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Characteristics of Soil Seed Banks of Typical Plant Communities in Hilly Area of Funiu Mountain

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Abstract [**Objectives**] The purpose was to investigate the characteristics of soil seed bank of typical plant communities in hilly area of Funiu Mountain. [**Methods**] The seed density, number of species and species composition of the soil seed bank of typical plant communities such as *Themeda japonica*, *Imperata cylindrica*, *Vitex negundo*, *Quercus acutissima*, *Robinia pseudoacacia*, *Platycladus orientalis* and *Populus canadensis* in the surface, top 0 – 5 and top 5 – 10 cm soil were studied. [**Results**] The seed reserves of plant communities at different succession stages were (220.00 ± 95.39) – (2 650.00 ± 1 064.52) seeds/m^2. A total of 48 species were counted in the seed bank, belonging to 45 genera in 22 families. Total 27 species were identified in the above-ground vegetation, belonging to 25 genera in 14 families. In the shallow soil where the seeds gathered, the seed densities of *Imperata cylindrica* and *Themeda japonica* were relatively low. The reserves of plant communities with different naturalness degrees were (403.33 ± 64.29) – (2 110.00 ± 356.79) seeds/m^2. A total of 67 species were counted in the seed bank, belonging to 64 genera in 37 families. A total of 45 species were identified in the above-ground vegetation, belonging to 43 genera in 28 families. In the soil layers of 0 – 5 and 5 – 10 cm, the seed density of natural secondary *Q. acutissima* was higher than those of planted *P. canadensis*, *P. orientalis* and *R. pseudoacacia*. In each soil layer, the species number of natural secondary *Q. acutissima* forest was slightly smaller than those of planted *P. canadensis*, *P. orientalis* and *R. pseudoacacia* forests. [**Conclusions**] The seeds in the soil seed bank may not completely come from existing above-ground vegetation. Manual assistance is required for vegetation restoration or reconstruction relying on soil seed bank, to ensure the direction of community succession.

Key words Soil seed bank, Seed density, Species number, Species composition, Hilly area, Funiu Mountain

1 Introduction

Soil seed bank refers to the sum of all living seeds existing on the soil surface and in the soil[1]. It is a potential underground plant community and an important material basis for the natural regeneration of vegetation in the future. Therefore, studying the characteristics of soil seed bank is of great significance both in theory and practice[2]. It can predict community dynamics in theory[3], and in practice it is helpful to evaluating the provenance of vegetation restoration and reconstruction.

The main characteristic indices of soil seed bank research include seed density, number of species, and differences in the species composition between soil seed bank and the corresponding ground vegetation. Generally, the characteristics of soil seed bank are different for different vegetation types. The density of forest soil seed bank is generally 10^2 – 10^3 seeds/m^2, and that of grassland soil seed bank is generally 10^3 – 10^6 seeds/m^2[4–6]. The comparison of species composition between soil seed bank and the corresponding ground vegetation is usually measured by the similarity coefficient. Different community types lead to different conclusions. Liu Qingyan *et al.*[7] statistically analyzed the results of studies on the species similarity between wetland soil seed banks and the corresponding above-ground vegetation, and found that the soil seed bank of different wetland vegetation type has significant differences in species similarity with the corresponding above-ground vegetation. In the research on vegetation in the dry-hot valley and mountainous area of Jinsha River, Luo Hui *et al.*[8] found that the species composition of the soil seed bank and the corresponding ground vegetation has a high similarity. In addition, succession stage of the above-ground plant community also has a greater impact on the characteristics of the soil seed bank. Zhao Liya *et al.*[9] studied the characteristics of soil seed bank in the process of sandy land succession and restoration in the severely damaged land in Horqin Sandy Land. It was found that the species composition and density change of the soil seed bank were the same as those of the above-ground colonization community. Ou Zulan *et al.*[10] studied the soil seed bank of degraded vegetation in different succession stages in southwestern Guangxi and found that the similarity between any two succession stages was low, and the similarity coefficient of two adjacent succession stages was higher than that of two distant succession stages. The composition characteristics of seed banks of plant communities with different naturalness degrees are also different[11]. Chen Yong *et al.*[12] studied the characteristics of soil seed banks of plantation and natural forests of *Betula alnoides*. The results show that the number of seeds

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and species in the soil seed bank of plantation forest was smaller than that of natural forest; the plant species of the plantation and natural forests were different; and the plant species shared by the two accounted for the majority, and there was also a small part existing only in plantation forest or natural forest.

The hilly area of Funiu Mountain has serious soil erosion, shallow soil layer and poor fertility. The vegetation is low and sparse. Studying the soil seed bank of typical plant communities in the hilly area of Funiu Mountain is not only helpful to understand the dynamics and succession trends of the plant communities but also of important guiding significance for the near-natural restoration and later management of artificial plant communities in this type of areas.

