冷蒿草原土壤可萌发种子库特征及其对放牧的响应

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摘要: (1)采用萌发试验法对内蒙古冷蒿(*Artemisia frigida*)草原土壤种子库特征及其在不同放牧压力下的变化进行了研究。(2)冷蒿草原可萌发种子库由 4 种多年生禾草、11 种多年生杂草及 3 种 1 年生植物所组成。(3)每样中的可萌发种子量变化于 45 到 305 之间, 平均 102/样。多年生禾草、多年生杂类草及 1 年生植物的土壤中种子量分别占总可萌发种子库的 46.57%、51.96%和 1.57%。多年生禾草糙隐子草(*Cleistogenes squarrosa*)是种子库中的优势种。(4)土壤可萌发种子库与地上植被间的相关程度较低。但轻度放牧提高了种子库与植被的相似度。(5)冷蒿草原多数种类的可萌发种子在土壤中的分布为集聚型分布。(6)可萌发种子库的种类组成以及多数种类的土壤中种子量均随放牧压力的增加而减少; 但放牧增加了整个可萌发种子库分布的均匀度。

关键词: 可萌发种子库; 冷蒿草原; 放牧

Germinable soil seed bank of *Artemisia frigida* grassland and its response to grazing

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Abstract: Features of germinable seed bank in *Artemisia frigida* grassland in Inner Mongolia and their responses to grazing were studied using germination test. Four perennial grasses, eleven perennial forbs and three annual species were detected in the seed bank. The number of germinable seeds per soil sample ranged from 45 to 305 with an average of 102. Seeds of perennial grasses, perennial forbs and annuals accounted for 46.57, 51.96 and 1.47 percent of the total seed bank, respectively. Perennial grass *Cleistogenes squarrosa* was the most abundant species in the seed bank. A relatively low similarity was found between the soil seed bank and its associated vegetation. However, light grazing increased the degree of the correlation. Distribution patterns of the buried seeds of most species were clumped. Species richness of the seed bank and quantities of the germinable seeds of most species were reduced by grazing disturbance, while grazing impact increased evenness of the seed bank distribution.

Key words: germinable soil seed bank; *Artemisia frigida* grassland; grazing

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1 Introduction

The grassland in Inner Mongolia, which constitutes 38 percent of the total grassland area in China, is major base for husbandry of the country. However, grazing-degraded grassland area is increasing rapidly

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in recent years[1]. To halt grassland retrogression and reconstruct already degraded grasslands, it is important to understand regeneration process of the grassland vegetation and its response to grazing.

Soil seed bank is an important stage of the vegetation regeneration; species composition and quantity of the seed bank may have profound influence on future vegetation[2~4]. In this paper, we selected *Artemisia frigida* grassland, a wide spread grazing-degraded grassland in Inner Mongolia, to study features of germinable seed bank of the grassland and their responses to sheep grazing of different intensities.

2 Materials and methods

2.1 Study site

The study area lays in central Inner Mongolian Plateau (43°33′N, 116°40′E; elevation 1190m). Mean monthly temperatures range from −22.3℃ in January to 18.8℃ in July. Accumulated temperature≥10℃ is 1598℃ and frost free period is about 100 days. Annual precipitation is 350mm and 70 percent of it fall between July and September. The zonal soil is chestnut soil and the natural vegetation is typical temperate grassland dominated by *Stipa grandis* and *Leymus chinensis*. Along the river and around the residential places where grazing is much more frequent, the vegetation is dominated by *A. frigida*. Experimental plots was located at Xilin Gol River bank and the stocking rates for ungrazed, lightly grazed, moderately grazed and heavily grazed plots were 0, 4, 12, 20 sheep/hm^2, respectively. Vegetation and environmental conditions of the four plots were unanimous before the grazing experiment.

2.2 Seed bank and vegetation sampling

Since seeds of most plants in temperate zone need a period of low temperature treatment before germination, soil seed bank was sampled in spring (April 12, 1995), just before the vegetation turn green. From each of the four plots described above, ten $20\times20cm^2$, 2.5cm deep soil samples were taken randomly.

Vegetation was sampled in preceding growing season (July 1994). Five $1m^2$ quadrates were placed randomly on each of the four plots to record species composition and statistical features of the grassland communities under different grazing intensities.

2.3 Germination test

After litters and roots were removed, the soil samples were spread thinly(<2cm) in separate flower pots within 72 hours after collection. The flower pots were placed in a glass house under natural light and watered regularly to maintain soil moisture between 17.5 and 44.4 percent. Air temperature inside the glass house was 15～30℃.

The number of seedlings was recorded weekly after the first seedling emerged from the soil. Meanwhile, all the seedlings were identified to species except those of *Allium* spp., until no additional seedlings emerge from the soil. The germination test continued 80 days.

