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To cite this article: Li Luo *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **199** 032101

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Dynamic Analysis of Arbor Species Germinated from Soil Seed Bank under Watering Strategies Driving

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Abstract. The watering gradient is an important factor affecting the composition and structure of the soil seed bank community. The germplasm resources in the soil seed bank have their corresponding water germination intervals. The soil seed bank of Tianjin Guangang Forest Park was selected as the research object and different watering gradients were set to test. Through statistical analysis and regression equation model, we could analyse and evaluate the morphological features of arbor species in soil seed bank under different watering gradients and find out the soil moisture interval which was most suitable for the restoration effect of soil seed bank in Tianjin. The study results showed that: (1) the watering gradient was set to 1000 mL, the arbor population in the experimental dish had the highest plant height, the largest canopy cover and the best arbor community; when the water content was less than 1000 mL, it couldn't meet the water demand of plant growth and the number of seed germination was greatly reduced; while above 1000mL, the soil was in flooded state, inhibited the germination of some seeds; (2) under the same watering gradients, the average height and canopy cover of Fraxinus chinensis species showed great advantages compared with Robinia pseudoacacia L. and Koelreuteria paniculate species; (3) the average height and canopy cover of three arbor species were positively correlated by regression analysis, and when the watering gradient was set to 1000mL, its correlation was best.

1. Introduction

Soil seed bank refers to the sum of all vital seeds in the leaf layer of the soil and soil surface [1]. It is the provenance library for maintaining the natural regeneration of aboveground vegetation and the basis for population settlement, survival and reproduction [2]. Related studies had shown that the composition and structure of soil seed banks determined the structure and function of aboveground plant communities [3]. Ecosystems with larger soil seed banks can more easily achieve recovery targets after being destroyed [4]. By studying soil seed bank, we could adequately understand the structural composition, species diversity and local microenvironment climate of above-ground vegetation, which could provide an important basis for effectively judging the restoration potential [5-6] and provide primary materials for the implementation of future vegetation restoration projects [7].

In the early stage of laboratory research, we found that the germination and growth of arbor species in the soil seed bank were of great significance for the community succession to enter a higher succession stage [8-9]. The number and characteristics of arbor species could affect community restoration. Lyaruu and Backeus explored the vegetation restoration potential of hilly slopes in Tanzania, the results showed

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that woody plant seeds didn't germinate from soil seed bank, and to achieve the vegetation restoration effect, artificial introduction of seeds was required [10]. At present, most of the researches focus on the dynamic changes of the whole community [11-12], while there are few studies on the dynamic characteristics of arbor species.

In this experiment, three major arbor species were Fraxinus chinensis, Robinia pseudoacacia, and Koelreuteria paniculate and the number of germination was considerable, which greatly reduced the supplementary work of arbor species in the future vegetation restoration project. This paper studied the influence of different watering gradients on the morphological characteristics of arbor species, such as the average height and canopy cover and their relationships. Based on the study, the optimal watering gradient for vegetation restoration could be found, which would provide a reference data base for the future vegetation restoration projects.

2. Date and methods

2.1. Study area

Guangang Forest Park lies in the northern part of Tianjin Dagang. It is a warm temperate semi-humid monsoon climate with average annual precipitation of 360-970mm. The total area of Guangang Forest Park is 22.85km2, of which the land area is 17.71km2 and the water area is 5.14km2, it is known as Tianjin "Lake Small Baiyangdian". The soil in the study area is coastal saline-alkali soil with a salt content of 0.20%. And the species is rich here, including 45 families and 120 species, the common woody plants are Fraxinus chinensis, Robinia pseudoacacia, Ailanthus altissima and Koelreuteria paniculata. As an important part of the Tianjin Beidagang Nature Reserve and the experimental area, Guangang Forest Park is a critical test base in the suburbs of Tianjin, which provides an important vegetation study area.

