Quantitative attributes of three arbor species germinated from soil seed bank under different watering gradients

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Abstract. Soil seed bank plays a vital role in plant community succession and the restoration of damaged areas. As a key factor for plant growth, water directly affects seedling numbers of soil seed bank. A germination experiment was carried out in Tianjin Guangang Forest Park, where the germinated arbor species were Fraxinus chinensis, Koelreuteria paniculata, and Robinia pseudoacacia. This paper aims to study the quantitative attributes of soil seed bank under different watering gradients in the case of controlling variables from May to October. The results showed that the number of all kinds of seed bank germination would reach the maximum under 1000ml watering gradient, and the number of Fraxinus chinensis was the largest at 1000ml. The germination of Koelreuteria paniculata performed well under 1000ml or 1500ml water treatment. The total number of Robinia pseudoacacia kept stable at 3 individuals in the case of 500ml and 1000ml. According to the statistical analysis of the mortality rate, the results showed that the mortality rate was lower at 500ml and 1000ml, and the mortality rate was zero in September - October under all kinds of the watering gradient. It is helpful to provide a basis for studying of soil seed bank by exploring how watering gradient affect the growth of arbor population.

1. Introduction

Soil seed bank indicates the total amount of survived seeds in the upper strata of withering junk onto the soil and in the soil [1]. The soil seed bank is an effective way of vegetation restoration, which can maintain the stability of the ecosystem. The target species of soil seed bank for vegetation restoration are different from each other in different regions. Anyway, it is important to germinate species as many as possible in order to achieve the goal of vegetation restoration [2].

The addition of various nutrients can directly affect the growth of the seed bank. Bai et al. [3] studied the characteristics of soil seed bank and its relationship with standing vegetation in abandoned lands in croplands on the hilly-gullied Loess Plateau, and the potential significance of soil seed bank for vegetation restoration. Muvengwi, J. [4] studied the soil seed bank dynamics and soil nutrient concentrations in Lantana camara invaded and unininvaded patches at New Gada wetland in Harare, Zimbabwe. Moulton et al. [5] examined how experimentally adding soil nutrients for 13 and 20 years affected species composition, flower and fruit production, seed dispersal, the composition of the seed bank, and seedling establishment in a dry heath plant community in northern Alaska. Dalton et al. [6] studied the riparian above-ground vegetation at 24 sites located across a large North American watershed, the effects of agriculture on two dominant non-native grasses species and their effects on species...
richness were also assessed. Ochoa-Hueso [7] studied the effects of nitrogen and water supply on seed germination and vegetation establishment in semi-arid Mediterranean shrub soils.

Water is an essential factor for plant growth. In natural conditions, rainfall often has an important impact on the growth of soil seed banks. In this experiment, the quantative attributes of arbor population was studied by controlling the application of different watering gradients in the greenhouse from May to October, and the growth of Fraxinus chinensis, Koelreuteria paniculata and Robinia pseudoacacia were analyzed under different watering gradients. The mortality of the total number of plants was statistically analysed to explore the most suitable watering gradient for soil seed banks.

2. Materials and methods

2.1. Study area

Tianjin Guangang Forest Park is 40km away from Tianjin city center. It is a very important test area in the suburbs of Tianjin with total area of 22.85km^2 and the land area of 17.71km^2, the water area of 5.14km^2. Most of the area is coastal saline-alkali soil with a salt content of 0.20%. The species diversity in the park maintained at a high level, which remains more than 120 species in 45 families. The park has the characteristics of plain forests and the unique landscape of sea-land alternating zone, of which forest land accounts for 41%, there are lots of arbor plants in the park, such as Ailanthus altissima, Salix matsudana, Fraxinus chinensis, Robinia pseudoacacia and Koelreuteria paniculata and so on.

2.2. Sampling method

Tianjin Guangang Forest Park was selected as the topsoil sampling site in March,2016. The same random sampling method were adopted as follows: Firstly, 3 plots were selected randomly, of each was 20 m × 20 m square; then 20 small samples were set with an area of 1m × 1m square in each plot. At last, 0-15cm topsoil was collected as soil samples at the four corners and center of each small sample plot. After removing impurities such as sandstone and dead leaves in the sample, 300 soil samples were taken back to the lab [8-9]. At the same time, the status of surface vegetation population in each plot was recorded, including indicators such as species composition, quantities and vegetation coverage.