2.4 Statistical analysis

Differences among sites in seed densities of species detected in the seed banks were examined using ANOVA. Distribution pattern of the buried germinable seeds of each species was analyzed by variance-to-mean distribution index. Spearman's rank correlation coefficient was applied to assess the similarity between the seed bank and its associate vegetation. Species' ranks based on above-ground population density were paired with ranks based on density of buried germinable seeds for this analysis.

3 Results

3.1 Composition and quantity of the seed bank

Germinable seed bank of *A. frigida* grassland was composed of 18 species. Of them, there were four perennial grasses, eleven perennial forbs and three annuals. The number of germinable seeds per sample

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ranged from 45 to 305 with a mean of 102. Seeds of perennial grasses, perennial forbs and annuals constituted 46.57, 51.96 and 1.47 percent of the total seed bank, respectively. Perennial grass *Cleistogenes squarrosa* dominated the seed bank.

There were significant differences among plots in seed densities of species *C. squarrosa*, *S. grandis*, *Potentilla tanacetifolia*, *Allium* spp., *Artemisia scoparia* and *Chinopodium aristatum*(Table1). The number of buried germinable seeds of perennial species *C. squarrosa*, *P. tanacetifolia* and *Allium* spp. were decreased significantly with increasing grazing pressure, while that of annual species *Ch. aristatum* was increased monotonously along the grazing gradient. The size of germinable seed banks of *S. grandis* and *A. scoparia* was largest under light and moderate grazing, respectively. The quantity of buried germinable seeds of perennials was reduced with increasing stocking rate, while that of annuals increased.

3.2 Distribution of the seed bank

Distribution patterns of buried germinable seeds of most species detected in the seed bank of *A. frigida* grassland were clumped, and the degree of aggregation was increased by grazing disturbance for most species. However, distribution evenness of entire seed bank was increased by increasing grazing impact (Table 1).

3.3 Relationship between the seed bank and vegetation

Fifteen species appeared in the vegetation while 18 species were detected in the seed bank. Only ten of these species were shared by both vegetation and the seed bank. Spearman's rank correlation coefficients were 0.691, 0.784, 0.451 and 0.597 for ungrazed, lightly grazed, moderately grazed and heavily grazed plots, respectively. Therefore, it can be concluded that light grazing increased correlation between the seed bank and vegetation on *A. frigida* grassland.

4 Discussion

Seed banks of different vegetation types were frequently studied in recent years[3~13]; however, few studies were carried out on seed banks of vegetation in China[14~18], especially on features of seed bank of semiarid grassland in China[19].

There are two major kinds of methods to study composition and quantity of seed bank. One is germination test and the other is direct identification. The former one tends to underestimate size and composition of seed bank because not all the viable seeds in the soil would germinate under glass house condition, while the latter always overestimates seed bank since inviable seeds of some species may present in the soil. The latter also lacks accuracy in identification of seeds to species. In this paper, we applied germination test to study readily germinable seed bank of *A. frigida* grassland.

Since different species within the same community may have widely different distribution patterns in the seed bank[3], area of sample unit and number of repetition seem vital to seed bank study. We sampled uppermost 2.5 cm soil, since more than 85 percent of the buried germinable seeds in the seed bank were within this layer[19]. Samples of large size ($20\times20cm^2$) were taken to avoid big differences among samples. Species-area curve leveled at 8～9 samples (Fig. 1); therefore, ten soil samples could reflect basic properties of the seed bank of the grassland reliably.

Composition of the seed bank was rare and size was also small being compared with other studies conducted on grassland habitats[4,8,20]. Most probable causes are: 1). regeneration of some major components of the community depends largely on vegetative reproduction (such as *Leymus chinensis*); 2). the year prior to seed bank sampling was somewhat arid compared with average level; low precipitation may have reduced seed rain quantities of the species.

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Increasing stocking rate reduced species diversity of seed bank of *A. frigida* grassland. However,

Table 1 Densities and distribution indices of buried germinable seeds of species detected in seed banks of *A. frigida* grasslands under different stocking rates

