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Soil Seed Bank of the Marantaceae Forests of Ouesso Forest Industry (IFO), Republic of Congo

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Abstract

The soil seed bank is a key indicator of natural regeneration and/or forests resilience after disturbances. This study evaluates the soil seed bank characteristics in two Marantaceae forests plots of Ouesso Forest Industry (IFO) in north of the Republic of Congo. In each plot, 12 samples were taken per soil layers (0 - 5 cm, 5 - 10 cm, 10 - 15 cm and 15 - 20 cm deep). Diversity and abundance seed were estimated after germination of soil samples. The results revealed 101 seedlings belonging to 17 species for plot 1 and 129 seedlings belonging to 15 species for plot 2. The average densities of germinated seeds were respectively 281 seedling/m^2 and 358 seedling/m^2. There were no significant differences ($p > 0.05$) between the mean densities of the two plots. Herbaceous species dominated with percentages of 71% and 73%, respectively in plot 1 and plot 2. Both plots showed potential of regeneration from the soil seed bank. However, this potential seems higher in plot 2. Pioneer taxa were more abundant in the soil seed bank of plot 1 (4 woody pioneer species) than in plot 2 (1 woody pioneer species). The highest species richness was obtained in the first two soil layers (0 - 5 cm and 5 - 10 cm depth) while 25% of species were exclusively found in the deepest layer (15 - 20 cm) in plot 2. The study suggests silvicultural interventions based on planting or enrichment techniques for contribute to sustainable management of Marantaceae forests that could prevent the growth and development of seedlings.

Keywords

Soil Seed Bank, Seedlings, Marantaceae Forests, Natural Regeneration, Forest

Resilience, Republic of Congo

1. Introduction

Soil seed bank represents viable seeds stored in litter, on soil, and in soil [1] [2]. They are ungerminated seeds, capable of replacing adult plants having disappeared for various reasons [3]. Insofar as the soil seed bank intrinsically assumes the existence of an any form of dormancy of the seeds constituting it, it is mainly the so-called orthodox seeds (persistent seeds having a long viability in the soil) who compones the soil bank [4].

The soil seed bank is an important element of natural regeneration. It forms a reserve that can be expressed during a disturbance of arborescent covered [5] [6]. The importance of the soil seed bank in natural regeneration of forests has been relatively studied less in tropical zone and most studies have concerned America and Asia [5] [7]. In the moist forests of Central Africa, we can nonetheless note some studies [8] [9] [10] [11]. These studies globally demonstrate the dominance of pioneer tree species in the soil seed bank and the low similarity with the surrounding vegetation.

Nonetheless, to improve the regeneration of woody species, planting in open forest habitats with seedlings from nurseries should be more effective [10] [12] [13]. Studies of the soil seed bank in Marantaceae forests still remain an unexplored research axis in moist forests of Central Africa and even less in the Republic of Congo. Marantaceae forests are composed of giant and perennial herbaceous plants, with rhizomes that are often very covering and of imposing size [14]. They are distinguished by an original physiognomy characterized by the presence of a continuous stratum of giant herbaceous plants, associated with a disseminated wooded component presenting a deficit of natural regeneration [14].

Occupying large areas, Marantaceae forests can compromise the sustainability of logging activity to long term [14]. Consequently, the dynamics of regeneration through the soil seed bank within these Marantaceae forests is an innovative axis of research. The specific richness, diversity and abundance of the soil seed bank of Marantaceae forests can be an important source of natural regeneration, particularly in exploited forests which represent 26% of the forest cover of Central Africa [15]. Knowledge of the floristic composition of soil seed bank in Marantaceae forests is essential insofar as it will allow to assess their regeneration potential. It will also inform on their past and future vegetation cover.

General objective of the present study is to assess the natural regeneration potential of Marantaceae forests through the soil seed bank. Three questions are asked in this study:

1) Does the germination of the soil seed bank vary according to plots and soil layers within Marantaceae forests?

2) Does the floristic composition of the soil seed bank differ in terms of the

plots and soil layers of Marantaceae forests?

3) Does it exist exclusive species in the soil layers of the two Marantaceae plots?

2. Materiel and Methodes

2.1. Study Site

The study was carried in the forest concession allocated to Ouesso Forest Industry (IFO) in the Ngombe Forest Management Unit (FMU, Ngombe) in north of the Republic of Congo. The site presents a relatively flat relief with average altitudes between 400 m and 430 m [16]. The FMU Ngombe extends between 0˚27' - 1˚48'N and 15˚20' - 16˚38'E (**Figure 1**). The site is part of the semi-humid equatorial climate zone. It is characterized by two dry seasons and two rainy seasons per year [14]. Average annual rainfall and average temperatures are 1730 mm and 27˚C respectively.