2 Overview of study area and research method

2.1 Overview of study area The hilly area of Funiu Mountain (110°30′ – 113°30′ E and 32°45′ – 34°20′ N) is located in the southwest of Henan Province, China. The altitude is 44 – 2 173 m, mainly granite. The hilly area of Funiu Mountain is the transitional zone of the climate between the north and the south in China. It belongs to the subtropical-warm temperate and humid-semi-humid monsoon climate with obvious transition characteristics. Seasonal changes are obvious, and heat and water are at the same time. The total sunshine hours of the year are 1 800 – 2 200 h. The annual average temperature is 13.6 – 15.1 ℃. The annual precipitation is 700 – 1 100 mm. The soil is yellow brown earth. The vegetation is a transition type from warm-temperate deciduous broad-leaved forest to subtropical evergreen broad-leaved forest. The vertical band spectrum is obvious, with many types and wide distribution. Natural forests are mainly deciduous broad-leaved oak forests, and plantation forests mainly include *P. canadensis* and *P. orientalis*[13].

2.2 Research method

2.2.1 Soil sample collection of soil seed bank and germination experiment. The collection of soil samples from the soil seed bank was carried out in early March, 2017. During this period of time, the seeds of the previous year in the soil had not yet germinated, and there was no new seed input that year. Therefore, there were both short-term soil seed bank and long-term soil seed bank in the soil. It is a suitable time for sampling in the soil seed bank for full measurement. The *T. japonica* and *R. pseudoacacia* communities on the Guoding Mountain, the *V. negundo*, *I. cylindrica*, *P. canadensis* and *P. orientalis* communities in the Pingdingshan Peak Park and the *Q. acutissima* community on Wugang Erlang Mountain were selected. Three sampling areas were arranged in each typical plant community type to collect soil samples from the soil seed bank. In each sampling area, 10 sampling points were arranged according to the "S"-shaped route. In each sampling point, a square of 10 cm × 10 cm was arranged. The surface of the soil was swept for sampling; and the soil in the layers of 0 – 5 and 5 – 10 cm was dug as samples.

The seed density, number species and species composition in the soil seed bank were determined with germination method. After removing large litter, the soil of each sample collected in the wild was divided into three equal parts and the seeds in the soil were let germinate in the germination tray. The germination experiment started at the end of March, 2017. The germination trays were placed in the greenhouse of Pingdingshan University and watered regularly every afternoon to keep the soil in the trays moist, so as to ensure the germination of the seeds. The germination situation of the seeds were observed and recorded regularly. The germination experiment lasted for one and a half years until no more species germinated.

2.2.2 Investigation of characteristics of above-ground vegetation. The survey of characteristics of above-ground vegetation was carried out in summer. The species composition of the tree layer in each sampling area of the soil seed bank was investigated. Square of 5 m × 5 m were set for the survey on shrub layer. In each shrub survey square, a 1 m × 1 m herb layer survey square was set along the diagonal. The composition and number of species was recorded.

2.2.3 Statistical analysis. Density, species number, and species composition were selected to describe the characteristics of the soil seed bank. SPSS 16.0 was used for data processing and analysis. The differences in seed density and species number among different plant communities and different soil layers were analyzed by single-factor analysis of variance and multiple comparisons, with a confidence interval of 95%. The Sorensen similarity index was used to describe the species similarity between soil seed bank and the corresponding aboveground vegetation of each plant community, the species similarity between the soil seed banks, and the species similarity between the aboveground vegetation. Charts were drawn using Excel 2010.

3 Results and analysis

3.1 Characteristics of soil seed bank of plant communities at different succession stages As shown in Fig. 1, on the soil surface, the seed density of the soil seed bank of plant communities at different succession stages was (220.00 ± 95.39) – (2 650 ± 1 064.52) seeds/m^2. Among different plant species, the seed density of *V. negundo* was the highest, (2 650.00 ± 1 064.52) seeds/m^2, significantly different from those of *I. cylindrica*, *T. japonica* and *Q. acutissima* ($P < 0.05$). The seed density of *I. cylindrica* was (1 340.00 ± 525.07) seeds/m^2. The seed density of *T. japonica* was the lowest, (220.00 ± 95.39) seeds/m^2. In the soil layer of 0 – 5 cm, the seed density of the soil seed bank was (323.33 ± 182.30) – (2 000.00 ± 975.96) seeds/m^2. The seed density of *Q. acutissima* was the highest, (2 000.00 ± 975.96) seeds/m^2, significantly different from those of *I. cylindrica*, *T. japonica* and *V. negundo* ($P < 0.05$). The seed density of *I. cylindrica* was (936.67 ± 416.21) seeds/m^2. Among different plant species, *T. japonica* had the lowest seed density, (323.33 ± 182.30) seeds/m^2. In the soil layer of 5 – 10 cm, the seed density of the soil seed bank was (270.00 ± 51.96) – (916.67 ± 284.31) seeds/m^2. Among different plant species, *Q. acutissima* showed the highest seed density [(916.67 ± 284.31) seeds/m^2], followed by *I. cylindrica* [(430.00 ± 185.20) seeds/m^2], and *T. japonica* showed the lowest seed density [(270.00 ± 51.96) seeds/m^2]. There was no significant difference in seed density among *I. cylindrica*, *T. japonica* and *V. negundo* ($P > 0.05$), and the seed density of *Q. acutissima* was significantly different from those of *I. cylindrica*, *T. japonica* and *V. negundo* ($P < 0.05$).

