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Original Article

Silviculture

Soil Seed Bank at Different Depths and Light Conditions in a Dry Forest in Northern Minas Gerais

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ABSTRACT

The soil seed bank is an important natural regeneration strategy for plant communities and can determine floristic composition after disturbances. The aim of the present study was to evaluate the seed bank richness and abundance at different soil depths and under different light conditions in a dry forest. Litter and soil samples were collected at depths of 0-5 and 5-10 cm and submitted to two light conditions (light and shady). In total, 1,725 individuals from 85 species and 19 families emerged. Significant differences in richness between soil depths were observed, being greater at 0-5 cm, while abundance was similar. There were no variations in richness or abundance of germinated seeds between light conditions. Malvaceae and Verbenaceae families were the most representative in this study.

Keywords: seeds stock, soil layers, light conditions, seasonally, deciduous forest.

1. INTRODUCTION

Dry tropical forests (dry deciduous forests or *matas secas* in Brazil) are conditioned by strong climatic seasonality and are mainly characterized by tree formations showing pronounced leaf loss during the dry season (Murphy & Lugo, 1986). They have wide occurrence in Brazil, both in *Cerrado*, Atlantic Rainforest and *Caatinga* biomes (Scariot & Sevilha, 2005); therefore, vegetation has distinct characteristics depending on the area of occurrence (Pedralli, 1997). Although being quite diverse, they are one of the most threatened ecosystems in the world, with 60% of their territory already modified by anthropogenic actions directed toward agriculture (Sánchez-Azofeifa et al., 2013). Land abandonment after agricultural use is among the main causes for composition, structure and ecological function modification of these forests (Bullock, 1995; Colón & Lugo, 2006), which can lead to secondary succession, driven by the germination of seeds present in the soil (Martins et al., 2008).

The soil seed bank consists of a set of viable (non-germinated or dormant) seeds that remain in the soil (on the surface or buried) until adequate conditions for their germination are achieved, and adult plants in an environment are replaced (Garwood, 1989). It is a fundamental part of the regeneration process of the plant community, also determining the vegetation composition in frequently disturbed areas (Luzuriaga et al., 2005). Soil seed banks can also be managed to recover degraded areas (Reubens et al., 2007; Nóbrega et al., 2009; Pereira et al., 2010). Seeds come from the local community (seed rain) and from neighboring or distant areas brought by dispersing agents (Hall & Swaine, 1980).

After dispersion, some seeds are retained in the litter, while others reach different soil depths due to their morphological characteristics and dispersion structures (Yu et al., 2007). Soil texture also plays a role in this process (Thompson & Grime, 1979; Garwood, 1989). Seeds can be buried at several depths, being variable according to layer, amount of seeds, germination capacity and viability period. The highest germination percentage occurs in the most superficial soil layer, influenced by light and temperature conditions (Garwood, 1989; Baider et al., 2001), with dormancy breaking decreasing the deeper seeds are buried (Marthews et al., 2008).

Temperature and light are among the major environmental factors that influence seed germination in the soil, according to water and oxygen availability (Fenner & Thompson, 2005). Some seeds germinate after exposure to light (positive photoblastic), which exposure may be short or long. Other seeds germinate only in the absence of light (negative photoblastic) while others are indifferent (Vàzquez-Yanes & Orozco-Segovia, 1990). The number of hours of light required for the germination of photosensitive seeds varies according to the ecological requirements of the species (Araújo et al., 2003).

In regions marked by climatic seasonality, plant communities tend to exhibit adaptations to tolerate drought (xeromorphic characteristics) or to be dominated by annual plants that survive water scarcity, with dormant seeds in the soil (Howe & Smallwood, 1982). Thus, seed banks are one of the main strategies for the long-term survival of plant communities regarding climatic seasonality and irregular rainfall (Kemp, 1989; Baskin & Baskin, 1998; Reubens et al., 2007).

Therefore, dry tropical forests, being environments marked by climatic seasonality and irregular rainfall, may exhibit regenerative potential associated with the soil seed bank. Thus, knowledge about this vegetation component may assist in the management and restoration of these forests. The aim of the present study was to evaluate richness and abundance in the soil seed bank at different soil depths and light conditions in a dry tropical forest in the "Mata Seca" State Park, northern Minas Gerais. Thus, the following questions were addressed: (i) do the soil seed bank richness and abundance vary among different soil depths and under different light conditions? and (ii) what is the contribution of the seed bank to natural regeneration in the area? Richness and abundance are expected to be higher in superficial soil layers and when submitted to greater luminosity conditions.