The FMU Ngombe forests are semi-deciduous and installed on clay soils which develop on the alluvial deposits of the Congolese basin [16]. They are shelter many species typical of old secondary forests such as *Entandrophragma cylindricum*, *Entandrophragma utile*, *Erythrophleum suaveolens*, *Triplochiton scleroxylon*. A large part of FMU Ngombe is covered with Marantaceae forests [14]. These Marantaceae forests have a undergrowth invaded by giant herbaceous species of the Marantaceae and Zingiberaceae families, which can reach several meters height. The floor shrubby is poorly represented and displays a regeneration deficit [14] [16].

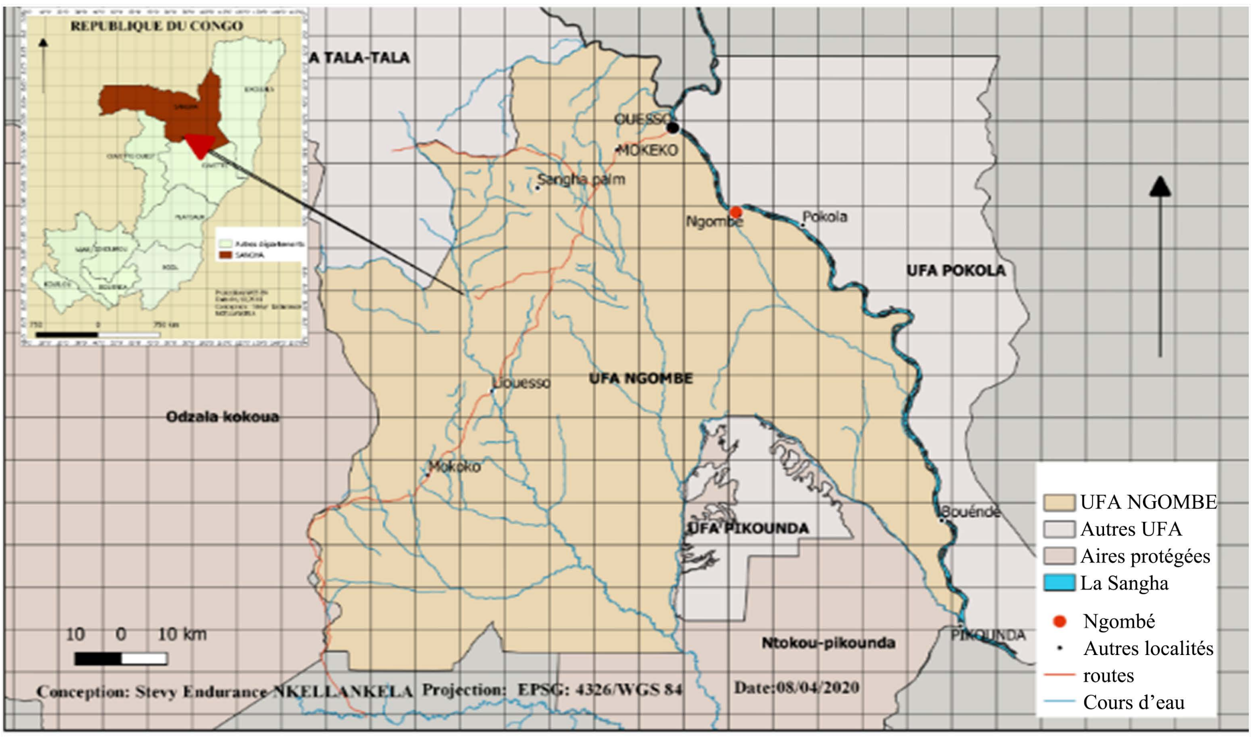

Figure 1. Location of the study area within FMU Ngombe (red dot).

2.2. Sampling and Germination Test of the Soil Seed Bank

The soil samples were taken in August 2020 (during the transition between the short dry season and the big rainy season) within two Marantaceae forests plots (plot 1, exploited in 2019, and plot 2, exploited in 2017). In each Marantaceae forests plot (1000 m * 500 m, area of one plot), three non-contiguous plots of 625 m^2 (25 * 25 m) were installed, at the rate of 6 plots for the two Marantaceae forests plots.

Inside each 625 m^2 plot, four sub-plots measuring 12.50 m were used for sampling points collection, *i.e.* a total of 12 collections points per plot (**Figure 2**). Four layers of soil were sampled per point: 0 - 5 cm, 5 - 10 cm, 10 - 15 cm et 15 - 20 cm. Each sample was composite, *i.e.* from the mixture of three unit samples taken on the vertices of an equilateral triangle with sides of 1 m [6] [8] [10]. Each sample concerned an area of 100 cm^2 (10 * 10 cm). The sampled area by Maranaceae forests plots covered accordingly 0.36 m^2.