2.2. Soil seed bank sampling

Tianjin Guangang Forest Park was selected as a sampling site and soil samples were collected in March 2016. The random sampling method was used to lay three plots of 20m×20m in the study area. In each plot, 20 small plots with an area of 1m×1m were randomly selected and the topsoil of 15cm at the four corners and center of each small plot were collected. After removing the clear stones and dead branches, the soil samples of 300 were collected and put into plastic bags, and then the samples were brought to the greenhouse in Nankai University East Gate Test Base for backup. Meanwhile the surface vegetation community was recorded.

2.3. Test design

In the greenhouse, the soil samples were thoroughly mixed with the vegetative substrates, nitrogen and phosphorus fertilizer, then the samples were laid in plastic trays of 40 cm × 20 cm × 2.5 cm (about 2L). After that, the soil samples were divided into five parts, and three repeated experiments were set for each part to obtain an average value. According to the calculation of the amount of precipitation in Tianjin, the watering strategies were set to 150 mL, 250 mL, 500 mL, 1000 mL, and 1500 mL, which were recorded as W1, W2, W3, W4, and W5, respectively. And then the height and canopy cover of each woody plant (Fraxinus chinensis, Robinia pseudoacacia L., Koelreuteria paniculata) were measured monthly from May to October.

2.4. Data Processing and Analysis

Data statistics and analysis were completed in Excel 2016, R 3.5.0 and SPSS 22.0. Excel 2016 and R 3.5.0 were used to analyse the parameters which were characterizing the growth potential of three arbor species. Principal component analysis was performed by using SPSS 22.0.

3. Results and analysis

3.1. The number of arbor species germinated under different watering gradients

In the study, when the watering gradients were set to W1 and W2, the arbor seed density were only 5 individuals/m^2 and 16 individuals/m^2. While the arbor seedling density was getting larger with the watering gradient increasing to W3, which was 45 individuals/m^2. The most obvious advantage was that when the watering gradient was set to W4, the arbor seed germination density reached up to 51 individuals/m^2. However, the soil seed bank was in a flooded state as the amount of watering increased, which inhibited the germination of some seeds significantly, the arbor seedling density became 33 individuals/m^2 at W5.

3.2. Changes of the average height of arbor species under different watering gradients

Figure 1 showed that changes of the average height of three arbor species (Fraxinus chinensis, Robinia pseudoacacia L. and Koelreuteria paniculata) under different watering gradients. We can see that the average heights for three arbor species showed the increasing trends with the time passing, but different arbor species had obvious differences under different watering gradients. In May, the heights for three arbor species were at lower level, and the differences were not significant. In June, the average height of species at W3, W4, and W5 began to show growth advantages. In July, the average height for Fraxinus chinensis species was the highest at W3, while the overall height for three arbor species was the highest at W4. From August to October, the arbor populations had obvious advantages at W4, the average height for three arbor species were higher than the other watering gradients.

