The potential for vegetation restoration from soil seed bank in abandoned croplands on the hilly-gullied Loess Plateau, China

Juying Jiao[1] – Wenjuan Bai

[1]Institute of Soil and Water Conservation, Chinese Academy of Sciences and Ministry of Water Resources, Xinong Road 26, Yangling, Shaanxi 712100, China. Tel.:86 13474375827; Fax: 86 29 87012210; E-mail: jiaojuying@yahoo.com.cn

1. Abstract

The results of field survey, germination and correspondence analysis showed that the soil seed banks density ranged from 900 to 6,467 seeds m^{-2} at 0-5 cm depth and 117 to 2,467 seeds m^{-2} at 5-10 cm depth, with species richness of 7-14. Early successional species dominated the soil seed bank, while later successional species occurred only at low density. The similarity between soil seed bank and standing vegetation was low. The most important variables discriminating community variation were soil water, extractable P, soil seed bank density and aspect. Soil seed bank alone explained 32.1% of the vegetation community variation. The potential for vegetation restoration from the soil seed bank is limited and it is recommended to transplant some later successional species into abandoned croplands to accelerate vegetation succession.

2. Introduction

Soil erosion is a major problem on the Loess Plateau of China, where soil erosion causes loss of cropland and silting up of rivers and reservoirs and contributes to flooding risk along the Yellow River Basin (Tang et al. 1998; Ritsema 2003; Hessel et al. 2003). Strategies to decrease soil erosion include returning slope croplands to forest or grass on a large scale. Alternatively natural plant community succession can be promoted on abandoned croplands. The success of this method depends on the availability of suitable propagules in the ex-arable soil (Lawson et al. 2004; Van der Putten et al. 2000), and an understanding of soil seed banks is important for effective vegetation restoration (Keddy & Reznicek 1982; Bertiller & Aloia 1997). However, the soil seed banks on the Loess Plateau region are poorly understood, and only the soil seed banks of the forests in the Ziwu Mountains and the grasslands in the Yunwu Mountains appear to have been studied (Wang & Ren 2004; Cheng et al. 2006). The aims of this study were to identify the characteristics of soil seed bank, the relationship with standing vegetation, and the potential significance of soil seed bank for vegetation restoration in abandoned croplands on the hilly-gullied Loess Plateau.

3. Methods

The study was conducted in the Ansai region (Lat 36° 31′ to 37° 20′N, Long108° 52′ to 109° 26′E) near the ecological experimental station of soil and water conservation, CAS. Soil samples of seed bank were collected in April 2005 from 12 plots that had been abandoned for 1 to 30 years including six south-facing and six north-facing slopes. The germination method was adopted to examine seed density and species composition of soil seed bank, and germination lasted 253 days. The above-ground vegetation was sampled in August 2005, and performed using six 1×1m quadrats located adjacent to the quadrats used for the soil seed bank samples, species composition, richness and cover were recorded. While soil samples were taken from six points in an S-shaped pattern sampling a depth of 0-10 cm for the analysis of organic matter, total N, extractable ammonium-N, total P, extractable P and extractable K, and soil water content at intervals of 20 cm depth in 0-500 cm soil layers was also measured.

Means and standard errors were calculated for the size of soil seed bank. Differences between plots in the number of seeds in the soil seed bank as well as the number of species in the standing vegetation were compared by one-way ANOVA. Canonical Variate Analysis (CVA) and variation partitioning (ter Braak & Smilauer 2002) were used to investigate the relationship between the soil seed bank and the four sets of measured variables, i.e. years since abandonment, soil water, soil nutrients and topography and vegetation variation in the abandoned croplands. Monte Carlo permutation tests were used to assess the significance of effects of each different combination of variables.

4. Results

4.1 Characteristics of soil seed bank

From the 144 soil samples, a total of 2,437 seeds germinated and was identified into 28 different species belonging to 23 genera and 11 families. Of the 28 species there were 8 Asteraceae, 6 Poaceae, 3 Boraginaceae, 2 Fabaceae, and 9 from the other 7 families. The species richness of the soil seed bank in the 12 plots ranged from 7 to14. The annual herb species *Artemisia scoparia* was the dominant species in the soil seed bank and appeared in all the plots and varied from 350±56 seeds m^{-2} to 6,167±1,463 seeds m^{-2} in the 0-5 cm layer, and from 33±21 seeds m^{-2} to 917±542 seeds m^{-2} in the 5-10 cm layer. However, the seed density of the dominant species in the later vegetation successional stages, such as *Lespedeza davurica, Bothriochloa ischaemun, Artemisia gmelinii, Stipa bungeana* were very low, ranging from 17 seeds m^{-2} to 300 seeds m^{-2}, accounting for 1.8%, 0.97%, 0.71% and 0.38% of the total seed bank respectively. The majority of the germinated seeds, 1,937 (79.5%) were found at the 0-5 cm depth and 500 (20.5%) at the 5-10 cm depth, corresponding to an overall seed density of 2,697 seeds m^{-2} in the first layer and 694 seeds m^{-2} in the second. Seed density was highly variable in the 12 plots, ranging from 900±351 to 6,466±7 108 seeds m^{-2} at the 0-5 cm depth, and 116±61 to 2,466±914 seeds m^{-2} at the 5-10 cm depth. And the variation of soil seed density in south-facing and north-facing slopes with years since abandonment was shown in Figure1.