The number of viable seeds in the soil samples has been estimated by the germination method [3] [10] [17]. The samples were sieved before the start of the experiment, in order to eliminate plant elements and minerals elements (leaves, smithereens of wood). Germination was realized in a greenhouse at the National School of Agronomy and Forestry (ENSAF) to Brazzaville, in a non-forest area in order to limit the risk of contamination of the samples by the surrounding vegetation.

Relative light intensity was about 30% - 40% of full light. Each soil sample was spread out on a layer of sterilized substrate-sand mixture about 1 cm thick [3] [10] [17]. Watering was daily, and germinations control was bi-weekly. When their stage of development allowed, the seedlings were withdrawned and repotted individually in polyethylene bags to promote their growth and identification.

As all the germinations took place over the course of the first 12 weeks, the experiment was stopped after 16 weeks (*i.e.* 4 months of experimentation).

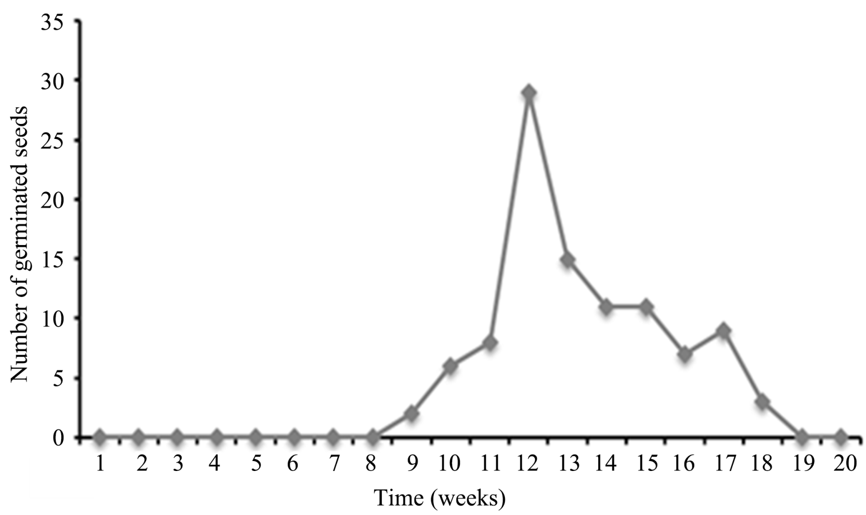

Figure 2. Number of germinated seeds in terms of time in plot 1 (exploited in 2019).

Voucher specimens were collected and species were identified by botanists (Gilbert Nsongola, Isaac Dzombo). We followed the taxonomy of the Geneva Herbaria Catalogue (http://www.ville-ge.ch/musinfo/bd/cjb/chg).

2.3. Data Analysis

2.3.1. Soil Seed Bank Germination

To evaluate the evolution of germination in terms of time, the number of seeds having effectively germinated in the soil bank has been estimated for each Marantaceae forests plot and soil layers [6] [18].

2.3.2. Floristic Composition of the Soil Seed Bank between Plots and Soil Layers

To identify the characteristics of the species observed in the soil seed bank, classification of tree and shrub species was done according to light requirements using the regeneration guilds of tropical forest species [19], and the dispersal syndromes of seeds [20]. Also, classification of species was done in terms of tree and shrub species, herbaceous species, liana species and undetermined species.

To describe the abundance of seeds from the two Marantaceae plots, the following parameters were used: the absolute density, *AD* (seed/m^2), the relative density, *RD* (%, number of seeds of a given species/the total number of seeds for all species), the relative frequency *RF* (%, proportion of samples containing the given species) and the species Importance Value Index (*IVI*) computed as the sum of *RD* and *RF* [8] [10] [21].

Nonetheless, the observed species richness S_{obs}, being a biased estimator and very dependent of sampling effort [22], the estimators Chao2, S_{chao2} (based on incidence) and Jackknife1, S_{jack1} (based on abundance) [23] [24] were used. These species richness estimators are defined as follows [25] [26]:

$$S_{Chao2} = S_{obs} + \frac{Q_i^2}{2Q_i} \quad (1)$$

$$S_{Jack1} = S_{obs} + \frac{Q_1(m-1)}{m} \quad (2)$$

S_{obs}: observed species richness;

Q_1: number of species detected in a single sample (unique);

Q_2: number of species detected in two samples (duplicate);

m: total number of individuals sampled.

EstimateS software 9.1.0 [27], was used to generate as well the observed species richness S_{obs} than the estimated richness, S_{chao2} (bias-corrected Chao2) and S_{jack1}. These two types of richness have been illustrated by tables. Biological diversity was estimated using Shannon indices (H'), Equitability of Pielou (E) and Sorensen [28]. Finally, the specificity of the soil layers in terms of species exclusively found in each soil layer was determined by reporting these "exclusive and/or endemic" species to total number of species collected in the soil layer (S_{excl}%).