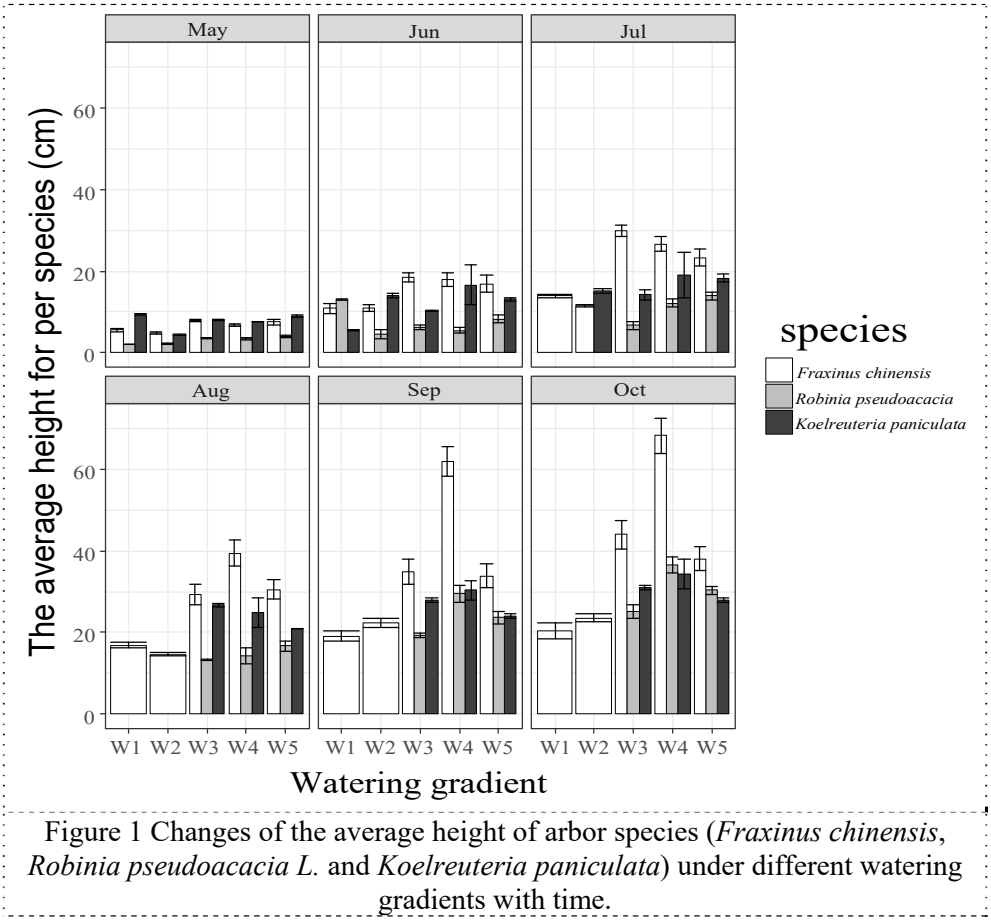


Figure 1 Changes of the average height of arbor species (*Fraxinus chinensis*, *Robinia pseudoacacia L.* and *Koelreuteria paniculata*) under different watering gradients with time.

3.3. Changes of the average canopy cover of arbor species under different watering gradients

Figure 2 showed that changes of the average canopy cover of Fraxinus chinensis, Robinia pseudoacacia L. and Koelreuteria paniculata species under different watering gradients with the time passing. As shown in the picture, the average canopy cover for three arbor species showed the steady growth trends with time, but the average canopy cover of different species under different watering gradients were significantly different. In May, the canopy cover for three arbor species were small, but we could also see that the canopy cover for Koelreuteria paniculata species was higher than the other two species. In June, except the W1, the canopy cover for Koelreuteria paniculata was still higher than Fraxinus chinensis and Robinia pseudoacacia L., while the canopy cover for Koelreuteria paniculate species was the largest at W1. What's more, the arbor populations at W4 and W5 had the largest whole coverage. In July, the canopy cover for arbor species at W3, W4, and W5 showed the significant growth advantages. In September, the canopy cover for per species under W4 watering gradient were higher than the other watering gradients, and the canopy cover for Fraxinus chinensis species was the largest, which might be related to the largest number of Fraxinus chinensis species. The changes of the canopy cover of the arbor population were similar between September and October.

