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Recent advances in soil seed bank research

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ABSTRACT

Soil seed bank is an important component of ecosystem resilience and represents a stock of regeneration potential in many plant assemblages. Soil seed banks can be used to predict the composition of new plant recruitment. Species overcome periods of unfavorable weather conditions by building up a large seed bank. With this strategy, the species diversity is preserved and information on their dynamics and structure is retained. The research on soil seed bank has received wide interest because of its important role in plantation renovation and restoration, biological diversity preservation, vegetation succession and diffusion processes and other aspects. This paper reviews the relationship between soil seed bank and disturbance, geographic factor, vegetation and seed size and is aimed at providing some useful reference for future research.

Key words: soil seed bank, disturbance, geographic factor, vegetation, seed size.

Soil seed bank is an important component of ecosystem resilience and represents a stock of regeneration potential in many plant assemblages [1]. As a potential plant population soil seed bank plays an important role in the research of plant ecology, as well as one of the hot research topics in plant population ecology and vegetation ecology [2]. Pioneer species invasion triggers the dynamic of community succession, and soil seed banks can be used to predict the composition of new plant recruitment [3]. Species overcome periods of unfavorable weather conditions by building up a large seed bank. With this strategy, the species diversity is preserved and information on their dynamics and structure is retained [4]. The relevant soil seed bank research has started early in foreign countries: for instance, Harper compared a seed bank respectively to a current and deposit account in a bank, and the term "seed bank" was frequently used for this latent plant community as early as 1977 [5]. The definition of soil seed bank by Simpson embraces all survived seeds existing in soil and upper litter of soil [6]. At present most scholars conduct their soil seed bank research using Simpson's definition. The research on soil seed bank has been attached wide interest because of its important role in plantation renovation and restoration, biological diversity preservation, vegetation succession, diffusion processes and other aspects [7]. By contrast, the soil seed bank research started relatively late, but developing rapidly in China [8].

This paper reviews the relationship between soil seed bank and disturbance, geographic factor, vegetation and seed size and is aimed at providing some useful reference for future research.

THE RELATIONSHIP BETWEEN SOIL SEED BANK AND DISTURBANCE

Species composition of soil seed bank and disturbance. Species composition of soil seed bank in an extraneous interference habitat have been a hot issue. Within the biodiversity hotspot of southwest Australia some research scholars investigated the composition and diversity of the Banksia woodland soil seed bank in good condition, medium condition and poor condition invaded by the South African perennial species Ehrharta calycina and Pelargonium capitatum, and showed that the species richness in medium condition and poor condition invaded by the South African perennial species Ehrharta calycina and Pelargonium capitatum is lower than the soil seed bank in good condition [9]. A study of the role of soil seed bank along a grazing disturbance gradient and its relationship with the vegetation of alpine meadows on the Tibet plateau, showed that significant differences of species composition between seed bank and vegetation, except for the seriously disturbed site and the proportion of perennial species decreased with increase in disturbance [10]. Although the soil seed bank cannot represent the species composition of aboveground vegetation, but in the long term extraneous interference habitat, the native species keep 70 % of vegetation coverage in the long-term [11]. Hölzel and Wellstein in their respective research confirmed that the pioneer species seeds with small and short life occupy the dominant position in the soil seed bank [12, 13].

However, some other surveys suggested the opposite – the density of short-term persistent seeds (1year < seed longevity < 5years) in the soil is highest in fen meadows and the density of long-term persistent seeds (seed longevity > 5years) is highest in degraded meadows [14]. A large number of persistent seeds in severely disturbed habitats was also found by other authors [15–17].

Soil seed bank density and disturbance. Whilst temporal and spatial variation in opportunities for regeneration by seed appear to play a vital part in the maintenance of diversity in herbaceous vegetation, and the dominant species overcome environmental disturbance by producing a large number of seeds at a fast speed [18]. Kotowski and Van [19] studied the screening of the light in fen vegetation, and showed that vegetation resisted habitat degradation through reproducing more seeds by themselves, and later Fenner and Thompson [20] made a similar conclusion in their soil seed bank study.