To compare the floristic composition of the two Marantaceae forests plots, we performed a Principal Component Analysis (PCA) based on the abundance data of species, using R software with Vegan package [29]. Samples that gave no germination were excluded from the analysis.

3. Results

3.1. Soil Seed Bank Germination of the Two Marantaceae Forests Plots

The evolution of germination all layers mixed, of the soil seed bank within the two Marantaceae forests plots indicates that in plot 1 (exploited in 2019), the first germination was observed from the ninth week to reach peak at the twelfth and thirteenth week (**Figure 2**).

Nonetheless, during the last two weeks (twelfth and thirteenth), nearly 29 and 15 new seedlings were recorded respectively. The last germinations occurred from the eighteenth week (**Figure 2**).

However, in plot 2 (exploited in 2017), the first germinations occurred from the fifth week to reach peak at the twelfth and thirteenth week (**Figure 3**). We recorded respectively nearly 20 and 30 new seedlings. Germinations regressed globally from the fourteenth up to the sixteenth week with 7 new seedlings (**Figure 3**).

Nonetheless, the evolution of germinations in terms of soil layers within the two plots demonstrate that in plot 1 (exploited in 2019), the first germination occurred from the eighth week with the 0 - 5 cm layer to reach peak at the twelfth and fifteenth week (**Figure 4**). This layer is illustrated as the most representative in number of germinated seeds. Moreover, in the 15 - 20 cm layer, 7 germinated seeds were recorded during the eleventh and seventeenth week. The last germinations occurred from the nineteenth week with the two aforesaid layers (**Figure 4**).

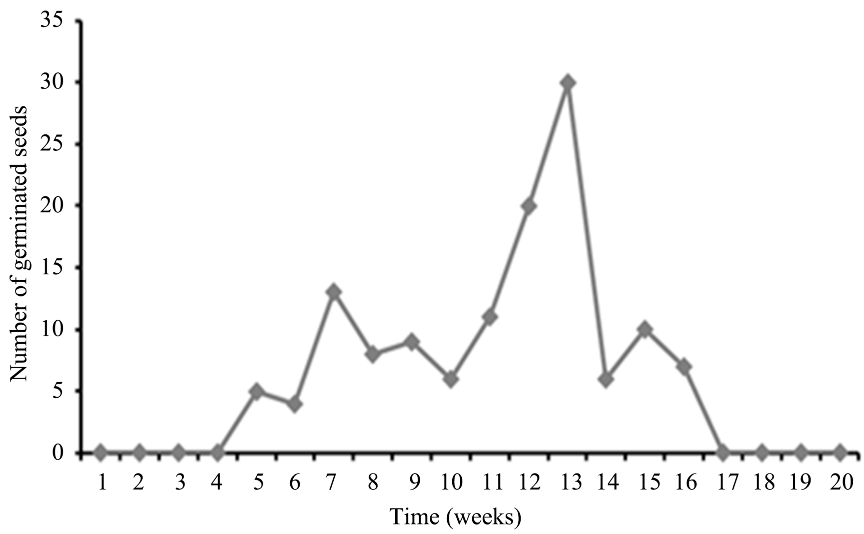

Figure 3. Number of germinated seeds in terms of time in plot 2 (exploited in 2017).

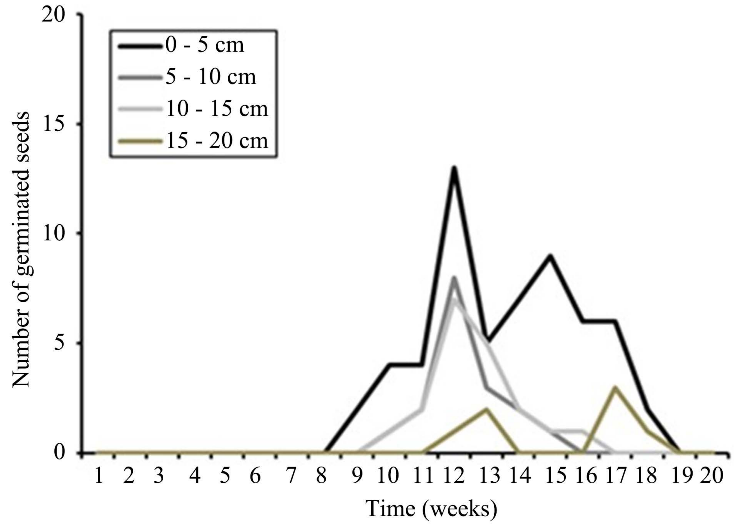

Figure 4. Seeds germination according to soil layers in terms of time in plot 1 (exploited in 2019).

