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Soil seed bank characteristics in Cameroonian rainforests and implications for post-logging forest recovery

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ABSTRACT

The soil seed bank is considered as an important component for resilience of climacic vegetation. Whereas several related studies have been conducted in Asian, American and some African tropical forests, no investigation has ever been conducted in Central African rainforests, especially in logged forests where the soil seed bank could contribute to regeneration of timber of trees species. We studied the soil seed bank characteristics in relation to the standing vegetation in three Cameroonian forest zones with different disturbance regimes. There was no significant difference between sites in terms of density of the seed bank; the average mean density was 87.6 seeds m^{-2}. But dissimilarities of the floristic compositions between sites were quite high. Overall, seeds came from 43 species including three commercial tree species. Whereas the seedlings emerging from soil samples mostly came from weedy and short-lived pioneer species, climax species predominated in the extant vegetation, leading to a very weak similarity between soil seed flora and the surrounding vegetation: Sorensen's index ranged from 3.5 to 7.6%. Canopy openness could significantly affect the species richness of soil seed stocks but not the seed density. These results show that the soil seed bank contribution to the resilience of mature tropical forests is low. In particular, very few timber tree species could benefit from soil seed stocks for their regeneration. Therefore, the development of enrichment techniques including use of the soil seed bank as a source of tree regeneration in such a context would be irrelevant.

1. Introduction

Since Symington (1933) found a large quantity of seeds in Malaysian forest soil and as seed rain seems to account for only a small proportion of forest regeneration in disturbed zones (Putz and Appanah, 1987; Lawton and Putz, 1988), the importance of seed banks in vegetation dynamics is receiving increasing attention. Seed banks are a significant source of regeneration (Hosogi and Kameyama, 2006) and have been included in several restoration projects (Lemauviel et al., 2005; Williams et al., 2008) or weed control programs (Marks and Nwachuku, 2006).

A soil seed bank is defined as the number or store of viable seeds buried in the soil at a given time, representing a record of the recent vegetation of an area (Martins and Engel, 2007). According to Swaine and Whitmore (1988), seeds in the soil are of two kinds: (a) transient or ephemeral seeds, from species with very brief viability in forest soils (either they germinate quickly when water is available, or they die); (b) persistent seeds of species which have an extended viability in soil, and are commonly associated with the phenomenon of dormancy. However, various authors have emphasized the continuity between these two groups of species. Regarding tropical regions, Garwood (1989) defined three more soil seed bank strategies as intermediates to the two categories mentioned earlier.

Studies tend to show that persistent and pseudo-persistent seeds of weedy and short-lived pioneer species are the most commonly observed (Hopkins and Graham, 1983; Garwood, 1989; Dalling et al., 1998). Schmidt (2007) reported that many trees of humid tropical forests are animal-dispersed and rarely have post-dispersal seed dormancy; their seeds are adapted to rapid germination, even in shaded environments. Thus, seed banks in tropical forests, even in primary forests may be composed almost entirely of pioneers (*sensu* Swaine and Whitmore, 1988). In fact, several studies from tropical America (e.g., Ten Hoopen and Kapelle,

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2006; Dalling and Brown, 2009), Asia (e.g., Chandrashekara and Ramakrishnan, 1993; Metcalfe and Turner, 1998; Howlett and Davidson, 2003) and some parts of Africa (e.g., Keay, 1960; Hall and Swaine, 1980; De Villiers et al., 2003; Kassahun et al., 2009) have confirmed that the soil seed bank could be an important mechanism for the regeneration of only pioneer and secondary forest species (see also Garwood, 1989; Jankowska-Błaszczuk and Grubb, 2006).

Concerning the role of environmental patterns on seed bank characteristics, the effect of canopy disturbance on seed stocks in tropical forest soils has also been studied, but no clear trend can be seen. For instance, whereas Lindner (2009) found no relationship between canopy openness and seed bank characteristics, Perera (2005) revealed an influence of canopy openness on the species richness of the forest soil.

In the Congo Basin rainforests, many surveys of regeneration have been performed (Hall et al., 2003; Kouadio, 2009), but these studies have not been able to disentangle the relative contributions of seed rain and seed bank. In particular, in regard to logged African tropical forests, addressing the role of soil seed bank is relevant as it could be an interesting tool in forest management. Nowadays, national regulations for logging concessions in Central Africa recommend implementation of enrichment techniques with a significant cost (Doucet et al., 2009). Thus, beyond its contribution to the natural maintenance of biodiversity, a soil containing numerous seeds of timber trees could be implicated in forest enrichment in a number of ways. For example, as soil in logging gaps is generally compacted, repeated stirring of the soil could favor the emergence of commercial seedlings. Similarly, the transportation of seed-rich topsoil from an intact forest zone to nearby degraded lands could contribute to accelerate development of the appropriate vegetation (Skoglund, 1992). As most timber tree species are light-demanders (Doucet, 2003), their regeneration rates could be considerably improved with such techniques.