On the soil surface, the species quantity in soil seed bank of plant communities at different succession stages was (4.33 ± 2.08) – (15.33 ± 3.06) species/0.01 m^2. *I. cylindrica* showed the most species [(15.33 ± 3.06) species/0.01 m^2], followed by *V. negundo* [(12.33 ± 0.58) species/0.01 m^2], and *T. japonica* had the least species [(4.33 ± 2.08) species/0.01 m^2]. There was no significant difference in species quantity between *I. cylindrica* and *V. negundo*, *V. negundo* and *Q. acutissima*, or *Q. acutissima* and *T. japonica* ($P > 0.05$), but the species quantity of *I. cylindrica* was significantly different from those of *Q. acutissima* and *T. japonica*, and the species quantity of *T. japonica* was significantly different from that of *V. negundo* ($P > 0.05$). In the soil layer of 0 – 5 cm, the quantity of species in the soil seed bank ranged from (4.33 ± 1.53) to (16.00 ± 3.46) species/0.01 m^2. Among different plant species, the species quantity of *I. cylindrica* community was the highest, (16.00 ± 3.46) species/0.01 m^2, followed by that of *V. negundo* community [(12.00 ± 3.00) species/0.01 m^2], and the species quantity of *T. japonica* was the lowest, (4.33 ± 1.53) species/0.01 m^2. The differences in species quantity between *I. cylindrica* and *V. negundo*, and *T. japonica* and *Q. acutissima* were insignificant ($P > 0.05$), while those between *I. cylindrica* and *Q. acutissima*, *T. japonica*, and between *V. negundo* and *T. japonica*, *Q. acutissima* were significant ($P < 0.05$). In the soil layer of 5 – 10 cm, the species quantity of the soil seed bank was in the range of (3.67 ± 2.08) – (11.00 ± 1.00) species/0.01 m^2. *V. negundo* community had the most species, (11.00 ± 1.00) species/0.01 m^2, followed by *I. cylindrica*, (9.00 ± 3.46) species/0.01 m^2, and *T. japonica* showed the least species, (3.67 ± 2.08) species/0.01 m^2. There was no significant difference between *I. cylindrica* and *V. negundo*, *I. cylindrica* and *Q. acutissima*, or *Q. acutissima* and *T. japonica* ($P > 0.05$), and there were significant differences between *I. cylindrica* and *T. japonica*, *T. japonica* and *V. negundo*, and *V. negundo* and *Q. acutissima* ($P < 0.05$) (Fig. 2).

The Soresen similarity coefficients (SC) between soil seed banks of plant communities and the corresponding above-ground vegetation were calculated, and the results are shown in Table 1. The similarity coefficient between the soil seed bank of *I. cylindrica* community and the corresponding above-ground vegetation was 0.60, relatively high, while the similarity coefficients between soil seed banks of the other three plant communities and the corresponding above-ground vegetation were low. Between the soil seed bank of *I. cylindrica* community and the corresponding above-ground vegetation, the shared plant species were *Artemisia argyi*, *I. cylindrica*, *Setaria viridis*, *Cynodon dactylon*, *Broussonetia papyrifera*, *T. japonica*, *V. negundo*, *Sonchus oleraceus*, *Digitaria sanguinalis*, *Arthraxon lanceolatus*, *Cyperus iria*, *Conyza canadensis*, *Artemisia capillaris*, *Viola philippica* and *Oxalis corniculata*, a total of 15 species, belonging to 15 genera in 7 families. Among them, most were gramineous plants (6 species).

The similarity between soil seed banks of different succession stages was analyzed, and the results are shown in Table 2. The soil seed banks of *I. cylindrica* and *T. japonica* communities shared the following species: *I. cylindrica*, *P. canadensis*, *S. viridis*, *C. dactylon*, *T. japonica*, *V. negundo*, *S. oleraceus*, *D. sanguinalis*, *A. lanceolatus*, *C. iria*, *Acalypha australis*, *A. capillaris* and *O. corniculata*, belonging to 13 genera in 7 families. The species similarity of the two soil seed banks was 0.55. The common plants between the soil seed banks of *I. cylindrica* and *V. negundo* communities were *A. argyi*, *S. viridis*, *C. dactylon*, *Lysimachia christinae*, *V. negundo*, *S. oleraceus*, *Portulaca oleracea*, *D. sanguinalis*, *A. lanceolatus*, *Eleusine indica*, *C. iria*, *A. australis*, *Conyza Canadensis*, *V. philippica*, *Medicago sativa*, *O. corniculata* and *Chrysanthemum indicum*, belonging to 17 genera in 10 families. The similarity coefficient between the soil seed banks was 0.63. The soil seed banks of the *I. cylindrica* and *Q. acutissima* communities shared the following species: *I. cylindrica*, *V. negundo*, *A. lanceolatus*, *Duchesnea indica*, *C. iria*, *A. australis*, *C. canadensis*, *V. philippica*, *M. sativa* and *Broussonetia papyrifera*, belonging to 10 genera in 9 families. The similarity coefficient between the soil seed banks was 0.39. The common species between the soil seed banks of *T. japonica and V. negundo communities* were S. *viridis*, *C. dactylon*, *V. negundo*, *S. oleraceus*, *D. sanguinalis*, *A. lanceolatus*, *C. iria*, *A. australis* and *O. corniculata*, belonging to 9 genera in 6 families. The similarity coefficient between the soil seed banks was 0.46. The soil seed banks of the *T. japonica* and *Q. acutissima* communities showed the common species of *I. cylindrica*, *V. negundo*, *A. lanceolatus*, *C. iria*, *Allium paepalanthoides* and *A. australis*, belonging to 6 genera in 5 families. The similarity coefficient between the soil seed banks was 0.33. The soil seed banks of the *V. negundo* and *Q. acutissima* communities shared the species of *V. negundo*, *A. lanceolatus*, *C. iria*, *A. australis*, *C. canadensis*, *V. philippica* and *M. sativa*, belonging to 7 genera in 7 families. The similarity coefficient between the species of the two soil seed banks was 0.33.