2.3. Greenhouse germination test

In the greenhouse of the test base, these 300 soil samples were removed from the residual gravel and plant roots, and added the same nutrients. The soil samples were placed in 50 cm × 20 cm × 5 cm germination trays, the greenhouse temperature was controlled at 25 °C-35 °C, relative humidity maintained at 50% -70%, and sprayed the different amount of water in each germination tray with watering can at 18:00 every three days. The rainfall gradient was set to 3mm, 5mm, 10mm, 20mm, 30mm by artificially simulating the stimulating effect of different daily rainfall on the soil seed bank. According to the calculation of the size of the bottom area of the germination tray and the amount of precipitation, the samples should be watered at 150ml, 250ml, 500ml, 1000ml, 1500ml [10]. The number of seedlings germinated in the soil seed bank was counted every two days from May to October, and the species and quantities of seedlings were identified at the same time. The plan of watering is shown in Table 1.

| Serial number | Watering gradient (mL) |
|---------------|------------------------|
| W1            | 150                    |
| W2            | 250                    |
| W3            | 500                    |
| W4            | 1000                   |
| W5            | 1500                   |
3. Results and analysis

3.1. Influence of watering gradient on the number of germination seedlings

The germination of soil seed bank was greatly inhibited when water is limited \cite{11}. The seedling density was low at the initial watering of W1, while the total seedling increased obviously at W3. From the perspective of different months, although the seedling density reached 84 individuals in total at W2 in the initial stage of germination in May, the total seedlings showed a significant downward trend along with the experiment time passing, and the total amount of seedlings decreased to 22 individuals in July. When the watering gradient was W4, the total germination numbers were 66 individuals in May, the number of germination was stable at 51 individuals from July to October, and the amount of seedlings was the highest compared with other watering gradient from August to October. So W4 was the most suitable gradient for getting the largest amount of seedlings.

Figure 1. Influence of different watering gradients on the number of seedlings under different months (individual/m$^2$)

3.2. Influence of watering gradient on the number of woody plants

3.2.1. Effect of watering gradient on the germination of Fraxinus chinensis. In this experiment, Fraxinus chinensis, Koelreuteria paniculata and Robinia pseudoacacia were three woody germinated plants. By analyzing the quantitative statistics, it showed that the number of Fraxinus chinensis was the most compared with the other two species \cite{12}. When the amount of watering maintained at W2, the number of Fraxinus chinensis germination was the largest in May. However, with time passing, the watering gradient was difficult to meet the need of Fraxinus chinensis, and the number of plants decreased greatly. The number of Fraxinus chinensis was only 16 individuals by October. When the amount of water was W4, the amount of germination basically stabilized at about 40 individuals in different months. It can be considered that W4 was the most suitable gradient for the growth of Fraxinus chinensis. What’s more, the growth trend of Fraxinus chinensis was almost same as the total species germination.
Figure 2. Numbers of Fraxinus chinensis germination under different watering gradients in different months (individual/m²)

3.2.2. Effect of watering gradient on the germination of Robinia pseudoacacia. Under different watering gradients, the number of Robinia pseudoacacia germination was also different. The number of Robinia pseudoacacia was the highest at W5 in May, but as the month passing, the number of Robinia pseudoacacia decreased significantly from May to July, then the number is basically stable in 6 individuals from August to October. When the watering gradients were W1 and W2, the germination number of the Robinia pseudoacacia were 7 individuals and 11 individuals respectively in May, and the number decreased significantly in June, there were 1 and 4 individuals respectively. In the following months, the number of Robinia pseudoacacia decreased to zero under W1 and W2 watering gradients.