Some authors have suggested that the restoration in some disturbed regions do not rely on soil seed bank, because the density of soil seed bank increases with disturbance degree [10]. Researchers who studied the species trait shifts in vegetation and soil seed bank during fen degradation, found that an increase in soil seed bank density during fen degradation, the seed density in the fen site was 35,304 seeds m^{-2} and increased to 57,550 seeds m^{-2} and 49,454 seeds m^{-2} in the fen meadow site and the degraded meadow, respectively [14].

Studies of the vertical distribution of seeds in the soil found that the density of soil seed bank is increasing during the degeneration [21, 22]. Many other studies reported similar trends of increasing seed density with degradation in the soil seed banks at different regions and different plant communities [23–25]. In addition, some studies suggested that long life seeds density will increase in the anaerobic and low-temperature environment [26–28]. However, the soil seed bank density obviously decreased in regions with moderate and serious species invasions [9].

THE RELATIONSHIP BETWEEN SOIL SEED BANK AND GEOGRAPHIC FACTOR

Wydkiewicz and Kwiatkowska-Falinska [29] studied the small scale spatial pattern of a soil seed bank in an old-growth deciduous forest and found that seed density in upper soil layer was negatively correlated with elevation ($r = -0.485$, $P = 0.0422$). A recent study of the soil seed bank and extant vegetation at different elevations found that there were no significant differences in seedling density or species richness of soil seed banks among the four elevations. In contrast, species richness of standing vegetation differed significantly with elevation [30].

The relationship between the slope angle and the density of buried seeds was analyzed, and slope angle was found to be the most important controlling factor for the density of buried seeds, in upper basins with many steep slopes, the loss of seeds by rolling off and draining off played greater role in forming the soil seed bank than seed inputs, slope angle having the negative effects on the seeds accumulation [31].

The development of the seed bank during the early stages of the restoration of coal wastes by hydroseeding has been shown to be affected by the distance from natural communities, and by topography in the case of the hydroseeded species: if the restoration area was close to natural communities, the native species component of the seed bank density increased [1]. Quintana-Ascencнo and Menges [32] inferred metapopulation dynamics from patch-level incidence of Florida scrub plants, suggested that the lowest richness and diversity values were found on the flat isolated area, and the greatest values were found in slope area that was in contact with the natural community, hence isolation decreases the probability of colonization. Moreover, many other studies reported similar trends with Quintana-Ascencнo and Menges [33, 34].

THE RELATIONSHIP BETWEEN SOIL SEED BANK AND ABOVEGROUND VEGETATION

The vegetation species richness and soil seed bank. Soil seed bank is an important propagule source for vegetation restoration [30] and for restoration of species-rich vegetation [10]. Soil seed bank provides a memory of past vegetation and represents the structure of future populations [9]. The relationship between soil seed bank and original plants is the key point in evaluating the revegetation potential [30]. Elizabeth's study indicated that cover and diversity of standing vegetation changed as tree cover increased. However, the soil seed bank did not differ in overall seed density or species diversity because the 13 species that comprised 86 % of the seed bank occurred in similar density across the tree cover groups. Interestingly, 63 % of the species that were in the seed bank were absent from the vegetation, and these species were mostly annual forbs. In addition 49 % of the species that occurred in the standing vegetation were not found in the seed bank, and these species were perennial forbs and subshrub/shrubs [3]. There was little relation between the species composition of the seed bank and the composition of the aboveground vegetation in pastures of diverse mixtures of temperate forages, which were the same plots as in Elizabeth's study [35]. The species composition of the aboveground vegetation and the soil seed bank can differ [13, 36]. A research of the relationship between soil seed bank and aboveground vegetation of 8 species at 4 different sites, showed that there were no species overlaps between soil seed bank and established vegetation at two sites, six species from extant vegetation were absent from the seed bank at one site, all this showed both seedling density and species richness of the soil seed bank among the four sites were significantly different [30]. Examination of the role of the soil seed bank along a grazing disturbance gradient and its relationship with the vegetation of alpine meadows on the Tibet plateau suggested that 62 species were identified in the vegetation and 87 in the seed bank, 39 species being common to both, significant differences of species composition between seed bank and vegetation (except for the seriously disturbed site) were found [10].