	Seed number per sample					Distribution index			
	UG	LG	MG	HG	*F* value	UG	LG	MG	HG
Perennial grasses									
Cleistogenes squarrosa	43.5	33.5	31.3	10.0	4.92**	6.2+	6.7+	33.6+	6.7+
Stipa grandis	0.2	0.5	0.1	0.0	2.71*	0.9	1	1	—
Leymus chinensis	0.0	0.1	0.0	0.0	1.0	—	1	—	—
Carex duriuscula	3.7	4.0	6.6	3.0	2.42	2	2.4+	2.7+	2
Koeleria cristata	0.1	0.0	0.0	0.0	1.0	1	—	—	—
Perennial forbs									
Artemisia drancunculus	0.5	1.4	0.8	0.2	0.36	5+	14+	8+	2+
Artemisia frigida	3.3	4	2.2	0.6	1.39	5+	10.6+	1.4	1.9
Artemisia pubescens	32.4	0.2	0.1	0.0	1.94	165+	0.9	1	—
Artemisia scoparia	10.7	24.3	35.5	20.9	2.64*	5.4+	6.5+	35.1+	10.7+
Astragalus galactities	0.0	1.0	0.0	0.0		—	10+	—	—
Gueldenstaedtia verna	0.0	0.0	0.0	0.1	1.0	—	—	—	1
Melilotoides ruthenicus	0.8	0.4	0.0	0.0	1.39	3.3+	4+	—	—
Thalictrum petaloideum	0.1	0.1	0.0	0.0	0.67	1	1	—	—
Potentilla tanacetifolia	2.1	0.0	0.0	0.6	6.64***	2.3+	—	—	1.9
Potentilla acaulis	0.9	0.5	1.7	1.9	1.45	5.5+	1.4	2.4+	1.2
Kochia prostrata	0.0	0.0	0.0	0.1	1.0	—	—	—	1
Poligonum divaricatum	0.0	0.2	0.2	0.0	1.5	—	0.9	0.9	—
Allium spp.	2.0	1.1	0.0	0.0	4.50*	2.4+	3.1+	—	—
Iris tanuifolia	0.1	0.0	0.0	0.0	1.0	1	—	—	—
Orostachys fimbriatus	0.1	0.0	0.0	0.2	0.73	1	—	—	2
Annuals									
Chenopodium aristatum	0.1	0.1	2.1	11.5	12.5***	1	1	7.3+	6.9+
Chenopodium glaucum	0.1	0.0	0.0	0.3	1.44	1	—	—	1.5
Lappula redowskii	1.3	1.9	1.4	2.3	0.18	1.4	4.7+	2.4+	15.3+
Setaria viridis	0.0	0.0	0.5	0.0	1.86	—	—	2.3+	—
Total	102	73.3	82.5	51.7	2.20	54.9+	7.9+	15.4+	9.2+
Species number	18	16	12	13					

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, otherwise $P>0.05$. + aggregate distribution.

buried germinable seed densities of perennial grass *Stipa grandis* and perennial forb *Artemisia scoparia* were highest under 4 and 8 sheep/hm^2 stocking rates, respectively. Several reasons may account for this: 1). defoliation stimulated the species to set more seeds; 2). trampling promoted burial of the seeds; 3). Livestock digestion and trampling facilitated germination of the seeds. Buried seed densities of other main

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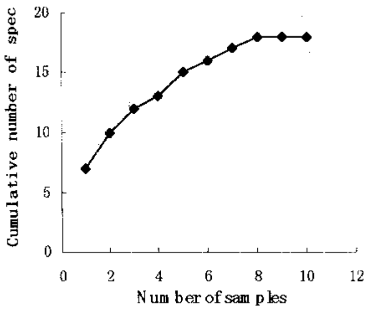

Fig. 1　Cumulative number of species detected in germinable soil seed bank of *A. frigida* grassland with increase of soil samples

perennial species decreased monotonously with increasing stocking rate. Seed densities of all major components were lowest in the plot of 20 sheep/hm^2 stocking rate except that of annual species *Chenopodium aristatum*. Therefore, stocking rate on *A. frigida* grassland should not exceed 8 sheep/hm^2 since seed bank of *A. frigida* grassland under higher stocking rate may fail to support normal regeneration of the community.

Germinable seed bank of *A. frigida* grassland showed an aggregate distribution pattern, which means a limited dispersal of the seeds of the species on the grassland. However, distribution evenness of seed bank was highest under 4 sheep/hm^2 stocking rate, which indicated that light grazing could promote dispersal of the seeds on *A. frigida* grassland.

A relatively low correlation was observed between the seed bank and its associate vegetation; similar results were reported by several other studies carried out on grassland[4,7,8,21,22]. This is probably because: 1). some seeds still remain dormant under glass house condition; 2). seeds could accumulate in soil through years if environmental conditions cannot break their dormancy; 3). wind and animal activities could bring seeds of neighboring communities into the soil of *A. frigida* grassland while a portion of seed rain of the grassland may also be lost; 4). predation from vertebrate and invertebrate predators. Light grazing increased relationship between the seed bank and vegetation of the grassland in this study; interpretation of mechanism for this phenomenon needs further study.