The similarity in above-ground vegetation between different succession stages was analyzed, and the results are shown in Table 3. The common species in above-ground vegetation between the *I. cylindrica* and *T. japonica* communities included *A. argyi*, *T. japonica*, *D. sanguinalis*, *C. canadensis* and *A. capillaris*, belonging to 5 genera in 4 families. The species similarity between the above-ground vegetation of the two communities was 0.27. The above-ground vegetation of *I. cylindrica* and *V. negundo* communities shared the species of *V. negundo* and *D. sanguinalis*, belonging to 2 genera in 2 families. The species similarity between the above-ground vegetation was 0.15. The above-ground vegetation of *I. cylindrica* and *Q. acutissima* communities had only one common species, *B. papyrifera*. The species similarity between the above-ground vegetation was 0.08. The above-ground vegetation of *T. japonica* and *V. negundo* communities shared the following species: *Ixeris sonchifolia*, *L. bicolor*, *D. sanguinalis* and *Stipa bungeana*, belonging to 4 genera in 3 families. The species similarity between the above-ground vegetation of the two communities was 0.32. There was no common species between the above-ground vegetation of *T. japonica* and *Q. acutissima* communities, and *V. negundo* and *Q. acutissima* communities, so the species similarity was both zero.

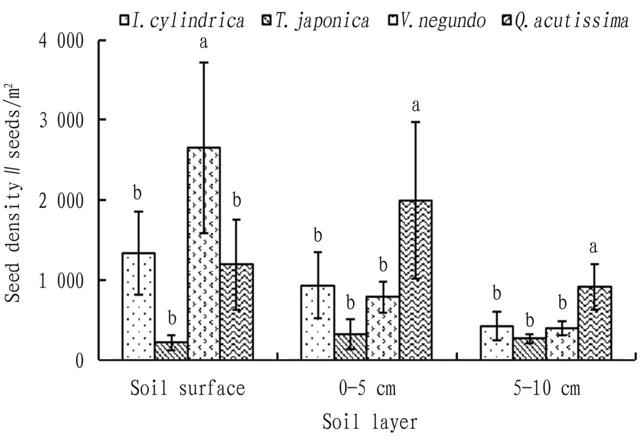

Fig.1 Seed density of soil seed banks of plant communities at different succession stages in different soil layers

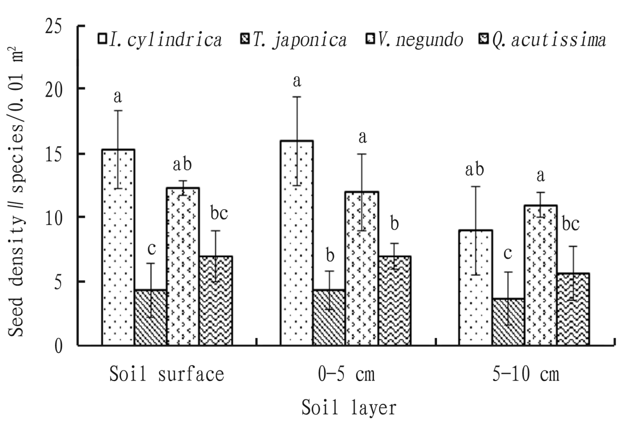

Fig.2 Species number of soil seed banks of plant communities at different succession stages in different soil layers

Table 1 Similarity of species composition between soil seed bank of different plant community and corresponding above-ground vegetation

Plant community	Total number of species		Number of common species	Similarity coefficient
	Soil seed bank	Above-ground vegetation		
I. cylindrica	31	19	15	0.60
T. japonica	16	18	3	0.18
V. negundo	23	7	3	0.20
Q. acutissima	20	6	3	0.23

Table 2 Similarity of species composition between soil seed banks of plant communities at different succession stages

Similarity coefficient	*I. cylindrica*	*T. japonica*	*V. negundo*	*Q. acutissima*
I. cylindrica	1.00			
T. japonica	0.55	1.00		
V. negundo	0.63	0.46	1.00	
Q. acutissima	0.39	0.33	0.33	1.00

Table 3 Similarity of species composition between above-ground vegetation of plant communities at different succession stages

Similarity coefficient	*I. cylindrica*	*T. japonica*	*V. negundo*	*Q. acutissima*
I. cylindrica	1.00			
T. japonica	0.27	1.00		
V. negundo	0.15	0.32	1.00	
Q. acutissima	0.08	0.00	0.00	1.00