The study of characteristics and dynamics of the soil seed bank at the north edge of Taklimakan Desert found that 7 plant species in the above-ground community and 9 plant species in soil seed bank were identified, two species that were found in soil seed bank but did not exist in the above-ground vegetation community, the similarity coefficient between soil seed bank and above-ground vegetation being 0.778 [37]. In addition, the similarity between the aboveground vegetation and the soil seed bank in a Mediterranean coastal sand dune were found to be seasonally dynamic with highest similarity value occurring during May to September and the lowest value at about the end of April when no new seedlings were emerging [38].

The vegetation species recovery and soil seed bank. Soil seed bank plays an important part in the vegetation restoration process, and it seems to be essential that management plans take in consideration the differences in seed bank development of each site [1]. Oostings and Humphreys investigated the relationship between soil seed bank and vegetation succession as early as 1940 [39]. Fourie [40] suggested that the soil seed bank would be adequate to enable a functional cover of indigenous vegetation to re-establish after clearing. In order to improve vegetation structure and composition, the addition of some missing guilds would facilitate restoration, provided that post-clearing follow-up treatments do not prevent or hinder the establishment of these indigenous species. But the study of soil seed bank along a degradation gradient in arid rangelands of the Somali region, eastern Ethiopia showed that there was no adequate evidence to prove that severe degraded rangelands in eastern Ethiopia maintain adequate soil seed banks that would improve the condition of it through restoration [41]. Interestingly, some other authors have suggested that the establishment of new species in severely disturbed areas is more dependent on the seed bank, by contrast, the restoration in less-disturbed and mature meadows did not rely on seed banks, and the establishment of the vegetation in these communities is more likely to rely on seed dispersal from the standing vegetation and on species with vegetative reproduction [10].

THE RELATIONSHIP BETWEEN SOIL SEED BANK AND SEED SIZE

The relationship between seed size and soil seed bank was summarized systematically by some researchers, and four patterns were distinguished. First, seed weight and shape can predict persistence since small and compact seeds tend to be persistent in soil. Second, seed weight is related to persistence in soil, but seed shape is not. Third, there is apparently no relationship at all between seed weight, shape and persistence. Fourth, large seeds tend to form persistent soil seed banks, but seed shape is irrelevant [42].

Some researchers suggested that soil seed bank formation related to small seeds, because small seeds can easily enter into deep soil [43]. A database comprised of 18 plant traits and seed bank formation or persistence data, indicated that only life history and seed size were closely related to seed bank formation, and dormancy was not essential for the formation and persistence of a seed bank [41]. The diversity of seed size could enhance opportunities for seedling establishment in the heterogeneous environment allowing plants to respond to different sand burial depths, enhance their ability to adapt to the changing environment, and increase survival [44]. Ma [45] found the seed from persistent seed bank tend to have smaller seeds than species with transient seeds and the smaller seeds tend to exist in higher altitude area.

CONCLUSIONS

The studies of soil seed bank by different researchers were carried out at different sampling time, with different number of plots, plot size, sampling depth and the soil seed bank immediate environment, all these having led to different conclusions in similar research contexts, even the opposite ones.

The interest in biological invasions has increased substantially over the past few decades as a result of increases in the magnitude and occurrence of alien species in recent years [46, 47]. The propagulum traits and the impact of microhabitat and functional group on the soil seed bank have gained gradually more notice and need future research.

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