Detailed studies of entire regeneration processes (i. e. population→seed rain→seed bank→seedling recruitment→population and/or population→vegetative propagule→population) of main species and their responses to abiotic and biotic environmental factors should be the focus of the future research.

References

[1] Li Bo, Yong Shipeng, Zeng Sidi, *et al*. Remote sensing analysis and mapping of vegetation in Inner Mongolia. *Application Research of Remote Sensing on Grassland Resources Survey in Inner Mongolia*. Inner Mongolia University Press, Huhhot, China. 1987, (3):111～127.

[2] Harper J L. *Population Biology of Plants*. Academic press, London, 1977.

[3] Thompson K. Small-scale heterogeneity in the seed bank of an acidic grassland. *Journal of Ecology*, 1986, **74**: 733～738.

[4] Henderson C B, Petersen K E & Redak R A. Spatial and temporal patterns in the seed bank and vegetation of a desert grassland community. *Journal of Ecology*, 1988, **76**:717～728.

[5] Graham A W & Hopkins M S. Soil seed banks of adjacent unlogged rainforest types in North Queensland. *Australian Journal of Btany*, 1990, **38**: 261～268.

[6] Hopkins M S, Tracey J G & Graham A W. The size and composition of soil seed-banks in remnant patches of three structural rainforest types in North Quensland. *Australian Journal of Ecology*, 1990, **15**: 43～50.

[7] Thompson K & Grime J P. Seasonal varia-tion in the seed banks of herbaceous species in ten contrasting habitats. *Journal of Ecology*, 1979, **67**:893～921.

[8] Coffin D P & Lauenroth W K. Spatial and temporal variation in the seed bank of a semiarid grassland. *American journal of Botany*, 1989, **76**(1):53～58.

[9] Poiani K A & Johnson W C. Effect of hydroperiod on seed-bank composition in semipermanent prairie wetlands.

万方数据

Canadian Journal of Botany, 1989, **67**:856～864.

[10] Ungar I A & Woodell S R J. The relation-ship between the seed bank and species com-position of plant communities in two British salt marshes. *Journal of Vegetation Science*, 1993, **4**:531～536.

[11] Vieno M, Komulainen M & Neuvonen S. Seed bank composition in a subarctic pine-birch forest in Finnish Lapland: natural variation and the effect of simulated acid rain. *Canadian Journal of Botany*, 1993, **71**,379～384.

[12] Ingersoll C A & Wilson M W. Buried propagule bank of a high subalpine site: microsite variation and comparisons with aboveground vegetation. *Canadian Journal of Botany*, 1993, **71**:712～717.

[13] Cocks P S. Changes in the size and composition of the seed bank of medic pastures grown in rotation with wheat in North Syria. *Australian Journal of Agricultural Research*, 1992, **43**:1571～1581.

[14] Liu Qinghong. The dispersion of korean pine seeds and the effect on natural regeneration in the mixed korean pine and broad-leaved tree forest of the Xiao Xing An Mountains. *Acta Phytoecologia et Geobotanica Sinica*, 1988, **12**(2):134～142.

[15] Xiong Limin, Zhong Zhangcheng & Li Xuguang. A preliminary study on the soil seed banks of different successional stages of subtropical evergreen broad-leaved forest. *Acta Phytoecologia et Geobotanica Sinica*, 1992, **16**(3):249～257.

[16] Liang Xuegong & Wang Gang. Dynamic of soil seed bank and prediction of vegetation succession in Sha Po Tou sand fixation area. *Annual reports from Sha Po Tou desert research shation*, Can Su science and techno-logy press, Lan Zhou, China. 1993

[17] Yang Yunfei, Zhu Ling & Zhang Hongyi. Analysis on the flux of soil seed bank and the seedling mortality in the Song Nen Plain in China. *Acta Ecologia Sinica*, 1995, **15**(1):66～71.

[18] An Shuqing, Lin Xiangyang & Hong Bigong. A preliminary study on the soil seed banks of the dominant vegetation forms on Bao Hua Mountain. *Acta Phytoecologica Sinica*, 1996, **20**(1):41～50.

[19] Sudebilige H. Experimental study on seed banks of XILINGOL steppe in Inner Mongolia, M. Sc. thesis. Inner Mongolia University, Hohhot. 1996

[20] Williams E D. Changes during 3 years in the size and composition of the seed bank beneath a long-term pasture as influenced by defoliation and fertilizer regime. *Journal of Applied Ecology*, 1984, **21**:603～615.

[21] Champness S S & Morris K. Population of buried viable seeds in relation to contrasting pasture and soil types. *Journal of Ecology*, 1948, **36**:149～173.

[22] Chippindale H G & Milton W E J. On the viable seeds present in the soil beneath pastures. *Journal of Ecology*, 1934, **22**:508～531.

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