3.2 Characteristics of soil seed bank of plant communities with different naturalness degrees On the soil surface, the seed density of soil seed bank of *R. pseudoacacia* community was the highest, (2 110 ± 356.79) seeds/m^2, followed by that of *P. canadensis* community[(1 883.33 ± 635.09) seeds/m^2], and the seed density of soil seed bank of *Q. acutissima* community was the lowest. In the soil layer of 0 – 5 cm, the seed density ranged from (970.00 ± 554.35) to (2 000 ± 975.96) seeds/m^2. Among different species, *Q. acutissima* community had the highest seed density, followed by *R. pseudoacacia* community [(1 406.67 ± 191.40) seeds/m^2], and *P. orientalis* community showed the lowest seed density, (970.00 ± 554.35) seeds/m^2. In the soil layer of 5 – 10 cm, the seed density of *Q. acutissima* community was the highest, followed by that of *P. canadensis* community, and the seed density of *P. orientalis* community was the lowest. There was a significant difference between *P. orientalis* and *Q. acutissima* ($P<0.05$) (Fig.3).

On the soil surface, the species number of soil seed banks of plant communities at different naturalness degrees was in the range of (7.00 ± 2.00) – (17.33 ± 5.69) species/0.01 m^2. *P. canadensis* community had the most species, followed by *R. pseudoacacia* community and *Q. acutissima* community had the least species. The differences among *P. canadensis*, *R. pseudoacacia* and *Q. acutissima* were significant ($P<0.05$). In the soil layer of 0 – 5 cm, the species number of soil seed banks was (7.00 ± 1.00) – (15.33 ± 4.51) species/0.01 m^2. *P. canadensis* community had the most species, (15.33 ± 4.51) species/0.01 m^2. The species number of *R. pseudoacacia* community ranked second, (14.67 ± 5.03) species/0.01 m^2. The species number of *Q. acutissima* community was the least. There was no significant difference among the four plant communities ($P>0.05$). In the soil layer of 5 – 10 cm, the species number of the soil seed banks ranged from (5.67 ± 2.08) to (10.67 ± 3.51) species/0.01 m^2. *P. canadensis* community had the most species, (10.67 ± 3.51) species/0.01 m^2, followed by *R. pseudoacacia* community [(10.00 ± 2.00) species/0.01 m^2], and *Q. acutissima* communities contained the least species. There was no significant difference among the four plant communities ($P>0.05$) (Fig.4).

The Sorensen similarity coefficient (SC) between the soil seed bank of different plant community and the corresponding above-ground vegetation was calculated. As shown in Table 4, the similarity coefficient between the soil seed bank of *P. canadensis* community and the above-ground vegetation was 0.81, and the similarity coefficients between the soil seed banks of *P. orientalis*, *R. pseudoacacia* and *Q. acutissima* communities and the corresponding above-ground vegetation were in the range of 0.14 – 0.23. The above-ground vegetation and soil seed bank of *P. canadensis* community shared the species of *A. argyi*, *Arabis pendula*, *Rehmannia glutinosa*, *Myosoton aquaticum*, *S. viridis*, *B. papyrifera*, *Eragrostis pilosa*, *S. oleraceus*, *Aquilegia viridiflora*, *P. oleracea*, *E. indica*, *C. iria*, *A. australis*, *Clinopodium polycephalum*, *Chenopodium gracilispicum*, *C. canadensis*, *A. capillaris*, *Ixeridium chinense*, *V. philippica*, *M. sativa* and *O. corniculata*, belonging to 20 genera in 15 families, of which the composite plants are the majority.

The similarity between soil seed banks of plant communities with different naturalness degrees was analyzed, and the results are shown in Table 5. The common species between the soil seed banks of *Q. acutissima* and *Populus canadensis* communities were *A. pendula*, *M. aquaticum*, *B. papyrifera*, *A. lanceolatus*, *Capsella bursa-pastoris*, *C. iria*, *A. australis*, *C. Canadensis*, *V. philippica* and *M. sativa*, belonging to 10 genera in 9 families. The similarity coefficient between the soil seed banks was 0.39. The soil seed banks of the *Q. acutissima* and *P. orientalis* communities shared the species of *I. cylindrical*, *A. pendula*, *B. papyrifera*, *V. negundo*, *Sonchus arvensis*, *A. lanceolatus*, *C. iria*, *A. paepalanthoides*, *C. canadensis*, *V. philippica* and *M. sativa*, belonging to 11 genera in 9 families. The species similarity between the soil seed banks was 0.43. The common species between the soil seed banks of *Q. acutissima* and *R. pseudoacacia* communities included *B. papyrifera*, *V. negundo*, *S. arvensis*, *Ophiopogon japonicas*, *A. lanceolatus*, *D. indica*, *C. iria*, *A. australis*, *C. Canadensis* and *V. philippica*, belonging to 10 genera in 9 families. The species similarity between the soil seed banks was 0.33. The soil seed banks of *P. canadensis* and *P. orientalis* communities shared the following species: *A. argyi*, *A. pendula*, *S. viridis*, *B. papyrifera*, *L. christinae*, *S. oleraceus*, *P. oleracea*, *A. lanceolatus*, *Salix warburgii*, *C. iria*, *C. gracilispicum*, *C. canadensis*, *A. capillaris*, *V. philippica*, *M. sativa* and *O. corniculata*, belonging to 16 genera in 12 families. The species similarity between the soil seed banks of the two communities was 0.51. The soil seed banks of *P. canadensis* and *R. pseudoacacia* communities had the common species of *A. argyi*, *R. glutinosa*, *S. viridis*, *B. papyrifera*, *S. oleraceus*, *Galium aparine*, *P. oleracea*, *A. lanceolatus*, *Taraxacum mongolicum*, *C. iria*, *A. australis*, *C. gracilispicum*, *C. canadensis*, *Leonurus japonicas*, *A. capillaris*, *V. philippica* and *O. corniculata*, belonging to 17 genera in 12 families. The species similarity between the soil seed banks was 0.47. *A. argyi*, *Astragalus scaberrimus*, *S. viridis*, *C. dactylon*, *B. papyrifera*, *V. negundo*, *S. arvensis*, *S. oleraceus*, *P. oleracea*, *D. sanguinalis*, *A. lanceolatus*, *Persicaria hydropiper*, *C. iria*, *C. gracilispicum*, *C. canadensis*, *A. capillaris*, *O. corniculata* and *V. philippica* were common in the soil seed banks of *P. orientalis* and *R. pseudoacacia* communities. They belong to 17 genera in 9 families. The species similarity between the soil seed banks was 0.51.