2. MATERIAL AND METHODS

2.1. Study area

The study was carried out at "Mata Seca" State Park (MSSP), located in the Middle São Francisco River Valley, northern Minas Gerais. MSSP covers an area of 15,446 ha (Pezzini et al., 2014), located among municipalities of Manga, Itacarambi, São João das

Missões and Matias Cardoso (14°48’36”-14°56’59” S and 43°55’12”-44°04’12” W). The predominant climate in the region is As (Köppen classification), with pronounced dry season in winter, average annual temperature of 24° C and average annual rainfall of 818 mm (Madeira et al., 2009; Alvares et al., 2013). According to Coelho et al. (2013), the MSSP geology is associated with Cenozoic coverings (Bambuí and Urucuia Groups and quaternary deposits of the São Francisco River), presenting different soil types. In areas where the dry forest occurs, soils are derived from the carbonate-pelitic rocks and present the following taxonomic suborders: Haplic Cambisols, Red Latosols and Red-Yellow Latosols, Haplic and Argiluvic Chernosols, Haplic Vertisols, Petroferric Plinthosol, Haplic and Melanic Gleisols (Coelho et al., 2013).

Prior to the creation of MSSP, the main use of the park area was for cattle grazing. Therefore, vegetation remnants present variable regeneration degrees (Madeira et al., 2009). The study was developed in a dry forest section where the vegetation survey was carried out (see Madeira et al., 2009; Nunes et al., 2013), which considered 18 plots of 20 m × 50 m, marked in 2006 in an arbitrary manner. These plots represent three successional stages (initial, secondary and late), with six plots in each (Madeira et al., 2009). These plots had minimum distance from each other of 200 m and maximum distance of 5 km. For the present study, successional stages were not considered.

2.2. Soil seed bank sampling

Soil seed bank sampling was performed in plots described, and soil and litter samples were collected over four periods in 2013 (April, July and October) and 2014 (January). For soil sampling, four points were equidistantly marked in each plot, one at each vertex of the plot and 3 m away from the edges. Superficial litter samples (0.09 m^2 each sample) and two soil samples were collected at depths of 0-5 cm and 5-10 cm (0.045 m^3 each sample) at each point of the plot using a 30 cm × 30 cm wooden template. In total, 864 samples were collected from 18 plots. The four separate litter and soil samples were mixed to form a composite sample of each depth in each plot, totaling 216 composite samples. Samples composed of litter and soil were separately conditioned in properly identified plastic bags and transported to the Laboratory of Plant Ecology at “Unimontes” campus, Montes Claros/MG.

Each sample composed of litter and soil was divided into two plastic pots with dimensions of 22 cm × 12 cm × 8 cm, and litter samples were placed on sterilized sand, which had been previously autoclaved. Each pair of soil and litter samples was distributed in two greenhouses, with different light conditions (light and shade) to monitor the germination of the species, according to the different light intensity conditions. Greenhouses had dimensions of 11 m × 6 m × 2 m, one simulating direct light conditions (light condition), covered by white polyethylene screen on the top and sides, and plastic only on the top; and the other simulating shade conditions (shade condition), obtained through black polyethylene screen (50% shade), covered with black polyethylene screen on the top and sides, and plastic only on the top. The use of transparent plastic covering the top of greenhouses had the objective of controlling the humidity and avoiding infiltration by local rainfall. The ground in the two greenhouses was covered by gravel and black polyethylene sheeting to avoid the emergence of seedlings native to the experimental site. To avoid infestation by local seed rain, 35 plastic pots containing sterilized sand (autoclaved) were distributed in each greenhouse. Samples from both treatments were watered twice daily (morning and afternoon). The total number of experimental samples was 432 (18 plots × 3 depths × 4 collection periods × 2 light conditions).