On the other hand, in plot 2 (exploited in 2017), the first germinations occurred from of the fourth week with the 0 - 5 cm and 10 - 15 cm layers (**Figure 5**), and the germination peak occurred from the thirteenth week with the 0 - 5 cm layer. Also, the first germinations of the 15 - 20 cm layer were illustrated from the tenth week to fade around the seventeenth week with a overall number of 10 germinated seeds (**Figure 5**).

3.2. Soil Seed Bank Composition of the Two Marantaceae Forests Plots

101 seedlings germinated from soil seed bank of plot 1 and 129 seedlings from plot 2, with respective average densities of 281 and 358 seedling/m^2. There was no significant difference in the mean number of seedlings between the two plots (Kruskal-Wallis test, p-value = 0.5938). In plot 1, the seedlings belonged to 17 species with 4 species of trees and shrubs (23%), 12 herbaceous species (71%) and one species of liana (6%). The tree and shrub species group only included one commercial species: *Nauclea diderrichii* (De Wild. & T. Durand) Merr. (**Table 1**).

On the other hand, in plot 2, the seedlings belonged to 15 species with one species of tree and shrub (7%), 11 herbaceous species (73%) and 3 undetermined species (20%). No commercial tree species was observed. The most abundant trees and shrubs in the soil bank of plot 1 were *N. diderrichii* (43%) and *Harungana madagascariensis* Lam. ex Poire. (29%), while plot 2 presented only the species *Margaritaria discoidea* (Baill.) G. L. Webster (14%).

Nonetheless, the results of the Principal Component Analysis (PCA) display a total variability of the two marantaceae forests plots of 25.56%. Consequently, the two Marantaceae forests plots globally share the same species (**Figure 6**). This observation to confirm Sorensen's relatively low similarity value of 0.56% (**Table 2**).

Table 1. Soil seed bank composition of the two Marantaceae forests plots, plot 1 and plot 2. Dispersal mode: *Au* = autochory, *Z* = zoochory. *AD* = absolute density, *RD* = relative density, *RF* = relative frequency, *IVI* = species importance value index. Temperament: *p* = pioneer.

Species	Family	Guild	Dispersal mode	Number of seeds	AD (n/m²)	RD (%)	RF (%)	IVI
Plot 1 (exploited in 2019)								
Trees and shrubs (4 species)								
Margaritaria discoidea (Baill.) G. L. Webster	Phyllanthaceae	P	Au/Z	1	2.78	0.99	0.35	1.34
Harungana madagascariensis Lam. ex Poir.	Hypericaceae	P	Z	2	5.56	1.98	0.70	2.68
Nauclea diderrichii (De Wild. & T. Durand) Merr.	Rubiaceae	P	Z	3	8.33	2.97	1.06	4.03
Trema orientalis (L.) Blume	Cannabaceae	P	Z	1	2.78	0.99	0.35	1.34
Herbaceous (12 species)								
Alternanthera sessilis (L.) R. Br. Ex DC.	Amaranthaceae	-	-	13	36.11	12.87	4.58	17.45
Aneilema beniniense (P. Beauv.) Kunth	Commelinaceae	-	-	1	2.78	0.99	0.35	1.34
Aneilema umbrosum (Vahl) Kunth	Commelinaceae	-	-	6	16.67	5.94	2.11	8.05
Costus lucanusianus J. Braun & K. Schum.	Costaceae	-	-	1	2.78	0.99	0.35	1.34
Commelina sp.	Commelinaceae	-	-	6	16.67	5.94	2.11	8.05
Cyathula prostrata (L.) Blume	Amaranthaceae	-	-	4	11.11	3.96	1.41	5.37
Elytraria marginata Vahl	Acanthaceae	-	-	7	19.44	6.93	2.47	9.40
Lindernia diffusa (L.) Wettst.	Scrophulariaceae	-	-	8	22.22	7.92	2.82	10.74
Microtea debilis Sw.	Phytolaccaceae	-	-	3	8.33	2.97	1.06	4.03
Panicum brevifolium L.	Poaceae	-	-	8	22.22	7.92	2.82	10.74
Sabicea sp.	Rubiaceae	-	-	2	5.56	1.98	0.13	2.11
Tristemma hirtum P. Beauv.	Melastomataceae	-	-	34	94.44	33.66	11.97	45.63
Liana (1 species)								
Undetermined		-	-	1	2.78	0.99	0.35	1.34
Total				**101**	**281**	100	-	-
Plot 2 (exploited in 2017)								
Trees and shrubs (1 species)								
Margaritaria discoidea (Baill.) G. L. Webster	Phyllanthaceae	P	Au/Z	1	2.78	0.78	0.22	0.99
Herbaceous (11 species)								
Alternanthera sessilis (L.) R. Br. Ex DC.	Amaranthaceae	-	-	3	8.33	2.33	0.65	2.98
Aneilema umbrosum (Vahl) Kunth	Commelinaceae	-	-	7	19.44	5.43	1.52	6.94
Conyza sumatrensis (Retz.) E. Walker	Asteraceae	-	-	2	5.56	1.55	0.43	1.98