4.2 Relationship between soil seed bank and standing vegetation

A total of 54 species (17 Asteraceae, 10 Poaceae, 10 Fabaceae, and 17 from the other families) were recorded in the standing vegetation of the 12 plots, of which 48 are herbaceous, 4 are shrub or under shrub, and 3 are trees. The species richness ranged from 13 to 23 species per plot. A total of 65 species were recorded in the seed bank and the standing vegetation. Of these, 17 species were present both in the soil seed bank and the standing vegetation, 11 species were only present in the soil seed bank, and 37 species were only present in the standing vegetation.

There was a clear difference between the species composition of the soil seed bank and that of the standing vegetation. The proportions of herbaceous and annual plants in the soil seed bank were higher than in the standing vegetation, while the proportion of perennials and legumes were higher in the standing vegetation. Species richness and Shannon-Wiener index of the standing vegetation were higher than of the soil seed bank; however, these indices were apparently not related to the time since abandonment. Sorensen similarity coefficient between the seed bank and the standing vegetation ranged from 0.143 to 0.414, with an average of 0.261.

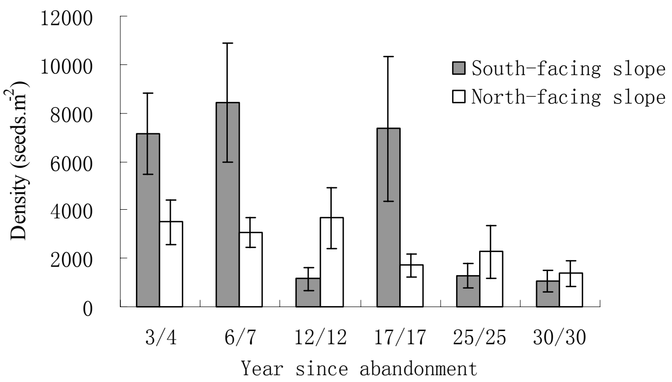

Figure 1 The variation of soil seed density in south-facing and north-facing slopes with years since abandonment

4.3 The effect of soil seed bank on vegetation variation

The CVA results showed that the most important variables discriminating the community variation were soil water content in the 200-500 cm layer, extractable P, soil seed bank density, and aspect ($p<0.05$), and explained 89.1% of the total inertia. Variation partitioning showed that soil seed bank, soil water, along with years since abandonment were all significant factors affecting vegetation community variation ($P<0.05$); and the years since abandonment, soil water and soil seed bank could explain 25.6%, 46.2% and 32.1% of the vegetation variation respectively. When the other 4 set of variables were partialled out respectively, the proportion of vegetation variation explained by the soil seed bank ranged from 11.7% to 29.5% (Table 1). Overall, the soil seed bank variable explained just 32.1% of standing vegetation community variation.

Table 1 The significance of soil seed bank in the explanation of the total variation

Model	CVA/PCVA（Community level）			
	explained Inertia	%	P value 1st axis	P value All axes
Year since abandonment	0.767	25.6		0.006
Soil seed bank	0.964	32.1	0.044	0.069
Soil nutrient	1.539	51.3	0.107	0.493
Soil water	1.385	46.2	0.003	0.035
Topography	0.818	27.3	0.121	0.109
Soil seed bank/ Year since abandonment	0.760	25.3	0.038	0.068
Soil seed bank/soil nutrients	0.556	18.5	0.439	0.489
Soil seed bank/soil water	0.352	11.7	0.494	0.520
Soil seed bank/topography	0.885	29.5	0.014	0.040

The inertia of CVA is 3.000；“/” = “partialling out”

Two main conclusions are evident from this study: 1) the soil seed bank of abandoned croplands in the hilly-gullied loess plateau has a low species diversity and a low seed density of later successional plant species compared to early successional species; 2) the soil seed bank can explain only a small proportion of the vegetation community variation and the main factors affecting the vegetation community composition are soil water content, extractable P, soil seed bank and aspect. These results show that the potential contribution of the soils seed bank to vegetation restoration in these abandoned croplands is low and that the vegetation succession process is likely to be slow. Thus, in order to accelerate vegetation restoration, it is not only important to take site conditions into account, but also to consider management interventions such as transplanting or sowing some later successional species e.g. *Bothriochloa ischaemun, Artemisia gmelinii, Lespedeza davurica, Stipa bungeana* into abandoned croplands, which can accelerate the rate of vegetation succession and reduce or even prevent soil erosion and loss on the hilly-gullied Loess Plateau.

5. References

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Acknowledgments

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