For the seed bank test, the Brown’s (1992) emergence method was used. Litter and soil samples were weekly monitored throughout the 12-week period. For this, all individuals whose seeds emerged and produced seedlings were counted, being also morphotyped for identification. After individual establishment (post-seedling stage) or when there was reproductive material (flower), the individual was removed for herborization. The botanical material was identified through consultations with specialists and specialized literature. The botanical material was treated according to traditional herborization techniques and deposited in the “Montes Claros” Herbarium (MCMG) at Unimontes. Angiosperm Philogeny Group III system (APG III, 2009) was used to classify species by family.

2.3. Data analysis

To evaluate the soil seed bank richness and abundance according to depth classes (litter, 0-5cm and 5-10 cm) and light availability (greenhouse: light and shade conditions), richness and abundance values were submitted to Analysis of Variance (ANOVA) in a GLM (Generalized Linear Model) (Nelder & Wedderburn, 1972), with "F" test and posterior contrast analysis. For analyses, the number of individuals observed in the soil seed bank amomg the different periods was added, maintaining two seasons (rainy and dry), totaling 108 samples (18 plots × 3 depths × 2 light conditions). Values were presented as mean ± standard error with differences between averages at 5% probability being considered significant. All analyses were performed using the $R_{3.1.3}$ software (R Development Core Team, 2015).

3. RESULTS AND DISCUSSION

Considering all depth levels of the soil seed bank sampled at MSSP, there were 1,725 individuals belonging to 85 species, 38 genera and 19 Angiospermae families, and three unidentified pteridophytes (Table 1). Families that presented the greatest richness were Malvaceae, with 13 species, followed by Verbenaceae and Fabaceae, with 12 species each. Malvaceae and Verbenaceae families were also the most abundant (260 and 233 individuals respectively), followed by Poaceae (214 individuals).

In relation to depth, 71 species (83.52% of total germinated species) were present at depth of 0-5 cm, 53 (62.35%) at depth of 5-10 cm and 49 (57.65%) in the litter (Table 1). The mean number of germinated species per sample was 8.46 ± 1.15 at the depth of 0-5 cm, 6.42 ± 0.87 at the depth of 5-10 cm and 4.92 ± 0.96 in the litter, being significantly greater at the depth of 0-5 cm in comparison with the other depths (Figure 1, Table 2). The abundance of seeds at the depth of 0-5 cm was 657 recruited individuals (38.09% of the total), 568 individuals in the litter (32.93%) and 500 individuals at the depth of 5-10 cm (28.99%). Considering the average number of individuals germinated per sample, there were 27.37 ± 5.65 individuals at the depth of 0-5 cm, 23.71 ± 8.89 in the litter and 20.92 ± 4.00 individuals at the depth of 5-10 cm. There were no significant

Table 1. Seed bank richness (S) and abundance (A) for botanical families of Seasonally Deciduous Forest in "Mata Seca" State Park (Manga, MG) under different soil depths and light conditions.

Family	Depth						Light conditions			
	Litter		0-5 cm		5-10 cm		Shade		Light	
	S	A	S	A	S	A	S	A	S	A
Amaranthaceae	0	0	1	1	1	8	1	4	1	5
Asteraceae	7	30	6	59	8	64	6	43	8	110
Bignoniaceae	0	0	0	0	1	1	0	0	1	1
Boraginaceae	0	0	3	15	2	10	3	10	2	15
Burseraceae	1	186	1	1	0	0	1	112	1	75
Commelinaceae	0	0	1	2	0	0	1	1	1	1
Convolvulaceae	2	10	4	13	2	4	3	15	4	12
Cyperaceae	0	0	1	2	1	3	1	3	1	2
Euphorbiaceae	4	32	4	23	3	71	4	40	4	86
Fabaceae	9	39	7	73	5	27	9	56	8	83
Lamiaceae	1	2	3	68	1	15	2	46	2	39
Malvaceae	3	83	12	125	8	52	8	53	11	207
Oxalidaceae	1	1	1	3	0	0	1	2	1	2
Phyllanthaceae	1	15	2	65	2	51	2	68	2	63
Poaceae	6	13	6	74	6	127	6	177	6	37
Rubiaceae	1	59	1	21	2	4	2	61	1	23
Smilacaceae	1	18	1	7	1	2	1	16	1	11
Solanaceae	2	2	3	4	0	0	3	3	3	3
Verbenaceae	9	75	12	98	9	60	9	151	12	82
Pteridophyta*	1	3	2	3	1	1	0	0	3	7
Total	49	568	71	657	53	500	63	861	73	864

*Group not classified in botanical family.