Figure 3. Numbers of Robinia pseudoacacia germination under different watering gradients in different months (individual/m²)

3.2.3. Effect of watering gradient on the germination of Koelreuteria paniculata. The quantity of Koelreuteria paniculata was much smaller during the whole experiment. The number of germination were 3 individuals at W3, W4 and W5 watering conditions in May. In the following months, the number of plants was kept at 3 individuals when the water treatment was W3 or W4. While the number of seedlings decreased under the watering of W5, and it was stable at 2 individuals from June to October. The Koelreuteria paniculata was 1 individuals from May to June under W1, and then decreased to zero in the following months. Under the water treatment of W2, the number of Koelreuteria paniculata was stable from May to July, and then the number decreased to zero in following months.
3.3. Impact of different watering gradients on species mortality
By calculating the mortality of woody plants under different watering gradients from May to October, we found that at W1 water application, the plants had the highest mortality rate in May-June, reaching up to 50%, however, the mortality rate was zero in August-September and September-October, indicating the number of plants remained stable. Under the W2 watering gradient, the plants had the highest mortality rate in June-July, reaching nearly 60%, then the mortality rate dropped to zero in September-October. The plant mortality rate was maintained at a low level under W3 watering gradient, and the plant mortality rate was 20% in July-August, it was the highest compared with other months. The mortality rate was below 10% in May-June, and the mortality rate was zero in September-October. Under W4 watering gradient, the mortality rate was the lowest compared to other watering gradients, and the number of plants is stable in July-October, the mortality rate was zero. The mortality rate reached around 30%, which was the highest in May-June, and the mortality rate was zero in August-October.

In general, regardless of the watering gradients, the mortality rate in the population was zero in September-October, because arbor population had grown to a certain extent, then the population reached a relatively stable state, which could adapt to some changes in the surrounding environment.
pseudoacacia under different watering gradients from May to October. Based on the above analysis, it could conclude that water had significant impacts on the germination of soil seed bank, especially when the watering gradient reached 1000ml, the number of germination reached the maximum. So the watering gradient of 1000ml was considered to be more suitable for germination of woody plants. Through the experiment, the most suitable watering gradient for the growth of the seed bank had been found out. It is beneficial to choose the watering gradient of the soil seed bank according to the actual needs in the future research, which will guarantee soil seed bank to achieve its maximum application value.

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References
[1] Xiu F., Chuan T., Yong D. (2007) The role and potential of soil seed bank in vegetation restoration and reconstruction. Journal of Inner Mongolia University (Natural Science Edition), 38:102-108.
[2] Li H. Y., Sato Z. X., SenBen X. Y., Zhu L. (2007) Application of soil seed bank in vegetation restoration project of abandoned land. Journal of Liaoning Technical University, 1:140-142.
[3] Bai W. J., Jonathan M., Jiao J. Y. (2010) Soil Seed Bank and Standing Vegetation of Abandoned Croplands on Chinese Loess Plateau: Implications for Restoration. Journal of Arid Land Research & Management, 24:98-116.
[4] Muvengwi J., Ndagurwa H. G. T. (2015) Soil seed bank dynamics and fertility on a seasonal wetland invaded by Lantana camara, in a savanna ecosystem. Journal of Soils & Soils, 100:190-194.
[5] Moulton C. A., Gough L. (2011) Effects of Soil Nutrient Availability on the Role of Sexual Reproduction in an Alaskan Tundra Plant Community. Arctic Antarctic & Alpine Research, 43:612-620.
[6] Dalton R. L., Carpenter D. J., Boutin C. (2017) Factors affecting soil seed banks of riparian communities in an agricultural ecosystem: potential for conservation of native plant diversity. Journal of Applied Vegetation Science, 20.
[7] Ochoahueso R., Manrique E.(2010) Nitrogen fertilization and water supply affect germination and plant establishment of the soil seed bank present in a semi-arid Mediterranean scrubland. Journal of Plant Ecology, 210:263-273.
[8] He M. X. (2015) Study on the effect of matrix addition on soil seed bank characteristics. Doctoral dissertation, Nankai University, Tianjin.
[9] Zhao N., He M. X., Li H. Y.(2016) Effects of Mixed Matrix Addition on Germination Characteristics of Soil Seed Bank. Journal of Environmental science research, 29:1811-1818.
[10] Wang X. D. (2016) Effects of nitrogen and water on saltwood desert community characteristics and soil nutrients. Doctoral dissertation, Xinjiang Agricultural University, Xinjiang.
[11] He M. X. (2018) Evaluation of Technical Parameters and Restoration Effect of Vegetation Restoration in Soil Seed Bank. Doctoral dissertation, Nankai University, Tianjin.
[12] Hu D., Baskin J. M., Baskin C. C. (2018) Ecological role of physical dormancy in seeds of Oxytropis racemosa in a semiarid sandland with unpredictable rainfall. Journal of Plant Ecology, 11:542-552.