Continued

Cyathula prostrata (L.) Blume	Amaranthaceae	-	-	9	25	6.98	1.95	8.93
Dinophora spenneroides Benth.	Melastomataceae	-	-	10	27.78	7.75	2.16	9.92
Lindernia diffusa (L.) Wettst.	Scrophulariaceae	-	-	22	61.11	17.05	4.76	21.82
Microtea debilis Sw.	Phytolaccaceae	-	-	4	11.11	3.10	0.87	3.97
Panicum brevifolium L.	Poaceae	-	-	17	47.22	13.18	3.68	16.86
Sabicea sp.	Rubiaceae	-	-	1	2.78	0.78	0.22	0.99
Spermacoce latifolia Aubl.	Rubiaceae	-	-	2	5.56	1.55	0.43	1.98
Tristemma hirtum P. Beauv.	Melastomataceae	-	-	47	130.56	36.43	10.18	46.61
Undetermined (3 species)								
Undetermined 1		-	-	2	2.78	1.55	0.43	1.98
Undetermined 2		-	-	1	2.78	0.78	0.22	0.99
Undetermined 3		-	-	1	2.78	0.78	0.22	0.99
Total				**129**	**358**	100	-	-

Table 2. Variability of diversity indices within the two Marantaceae forests plots.

Plots	Shannon index	Pielou's equitability index	Sorensen index	Common species
Plot 1	3.23	0.8	0.56	9
Plot 2	2.92	0.75		

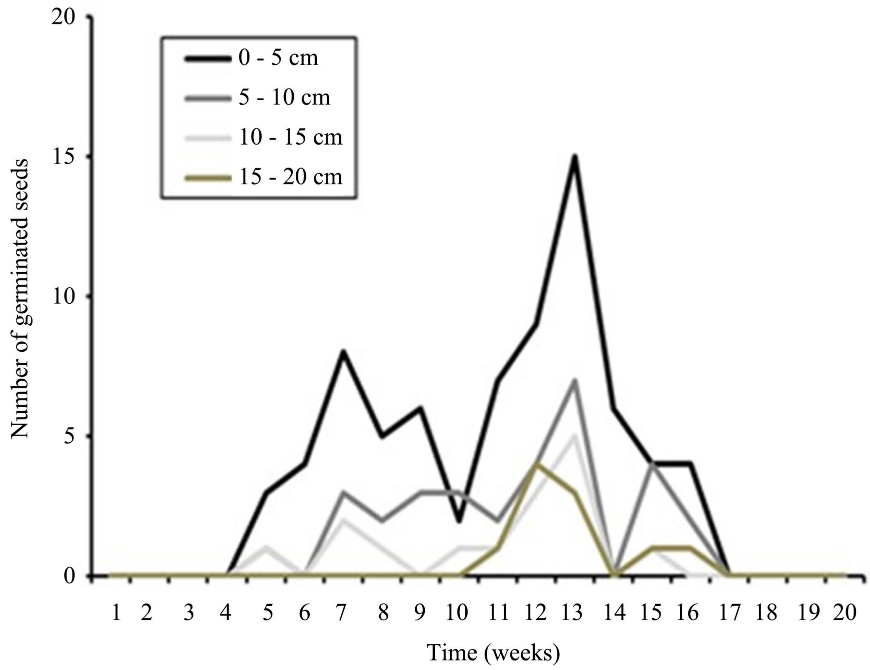

Figure 5. Seeds germination according to soil layers in terms of time in plot 2 (exploited in 2017).

3.3. Soil Seed Bank Abundance within the Soil Layers of the Two Marantaceae Forests Plots

All soil layers presented a significant number of seeds and taxa (Table 3). Regardless of the plot, the 0 - 5 cm and 5 - 10 cm layers present the highest values of the estimated species richness. Interesting fact, the deepest layer 15 - 20 cm of plot 2 also presented a non-negligible seeds abundance and species richness of 25% exclusive species (Table 3). Species found exclusively in the deepest soil layer were: *Margaritaria discoidea* (Baill.) G. L. Webster and *Sabicea* sp.