Up to now, no prior studies have documented soil seed bank characteristics and their possible relevance in Central African rainforests. Here, we investigated the potential of soil seed stocks in a Cameroonian forest concession, in relation with the main pattern of disturbance in this context: forest gaps made by cutting activities. We aimed to respond to the following questions:

(1) What are the dominant life-forms in seed banks of Central African rainforests, and hence, what stages in forest succession could benefit from forest soil for their regeneration?
(2) In order to promote regeneration of timber tree species through the potential of the soil seed bank, can forest soils be an important source of seedlings for these commercial species?
(3) How are the seed bank characteristics affected by canopy disturbance patterns?

2. Materials and methods

2.1. Study sites

The study was conducted in a Cameroonian forest concession of 118,052 ha located at the west of the Dja Reserve and logged by the company Pallisco (Fig. 1). The concession has a mean elevation of about 650 m and extends between 3°01′–3°25′N and 14°05′–14°31′E in a mostly a semi-deciduous forest zone (Kouadio and Doucet, 2009). Rainfall is distributed in two rainy periods (from March to June, and from August to December) alternating with two dry seasons. The mean annual rainfall and temperature are respectively about 1550 mm and 24 °C (DMNC, 2009). Humidity is high throughout the year. The concession zone is a low fairly flat plateau laid on a substratum of schists, gneisses and quartzite (Laclavère, 1979).

Three sites of late secondary forest with various logging histories were selected for the present study. The first stand of 8.25 ha, located in a protected forest area, *PF*, was never been exploited. The second site covered 4.80 ha and was located in a recently logged forest, *RLF*, where the most recent logging was performed two years ago. The third site was a 9-year-old logged forest, *OLF*, and covered 7.80 ha. Distances from one site to another varied from 10 to 20 km. These sites were fairly similar in species composition (Cerisier, 2009).

2.2. Soil sampling and seedling emergence test

Within each forest site, two or three transects were established with respect to the size of the site. The total length of transects was 300, 705 and 555 m for *RLF*, *OLF* and *PF*, respectively. Soil samples were collected every 15 m along the transects providing 21, 49 and 40 samples for *RLF*, *OLF* and *PF*, respectively. Each soil sample was a mixture obtained from three quadrats of 10 cm × 10 cm and 5 cm in depth established at the top of a 1 m-sided equilateral triangle. Large items of litter were removed before soil sampling. Thus, a total area of 3.3 m^2 and a total volume of 165,000 cm^3 of soil were sampled. Since Mbarga et al. (1999) noted that November to March is the period of the lowest level of fruiting in South-Cameroonian rainforests, the samples were collected in February to limit seed rain inclusions.

Quantitative and qualitative composition of the seed banks was investigated using the seedling emergence method. Samples were sieved before the experiment began, in order to detect large and viable diaspores. The seedling emergence experiment was performed in a greenhouse at Gembloux Agro-Bio Tech (University of Liege), under average temperature and humidity of 25 °C and 60.5%, respectively. Each soil sample was spread to 1 cm depth onto a substrate of sterilized sandy loam in a tray. The containers were watered as required, at least once a day. They were also redistributed randomly inside the greenhouse each week. The seeds found during sieving were also put to germination in the same greenhouse. Each emergent seedling was removed and repotted for further growth until large enough for identification. The seedling emergence experiment was ended after 16 weeks, as all germination events occurred during the first 12 weeks.

2.3. Characterization of habitats

Canopy openness was estimated within each site, assuming that this parameter could affect soil seed bank characteristics. Canopy cover was estimated 1 m above the ground using a spherical densiometer. Densiometer measures were performed by the same person at each soil sampling point and under similar weather conditions. The spherical densiometer is known to be a good compromise between speed and accuracy as far as measurement of canopy cover is concerned (Korhonen et al., 2006). Moreover, this instrument is well adapted to estimate canopy closure which is defined as the fraction of non-visible sky within a certain angle of view whereas canopy cover is the fraction of ground area covered by crowns (Paletto and Tosi, 2009).

The extant vegetation of tree species with diameter at breast height (dbh) >10 cm was also surveyed up to 50 m each side of the transects on which soil sampling was performed. This inventory was performed to (a) verify the similarity in the woody flora between sites, and (b) compare its characteristics to those of the soil seed bank. In total, 3, 5.5 and 7.1 ha were surveyed in *RLF*, *OLF* and *PLF*, respectively.