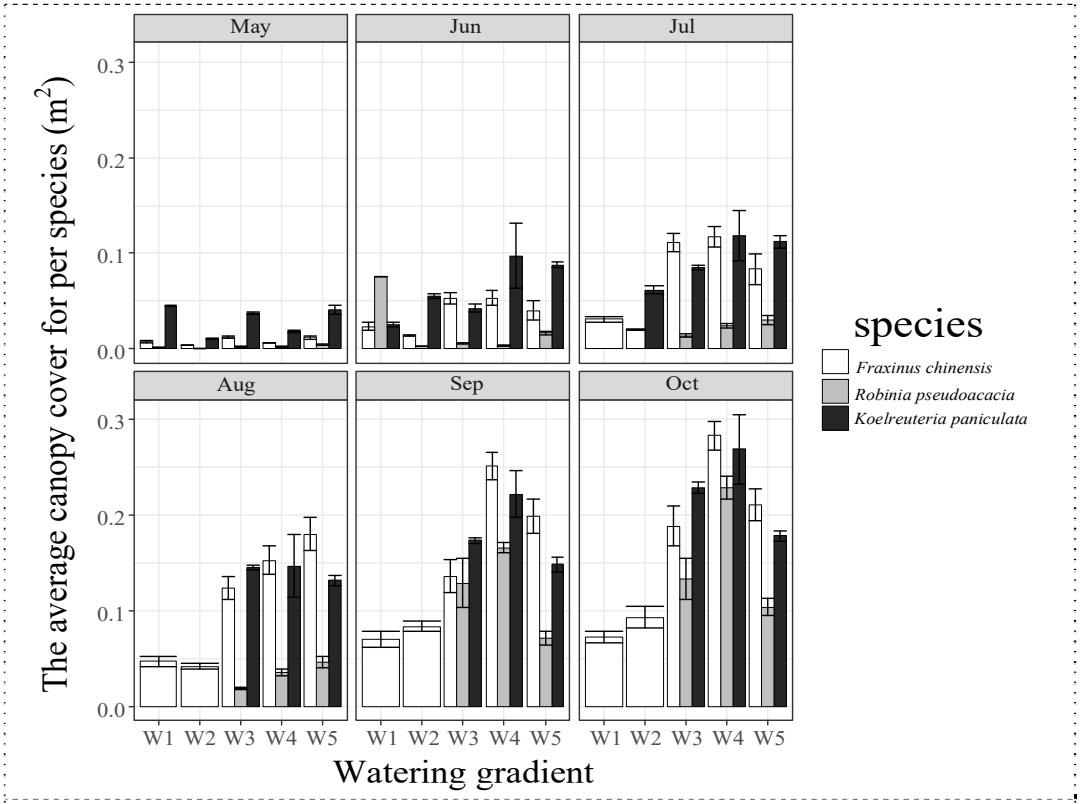


Figure 2 Changes of the average canopy cover of arbor species (*Fraxinus chinensis*, *Robinia pseudoacacia L.* and *Koelreuteria paniculata*) under different watering gradients with time.

3.4. The relationship between plant height and canopy cover under different watering gradients

Figure 3 reflected that the relationship between plant height and canopy cover of three arbor species under different watering gradients. We could see that the plant height of the arbor community showed an increasing trend with the increase of the canopy cover under different watering gradients, that is, the plant height and canopy cover of the community were positively correlated. The germination number of Robinia pseudoacacia L. and Koelreuteria paniculate were few under W1 and W2 watering gradients, which was difficult to conduct regression analysis. Among them, the regression equation model of Fraxinus chinensis at W1 was: Y=221.76X+5.0433 and R2 value 0.914, which was closed to 1,

indicating that best correlation was noticed between the plant height and canopy cover of Fraxinus chinensis. At W2, the regression model of Fraxinus chinensis was: Y=187.11X+6.2896 and had R2 value 0.766, compared with W1, the correlation was poor. When the watering gradient were W3, W4 and W5, the number of arbor species germinated and the community growth increased to some extent, and the regression model of the plant height and canopy cover of different species showed variances. At W3, the regression model of the Fraxinus chinensis species was: Y=169.63X+9.4164 and R2 value 0.843, the correlation was better; the regression equation model of the Robinia pseudoacacia L. species was: Y=120.91X+5.4847, R2 value 0.797, the correlation was good; the regression model of Koelreuteria paniculata was: Y=126.04X+4.7711 and R2 value 0. 932, the correlation was best. At W4, the regression model of Fraxinus chinensis was: Y=227.97X+4.0288 and had R2 value 0.972; the regression equation model of Robinia pseudoacacia L. was: Y=141.1X+5.6144 and R2 value 0.922; and the model of the Koelreuteria paniculata species was: Y=110.16X+6.1221 and R2 value 0.9335. The R2 value in the regression equation models of three arbor species were all closed to 1, indicated that when the watering gradient was set to 1000 mL, the linear correlation between the plant height and canopy cover of three arbor species was all best. At W5, the regression equation model of Fraxinus chinensis was: Y=134.46X+8.696 and R2 value 0.839; and the regression equation models of the Robinia pseudoacacia L. and Koelreuteria paniculata species were: Y=259.45X+4.1381 and Y =137.64X+2.9216 and the correlation indexes were 0.941 and 0.9447, respectively, indicated that the plant height and canopy cover of the Robinia pseudoacacia L. and Koelreuteria paniculata species had significant linear correlation.