The similarity between above-ground vegetation of plant communities at different naturalness degrees was analyzed, and the results are shown in Table 6. *B. papyrifera* was the only species shared by the above-ground vegetation of *Q. acutissima* and *P. canadensis* communities. The species similarity between the above-ground vegetation was 0.07. *B. papyrifera* was also the only species shared by the above-ground vegetation of *Q. acutissima* and *P. orientalis* communities. The species similarity between the above-ground vegetation of the two communities was 0.11. The common species between the above-ground vegetation of *Q. acutissima* and *R. pseudoacacia* communities were *B. papyrifera*, *Melia azedarach* and *Morus alba*, belonging to 3 genera in 2 families. The species similarity between the above-ground vegetation was 0.33. There was only one common species (*B. papyrifera*) between the above-ground vegetation of *P. canadensis* and *P. orientalis* communities, and the similarity coefficient of the species composition was 0.06. *B. papyrifera* was also the only species shared by the above-ground vegetation of *P. canadensis* and *R. pseudoacacia* communities, and the similarity coefficient of the species composition was 0.06. The above-ground vegetation of *P. orientalis* and *R. pseudoacacia* communities showed the common species of *R. pseudoacacia*, *B. papyrifera* and *V. negundo*, belonging to 3 genera in 3 families. The similarity coefficient of the species composition was 0.24.

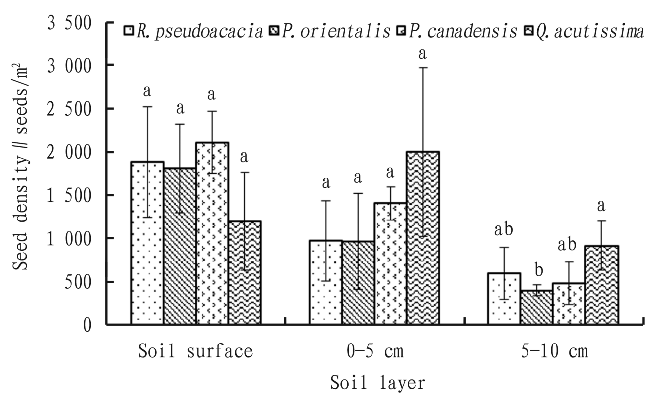

Fig. 3 Seed density of soil seed banks of plant communities with different naturalness degrees in different soil layers

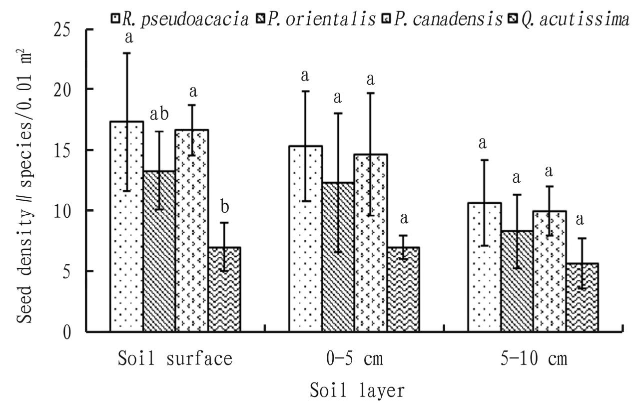

Fig. 4 Species number of soil seed banks of plant communities with different naturalness degrees in different soil layers

Table 4 Similarity of species composition between soil seed bank of different plant community and the corresponding above-ground vegetation

Plant community	Total number of species		Number of common species	Similarity coefficient
	Soil seed bank	Above-ground vegetation		
Q. acutissima	20	6	3	0.23
P. canadensis	31	21	21	0.81
P. orientalis	31	13	3	0.14
R. pseudoacacia	40	12	4	0.15

Table 5 Similarity of species composition between soil seed banks of plant communities with different naturalness degrees