Table 2. Analysis of Variance of the effect of treatments (depth and light) in response variables: soil seed bank richness and abundance of Seasonally Deciduous Forest in "Mata Seca" State Park (Manga, MG).

Response variable	Source of variation	DF	Deviance	Residual DF	Residual Deviance	F	*p*
Richness	SD	2	151.69	69	1657.6	3.194	0.047*
	LC	1	51.68	68	1605.9	2.176	0.145
	SD × LC	2	38.69	66	1567.2	0.815	0.447
Abundance	SD	2	503.58	69	70036	0.239	0.788
	LC	1	0.50	68	70036	0.001	0.983
	SD × LC	2	623.58	66	69412	0.297	0.744

SD = soil depth; LC = light conditions; DF = Degrees of freedom; F = Fisher's F test. *Statistically different ($p < 0.05$).

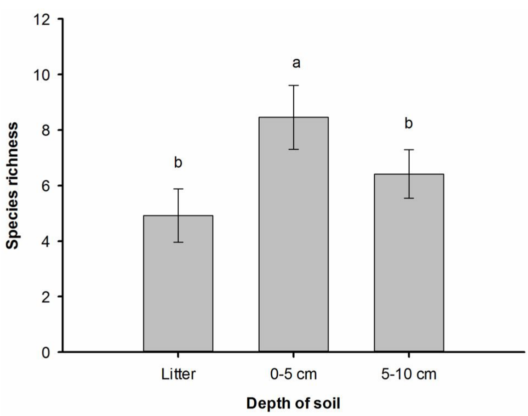

Figure 1. Soil seed bank richness (average number of species per sample), collected in different depths in a Seasonally Deciduous Forest (Manga, MG). Bars represent the standard error. Different letters indicate significant differences ($p < 0.05$; n = 108).

differences in the abundance of seeds germinated among the different soil layers (Table 2). The vertical distribution of the seed bank is derived from the action of different biotic and abiotic mechanisms for incorporation of seeds into the soil (Garwood, 1989). Most studies indicate higher seed abundance in the most superficial soil layers (Baider et al., 2001; Bossuyt et al., 2002; Costa & Araújo, 2003; Luzuriaga et al., 2005; Wang et al., 2009; Santos et al., 2010; Silva et al., 2013; Savadogo et al. 2017), which is favored by constant seed replacement, which determines the maintenance of the species in the plant community (Bossuyt et al., 2002). However, few studies have shown variations in richness (Korb et al. 2005; Wang et al., 2009; Jia et al., 2017), mainly due to the difficulty of species identification. According to Jia et al. (2017), environmental factors such as soil characteristics, topography, climate and vegetation distribution play an important role in the formation of the soil seed bank.

Between light treatments, the number of species germinated was 73 (85.88% of the total) in the light condition and 63 species (74.12%) in the shade condition (Table 1). The average species per sample in the light condition was 7.44 ± 0.90 and in the shade condition was 5.75 ± 0.76; but these values showed no significant difference (Table 2). Abundance also presented no significant differences between conditions evaluated, with 864 individuals (50.09% of the total, 24.08 ± 5.42 per sample) in the light condition and 861 individuals (49.91% of the total, 23.92 ± 5.16 per sample) in the shade condition. Other studies, such as Braga et al. (2008) and Martins et al. (2008) also showed no differences in the number of germinated seeds between different light intensities. Differences in germination in relation to light treatments are more common when each species is analyzed separately (Costalonga et al., 2006). The influence of light on dry forest seed banks is more likely to be lower, since these environments present marked foliar deciduousness (Nunes et al., 2012), which allows greater exposure to light inside the forest. On the other hand, water availability may be the main triggering factor for seed germination in these environments.