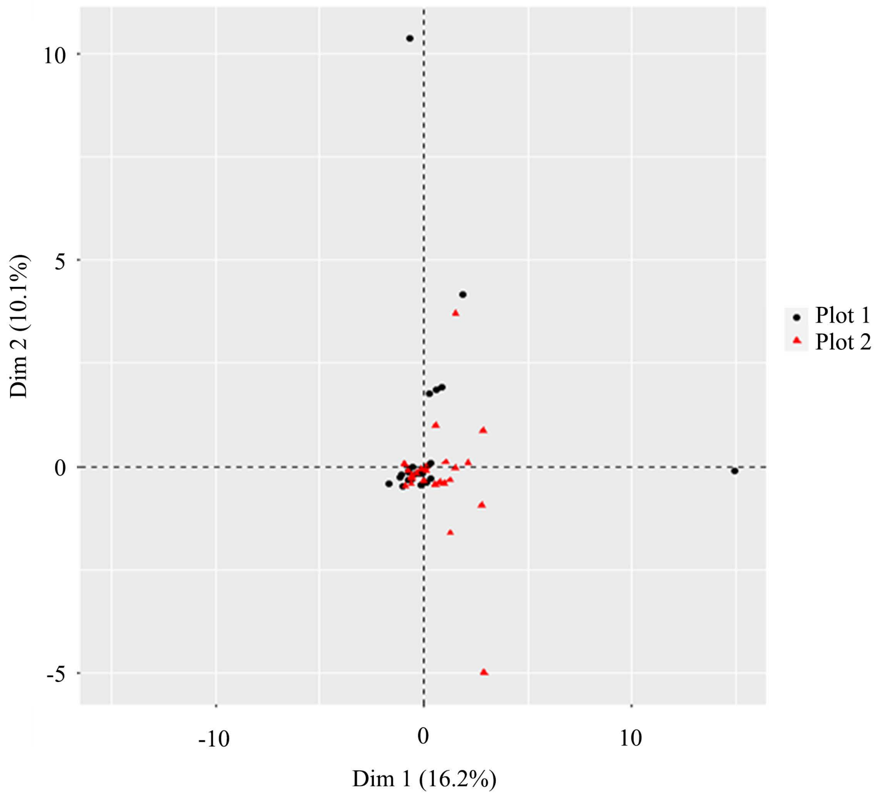

Figure 6. Principal Component Analysis (PCA) of soil samples from the two Marantaceae forests plots studied.

Table 3. Soil seed bank characteristics in the soil layers of the two Marantaceae forests plots. Sobs = observed species richness; Schao2 = estimated specific richness according to the approach Chao2; Sjack1 = estimated specific richness according to the approach Jackniffe1; Sexcl (%) = percentage of exclusive species in each soil layer; Density = Mean (±SD) of number seeds per area.

Soil layers	Plot 1					Plot 2				
	Sobs	Sexcl (%)	Schao2	Sjack1	Density (n/m^2)	Sobs	Sexcl (%)	Schao2	Sjack1	Density (n/m^2)
0 - 5 cm	13	6	17.08	15.7	36.11 (±38.82)	8	4	8.33	6.95	22.22 (±26.55)
5 - 10 cm	6	2	10.5	7.97	16.67 (±18.73)	9	2	12.13	14.72	25 (±29.71)
10 - 15 cm	6	2	8.5	6.9	16.67 (±18.73)	2	0	2	2.99	5.56 (±8.45)
15 - 20 cm	3	0	6	4.74	8.33 (±10.14)	8	2	12.16	14.48	22.22 (±26.55)
Total	17	/	10.52	8.83	281	15	/	8.66	9.79	358

4. Discussion

4.1. Soil Seed Bank Germination Varies in Terms of Marantaceae Forests Plots and Soil Layers

In the present study, we demonstrated that pioneer species of forest succession such as *Margaritaria discoidea*, *Harungana madagascariensis*, *Nauclea diderrichii* and *Trema orientalis* were present in the soil layers studied and much more abundant in plot 1 than in plot 2 which only presented the species *M. discoidea*. This could mean that this last one would be more mature than the first, which could be considered as a plot in process of recolonization.

All soil layers mixed, this study has demonstrated that in plot 1 (exploited in 2019), seeds germinated from the ninth week (*i.e.* about 2 months after germination of soil samples) to reach the germination peak from the twelfth week (*i.e.* about 4 months after germination of soil samples). No germination was recorded from the nineteenth week. On the other hand, in plot 2 (exploited in 2017), the seeds started to germinate from the fifth week (*i.e.* about 1 month after germination of soil samples) to reach the germination peak from the thirteenth week (*i.e.* about 3 months after germination of soil samples). From the seventeenth week, no germination was recorded. This slight difference germination times could be explained by the fact that in plot 2, exploited well before plot 1, the seeds stored in the soil bank would have lifted their dormancy, thus allowing enough rapid germination compared to plot 1.

The results of the present study differ in the logging company in southeast Cameroon (Pallisco), whose germination peak occurred from the fifth and seventh week. The last germinations occurred during the twelfth week [8]. Remember that this study was limited to the first five layers of soil. Likewise, germination peaks occurred from the third and fourth week to fade from the eighth week [30].