Similarity coefficient	*Q. acutissima*	*P. canadensis*	*P. orientalis*	*R. pseudoacacia*
Q. acutissima	1.00			
P. canadensis	0.39	1.00		
P. orientalis	0.43	0.51	1.00	
R. pseudoacacia	0.33	0.47	0.51	1.00

Table 6 Similarity of species composition between above-ground vegetation of plant communities with different naturalness degrees

Similarity coefficient	*Q. acutissima*	*P. canadensis*	*P. orientalis*	*R. pseudoacacia*
Q. acutissima	1.00			
P. canadensis	0.07	1.00		
P. orientalis	0.11	0.06	1.00	
R. pseudoacacia	0.33	0.06	0.24	1.00

4 Discussion and conclusions

Among *I. cylindrical*, *T. japonica*, *V. negundo* and *Q. acutissima* communities, *I. cylindrical* and *T. japonica* communities are herb succession stage, *V. negundo* community is shrub succession stage, and *Q. acutissima* community is tree succession stage. In the soil surface and 0 – 5 cm soil layer where seeds gather, the seed density of *I. cylindrical* and *T. japonica* communities in which herbaceous plants are the dominant are relatively low. Between them, the see density of the *T. japonica* community is lower. This might be because that the dense cluster and higher plant height of *T. japonica* hinder the import of seeds into the community. Coupled with its own strong asexual reproduction ability and weak seed reproduction ability, the soil seed bank has a lower seed density and fewer species. The clumps of *I. cylindrical* community are generally dense, but the plants are not as upright as *T. japonica*. The lighter seeds are easier to spread in by wind. Consequently, the seed density is slightly higher than that of *T. japonica*[14]. The seed density of *V. negundo* community is high in the surface soil. As the soil layer deepens, the seed density gradually decreases. The possible reason is that *V. negundo* has a large seed yield and seed volume, and it will be more difficult for seeds to enter the soil. Therefore, they basically have little chance to migrate downwards with the help of natural forces[15-16]. The seeds of the *Q. acutissima* community are mainly distributed in the 0 – 5 cm soil layer. It may be because most of the seeds on the soil surface, especially the seeds of *Q. acutissima*, will be eaten or transported by animals, so the seed density is low[17]. The species similarity index of soil seed bank between plant communities at different succession stages is generally higher than that of the above-ground vegetation. The species similarity index between the above-ground vegetation is below 0.35. In particular, the species similarity index between above-ground vegetation of *Q. acutissima* and *T. japonica*, *V. negundo* communities is zero. However, the species similarity index between the soil seed banks is 0.33. It indicates that seeds in the existing soil seed bank may not come from the existing above-ground vegetation completely. Once the existing above-ground vegetation is destroyed, if the soil seed bank is used for vegetation restoration or reconstruction, the succession direction may have multiple possibilities, and manual assistance is needed to ensure succession towards the target community.

The seed density of soil seed bank of natural secondary *Q. acutissima* forest is slightly higher than those of planted *P. canadensis*, *P. orientalis* and *R. pseudoacacia* forests. At different soil layer, the species number of natural secondary *Q. acutissima* forest was slightly smaller than those of planted *P. canadensis*, *P. orientalis* and *R. pseudoacacia* forests. The seed source of the soil seed bank of planted *P. orientalis* and *R. pseudoacacia* communities with lower naturalness degree may be more diversified, including both the input of existing vegetation on the ground and the spread of surrounding vegetation. Fast-growing *P. canadensis* is the dominant plant community. The seeds in the soil seed bank may mainly come from the input of above-ground vegetation. Therefore, the species similarity index between soil seed bank and above-ground vegetation can reach 0.81. The species similarity between the soil seed banks of plant communities with different naturalness degrees is generally greater than that between the corresponding above-ground vegetation, which also means that once the existing ground vegetation of these plant communities is destroyed, the seed sources require to be regulated by restoration and reconstruction, supplemented by artificial control[18].

References

[1] LIU GH, XIAO C, CHEN SF, *et al.* Role of soil seed bank in wetland restoration and biodiversity conservation in the middle and lower reaches of Yangtze River[J]. Progress in Natural Science: Materials International, 2007, 17(6): 741 – 747. (in Chinese).

[2] YU SL, JIANG GM. The research development of soil seed bank and several hot topics[J]. Acta Phytoecologica Sinica, 2003, 27(4): 552 – 560. (in Chinese).

[3] XU HL, LI JM, WANG ZR, *et al.* Spatial distribution characteristics of soil seed bank in lower reaches of Tarim River[J]. Journal of Soil and Water Conservation, 2007, 21(6): 183 – 186. (in Chinese).

[4] VECRIN MP, GREVILLIOT F, MULLER S. The contribution of persistent soil seed banks and flooding to the restoration of alluvial meadows [J]. Journal for Nature Conservation, 2006, 15(1): 59 – 69.

[5] MARTINS AM, ENGEL VL. Soil seed banks in tropical forest fragments with different disturbance histories in southeastern Brazil[J]. Ecological Engineering, 2007, 31(3): 165 – 174.

[6] ESAETE J, EYCOTT AE, REINIO J, *et al.* The seed and fern spore bank of a recovering African tropical forest[J]. Biotropica, 2014, 46 (6): 677 – 686.