In relation to floristic composition, 14 families were found in the litter, with Fabaceae and Verbenaceae families being the most representative (nine species each), followed by Asteraceae (seven) and Poaceae families (six) (Table 1). The family with the largest number of individuals was Burseraceae, with 186 individuals, with only one representative species, *Commiphora leptophloeos* (Mart.) J. B. Gillett., which was consequently the most abundant species. Of families with the highest richness and abundance registered in the MSSP seed bank, only Fabaceae family was recorded as one of the richest and densest in floristic composition surveys of the plant community in the same study site (Madeira et al., 2009; Nunes et al. 2013). Tropical forest seed banks are largely composed of seeds that are absent or rare in the local vegetation, presenting limited relationship with the plant community (Baider et al., 2001). Moreover, most of the seed bank is represented by seeds from herbaceous species (Garwood, 1989; Baider et al., 2001), which were not considered in the floristic studies carried out in MSSP. Additionally, the high abundance of *C. leptophloeos*, a pioneer tree species (Carvalho, 2008), characteristic of dry forests in the region (Santos et al., 2007; Sales et al., 2009; Arruda et al., 2011) and of the arboreal component of the studied forest (Madeira et al., 2009; Nunes et al., 2013), suggest that this species uses the seed bank as a reproductive strategy.

At the depth of 0-5 cm, 18 families were recorded, with Commelinaceae family being recorded only at this soil layer. Families that presented the greatest species richness were Malvaceae and Verbenaceae (12 species in each), followed by Fabaceae (seven species). Malvaceae was also the most abundant family, with 125 individuals (Table 1). The species of greatest abundance at this soil depth was *Sida planicaulis* Cav. (Malvaceae), with 100 individuals. This species is a small shrub, 0.5-1.0 m, widely distributed and common in disturbed areas (Bovini et al., 2001). In addition, the Malvaceae family was also listed among the most representative in other studies that evaluated the seed bank in riparian forest (Tres et al., 2007) and *Caatinga* vegetation (Silva et al., 2013).

At the depth of 5-10 cm, species from15 families were found, with Bignoniaceae being exclusive to this soil depth, although it was represented by only one individual. The most valuable family was Verbenaceae (nine species), followed by Asteraceae and Malvaceae families (eight species each) (Table 1). At this depth, the most abundant family was Poaceae (127 individuals) and the most prevalent species was an unidentified Poaceae, with 73 individuals. Asteraceae and Poaceae are also among the richest and most abundant families in a seed bank study conducted in the dry forests of the *Caatinga* biome (Mamede & Araújo, 2007).

Among light treatments, there were practically no differences in the number of families. In the light condition, the 19 families registered in the study were represented, while in the shade condition, 18 were recorded (Table 1). Only Bignoniaceae was not recorded in the shade condition. In the light condition, the family with the highest species richness was Verbenaceae (12 species) followed by Malvaceae (11 species). In the shade condition, the families with the greatest richness were Fabaceae and Verbenaceae (nine species each), followed by Malvaceae (eight species). The most abundant families in the light condition were Malvaceae (207 individuals) and Asteraceae (110 individuals), while in the shade, the most abundant family was Poaceae (177 individuals) followed by Verbenaceae (151 individuals) and Burseraceae (112 individuals). The species that germinated with greatest abundance in the light condition was *S. planicaulis*, with 173 individuals. As in litter, the most abundant species in the shade was *C. leptophloeos*, with 112 individuals. Although light is considered an important factor for the germination of many species found in the seed bank (Garwood, 1989), shading can also favor germination, since soil retains greater moisture content (Franco et al., 2012). This could explain the great similarity in the amounts of species and individuals germinating under both light and shade conditions found in this study.

The results of this study indicate the potential of the seed bank to regenerate the dry forests in the region. Although most recruited species are herbaceous and generalist, there are tree species that were recruited via soil seed bank. Information on the regenerative potential of tropical dry forests is extremely important, especially in terms of the reproductive strategies of their species, given the great anthropogenic pressures faced by these environments (Calvo Rodriguez et al., 2016). Therefore, understanding the seed bank functioning may be essential to preserve and restore dry forests.

4. CONCLUSION

The soil seed bank under study presented greater richness in the superficial soil layer, that is, in the first 5 cm of depth, but its abundance did not vary among layers or between the different light conditions. Malvaceae, Verbenaceae and Asteraceae families were among the most representative in the soil seed bank, considering the different layers and shading conditions. However, although the great majority of germinated seeds belong to herbaceous species, the high prevalence of *Commiphora leptophloeos* (Burseraceae) in the soil seed bank should be highlighted, as it is an important tree species characteristic of the studied physiognomy.

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