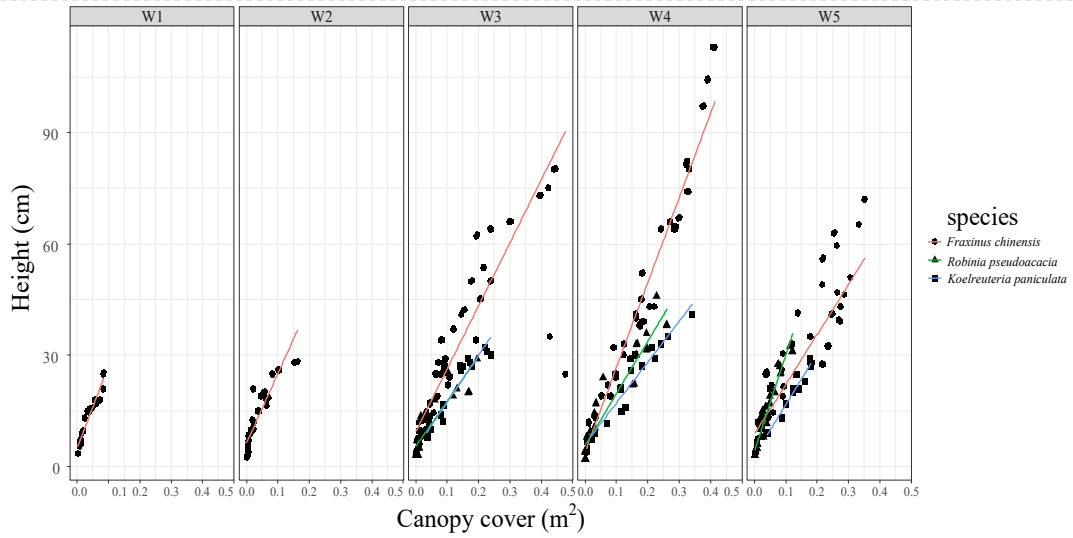


Figure 3 The relationship between plant height and canopy cover of three arbor species under different watering gradients.

4. Conclusions

Based on the above analysis, 1000mL of water was sprayed into the plastic trays daily could significantly affect the germination number and growth of woody plants in the soil seed bank. Under the W4 watering gradients, the plant height and canopy cover of the arbor community showed a steady increase over time. Compared with the other schemes, 1000 mL of water could better maintain the growth of the community. During the growing season, the average plant height and canopy cover of three arbor species (Fraxinus chinensis, Robinia pseudoacacia L. and Koelreuteria paniculate) were the largest; The R2 value of the regression equation model of the group were all closed to 1, indicated that the average plant height and canopy cover of arbor species had significant linear correlation. The horizontal growth of arbor species were consistent with the vertical growth, and the community had an absolute growth advantage.

Therefore, the watering gradient was set to 1000 mL/d, which could be used as an effective measure to provide a reference for the application of soil seed bank in vegetation restoration engineering projects.

Acknowledgments
This study is supported by the National Natural Science Foundation of China (Grant No. 31370700).

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