[7] LIU QY, JIANG M, LU ZG, *et al.* A review of similarity between soil seed bank and aboveground vegetation in wetlands[J]. Acta Ecologica Sinica, 2014, 34(24): 7465 – 747. (in Chinese).

[8] LUO H, WANG KQ. Soil seed bank and aboveground vegetation in Jinshajing Hot-Dry River Valley Hillslope vegetation restoration site[J]. Acta Ecologica Sinica, 2006, 26(8): 2432 – 2442. (in Chinese).
[9] ZHAO LY, LI YZ, CHEN HB, *et al*. Relationship between soil seed banks characteristics and aboveground colonization community along natural restoration gradients in Horqin sandy land[J]. Ecology and Environment, 2018, 27(2): 199 – 208. (in Chinese).
[10] OU ZL, LV SH, LU SH, *et al*. Preliminary study on soil seed banks of degraded karst vegetation in Southwest Guangxi[J]. Guihaia, 2006, 26(6): 643 – 649. (in Chinese).
[11] ZHANG L, FANG JY. Reserves and species diversity of soil seed banks in four types of forest on Mt. Taibai, Qinling Mountains[J]. Biodiversity Science, 2004, 12(1): 131 – 136. (in Chinese).
[12] CHEN Y, LIU HJ, ZHANG JF, *et al*. Soil seed bank characteristics preliminary comparison between plantation and natural forest of *Betula alnoides*[J]. Forest Inventory and Planning, 2013, 38(2): 20 – 26. (in Chinese).
[13] CHEN S, HAI X, YE YZ, *et al*. Contrastive analysis of soil nutrients in coniferous and broad-leaved mixed forest on southern and northern slope of Funiu Mountain[J]. Journal of Central South Forestry University, 2018, 38(9): 65 – 71. (in Chinese).
[14] SHENG L, WANG YL. Effects of rehabilitation of "black soil type" degraded grassland into sowing grasslands on soil seed bank and its relationship with vegetation in the source area of Yellow River[J]. Pratacultural Science, 2010, 27(8): 39 – 43. (in Chinese).
[15] LI QY, ZHAO WZ. Advances in the soil seed bank of arid regions[J]. Advances in Earth Sciences, 2005, 20(3): 350 – 358. (in Chinese).
[16] WANG CH, LIU QQ, WEN ZM, *et al*. Variation characteristics of soil seed bank during vegetation restoration in red soil erosion area[J]. Chinese Journal of Applied Ecology, 2020, 31(2): 417 – 423. (in Chinese).
[17] CHEN QH. Storage and composition of soil seed bank of Karst area in Maolan[J]. Earth and Environment, 2008, 20(3): 581 – 586. (in Chinese).
[18] YIN XW, JIANG ZX, JI SH, *et al*. Research summary of wetland vegetation restoration using soil seed bank[J]. Wetland Science, 2019, 17(6): 697 – 704. (in Chinese).

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can be constructed to further optimize the landscape characteristics of subordinate mountains.

Through the appearance of architectural form orientation based on classical aesthetics, it can better integrate the relationship between mountains and buildings, allowing small towns to build their own characteristic buildings.

6 Conclusions

This paper analyzes the architecture of Ciping Town from the perspective of nature, evaluates various elements of the architecture, and puts forward renovation strategies for the architecture. But in the analysis from the perspectives of nature and culture, the description of the elements of local buildings is not detailed enough, so that the depth of analysis needs to be strengthened. It is hoped that this can be strengthened in the future.

References

[1] LI GY, XIE HX, HUANG DS. The exploration of mountain town landscape features based on the space reconstruction of traditional dwellings: A case study of the Wuling Mountainous Area[J]. Urban Research, 2016, 31(1): 122 – 126. (in Chinese).
[2] LI HP, XUE W. Spatial construction of mountainous cities in southwestern China in the context of traditional Chinese aesthetics[J]. City Planning Review, 2015, 39(5): 68 – 75. (in Chinese).
[3] CAO K, LI HP, XIAO J, *et al*. Landscape design methodology of mountainous cities based on artificial-natural harmony: Taking urban design of Yunyang Northern New District, Chongqing as an example[J]. City Planning Review, 2018, 42(7): 52 – 60. (in Chinese).
[4] CUI GH, MA RC. Urbanization from below in China: Its development and mechanisms[J]. Acta Geographica Sinica, 1999, 65(2): 106 – 115. (in Chinese).
[5] LIU BY, CHEN W. Pondering over the planning and development of landscape in towns and villages at present in China[J]. Development of Small Cities & Towns, 2005, 23(9): 45 – 47. (in Chinese).
[6] LI YY, ZHAO WM, YANG G, *et al*. Multiple balances of comprehensive evaluation of building value of historical and cultural feature areas under new norms: Take Chongqing Cuntan as an example[J]. Journal of Xi'an University of Architecture & Technology, 2018, 50(1): 92 – 99. (in Chinese).
[7] LU Y, XIA LF, YING QY, *et al*. A comprehensive evaluation of protection of historic districts examined from green architectural environment[J]. Journal of Shaoxing College of Arts and Sciences, 2016, 36(7): 18 – 22. (in Chinese).