Regarding germination from the soil layers of the two plots, the 0 - 5 cm and 5 - 10 cm layers were the first to germinate compared to others soil layers. This observation could be explained by the following facts: 1) the studies inherent to the soil seed bank tend to demonstrate that the floristic richness of the soil seed bank decreases rapidly with depth, whatever the biotope considered, and this, up to 50 cm deep [6] [10] [11]; 2) the large majority of the soil seed bank is concentrated in the top 25 centimeters of soil, with greatest abundance in the top 5 or 10 centimeters [31]. Consequently, the seeds located in the soil layers superficial (0 - 5 cm and 5 - 10 cm) are exposed to light, the latter being a limiting factor for the germination of most species of tropical forests.

4.2. The Density and Floristic Composition of the Soil Seed Bank Differs in Terms of Plots and Soil Layers

In several studies, the spatial heterogeneity of the tropical forest soil seed bank has been emphasized [7] [8] [10] [32].

Nonetheless, in Cameroon during the study of soil seed bank characteristics at minimum depth (5 cm depth), 88 seedling/m^2 have been reported [8]. In mature forest and old secondary forest, we report densities ranging from 247 seedling/m^2 to 330 seedling/m^2, respectively [10].

In the present study, the seed densities obtained were higher and ranged from 281 seedling/m^2 to 358 seedling/m^2 because soil layers up to 20 cm deep were considered. The estimates reported in the literature can reach much higher values. Seed abundance in tropical soil layers ranges from 25 to 3350 seeds/m^2 [31].

This variation could also be due to the diversity of soil seed bank characterization methods, particularly sample size, season of soil sample collect, sample processing and depth of soils sampled [33]. The longevity of seeds in the soil bank could depend of their size and morphology. Long-lived persistent seeds are generally small size with a spherical shape [34].

In the present study, herbaceous species dominated with varying between percentages 71% and 73%, respectively in plots 1 and 2. Previous studies have also demonstrated relatively similar percentages [8] [35].

This can be explained by the following mechanisms: 1) herbaceous species produce a large amount of small seeds that naturally escape predation from the seed-feeding animals compared to large seeds; 2) these small seeds progressively accumulate in large quantities in the soil [36] and 3) they can survive for decades in the forester soil [10]. The tree species observed represented 7% and 23%, respectively in plots 2 and 1. In a similar forest in Cameroon, tree species such as: *Erythrophleum suaveolens*, *Musanga cecropioides*, *Macaranga* spp., *Margaritaria discoidea*, *Tetrochidium didymostemon*, *Zanthoxylum* spp. have been reported [8]. In the present study, the tree species found in the soil bank were: *Harungana madagascariensis*, *Margaritaria discoidea*, *Nauclea diderrichii* et *Trema orientalis*.

Only one tree species *Margaritaria discoidea* was found in the deepest soil layer of 15 - 20 cm. *Margaritaria discoidea* is frequent in wooded savannah, dry evergreen forest and dry secondary forest [37]. It is also found in semi-deciduous forest. Several parts of the plant are used in traditional medicine through out the African continent.

In West Africa, we chew filamentous and fibrous bark as purgative and aphrodisiac [38]. In north of Congo, it was reported that this species part of the indicator species of disturbed forests [14].

Overall, it was observed that the abundance and the floristic diversity seeds were higher in plot 2 (exploited in 2017) than in plot 1 (exploited in 2019). Such a trend has been observed elsewhere [10] [39], which could translate a fairly rapid recolonization of plot 2 compared to plot 1.

Regarding species richness, the number of observed species (Sobs) found in this study ranged between 15 and 17 species. These values were relatively lower to those observed in other African forest sites (11 to 43 specie) [8] [10]. However, the strong heterogeneity of the soil seed bank requires the use of species richness estimators instead of the number of species observed (*Sobs*) [40].

The most surprising discovery in the present study seems to be siginficant decrease of seeds abundance and species richness along soil depth. In the 15 - 20 cm layer, significant amount of viable seeds (about 25%) can still be observed. However, this layer is rarely explored during studies inherent at the soil seed bank. Clearly, deeper soil layers should not be ignored during studies of the soil seed bank in tropical forests.

5. Conclusion

The present study consisted to assess the potential of natural regeneration through the soil seed bank in the Marantaceae forests. The results highlighted the role that the soil seed bank could play in the natural regeneration of Marantaceae forests. At the end of this study, we can overall retain that: 1) soil seed bank characteristics vary from one plot to another; 2) seed stocks were substantial up to 20 cm soil depth, and some pioneer tree species had viable seeds in the deeper soil layers although they were absent in superficial layers; and 3) commercial tree species were not well represented in the soil seed bank of the two Marantaceae forests plots. Consequently, the study suggests silvicultural practices to improve the regeneration of commercial tree species in Marantaceae forests [3] [17] [41].

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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