and aerial tillers of *Lolium perenne* in the spring, when shoots typically grow rapidly[7]. With regard to the response of *A. chinense* shoots to light grazing, LI and WANG[10] have reported that light grazing of *A. chinense* shortened internodes on the rhizome and thus more shoots were produced, in contrast with the effects of moderate and heavy grazing.

The present results suggest that both changes in the rates of appearance and death of *A. chinense* shoots play an important role in altering shoot density under different grazing conditions. Grazing management at a low stocking density like 4 heads/ha used in this study would prevent the lowering of the appearance rate of this plant, as well as prevent an increase in the death rate. Thus, such a light grazing would be necessary for the maintenance of an *A. chinense* shoot population.

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