Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
https://periodicos.ufersa.edu.br/index.php/caatinga
ISSN 1983-2125 (online)

http://dx.doi.org/10.1590/1983-21252024v3712497rc

Scientific Article

Seed bank composition and floristic diversity of an inselberg in the semiarid region of Paraiba, Brazil

Composição e diversidade florística do banco de sementes de um inselbergue no semiárido paraibano

Alisson G. C. Guimarães[1]*, Ivonete A. Bakke[2], Thayná K. F. de Medeiros[3], Emanoel M. P. Fernando[2], Antonio W. Batista[4], Maria de F. de Araújo[5], Luciana F. de M. Mendonça[2], Cheila D. Ferreira[2]

[1]Department of Forest Sciences, Universidade Estadual do Sudoeste da Bahia, Vitória da Conquista, BA, Brazil. [2]Academic Unit of Forestry Engineering, Universidade Federal de Campina Grande, Patos, PB, Brazil. [3]Center of Agrarian Sciences, Universidade Federal da Paraíba, Areia, PB, Brazil. [4]Department of Forest Sciences, Universidade Estadual Paulista, Botucatu, SP, Brazil.[5]Academic Unit of Biological Sciences, Universidade Federal de Campina Grande, Patos, PB, Brazil.

ABSTRACT – The objective of this study was to evaluate the seed bank composition and floristic diversity, as well as the degree of vegetation similarity at different altitudes (base, middle, and top layers) of the Espinho Branco Inselberg, Patos, PB, Brazil. Forty-seven litterfall-soil samples (0-5 cm soil layer) were collected and placed on 95 perforated plastic trays to allow drainage of excess irrigation water. The trays were identified and distributed on benches in a shaded environment in the forest nursery at the Federal University of Campina Grande (UAEF/CSTR/UFCG), with a sunlight reduction factor of 50%. The emerged plants were classified by popular names, grouped according to family, genus, species, and plant type (herbaceous, sub-shrub, shrub, tree, and climber). Diversity and richness were evaluated using the Shannon-Weaver diversity and the Pielou equitability indices, and the similarity was determined using the Jaccard Index. The floristic composition of the collected samples showed 4,616 individuals from 40 families, 96 genera, and 111 species. The family Fabaceae had the highest number of species, followed by Euphorbiaceae, Malvaceae, and Poaceae. The predominant plant type was herbaceous. Cyperaceae, Onagraceae, and Poaceae were the most representative families in number of individuals. The Shannon-Weaver diversity and Pielou equitability indices were 2.92 and 0.62, respectively, and the Jaccard index was 0.93; the base layer had the greatest floristic richness. This work contributes with information to further researches on floristic diversity and richness and improves scientific studies in this field.

Keywords: Rocky outcrop. Altitude layers. Life forms.

RESUMO – O presente estudo objetivou avaliar a composição e diversidade florística do banco de sementes e verificar o grau de similaridade dessa vegetação nas diferentes porções altitudinais (Base, Porção Mediana e Topo) do Inselbergue Espinho Branco no município de Patos-PB. Foram coletadas 47 amostras de serapilheira+solo na profundidade de 0-5 cm, distribuídas em 95 bandejas plásticas perfuradas, para permitir a drenagem do excesso de água de irrigação. Estas foram identificadas e distribuídas nas bancadas do ambiente sombreado do viveiro florestal do CSTR com fator de redução solar de 50%. As plantas emergidas foram classificadas pelo nome popular, agrupadas de acordo com a família, gênero, espécie e a forma de vida. A diversidade e a riqueza foram avaliadas utilizando o Índice de Shannon-Weaver e o Índice de equabilidade de Pielou, enquanto a similadaridade foi determinada pelo Índice de Jaccard. A composição florística das amostras coletadas apresentou 4.616 indivíduos distribuídos em 40 famílias, 96 gêneros e 111 espécies. A família Fabaceae apresentou o maior número de espécies, seguida pela Euphorbiaceae, Malvaceae e Poaceae. A forma de vida predominante foi a herbácea. Em número de indivíduos, a família Cyperaceae, Onagraceae e Poaceae foram as mais representativas. Os índices de diversidade de Shannon-Weaver e de equabilidade de Pielou foram 2,92 e 0,62, respectivamente, e o Índice de Jaccard de 0,93, sendo a Base a porção com maior riqueza florística. Assim, este trabalho contribui com os estudos acerca da temática, representando um ganho para a sociedade e para a comunidade científica na promoção de pesquisas futuras.

Palavras-chaves: Afloramento rochoso. Porções altitudinais. Formas de vida.

Conflict of interest: The authors declare no conflict of interest related to the publication of this manuscript.

Received for publication in: February 7, 2024.
Accepted in: May 7, 2024.

***Corresponding author:**
<alissongeancg7@gmail.com>

INTRODUCTION

The semiarid region of the Northeast of Brazil has distinctive climate characteristic, with high levels of solar radiation and low, unevenly distributed rainfall depths in time and space. The Caatinga biome predominates in this region, covering an area of approximately 844,453 km², representing around 11% of the national territory; it is the fourth largest biome in Brazil (SOUZA, 2020).

The Caatinga vegetation encompasses a complex array of various physiognomies, with xerophytic and deciduous plants resistant to adverse conditions, including high solar radiation and temperatures and low rainfall depths. These conditions, combined with accelerated anthropogenic disturbances, mainly regarding areas for agriculture and pastures, challenge the survival of some species, leading to loss of diversity (RIBEIRO et al., 2017).

Caatinga is not a homogeneous biome, as it exhibits diverse landscapes expressed in different physiognomies, which denotes its biological importance (CÓRDULA; QUEIROZ; ALVES, 2008). Two physiognomies are usually considered: arboreal Caatinga and shrubby Caatinga (FERNANDES, 2000).

Inselbergs are common in various regions of the Northeast of Brazil, including the northern Borborema Massif, in Patos (Paraiba), the Seridó region (Rio Grande do Norte), Quixadá (Ceará), and in the state of Bahia (MAIA et al., 2015). The municipality of Patos, Paraíba, holds a crucial area for flora conservation, represented by a stretch of Caatinga vegetation between the Borborema Plateau and the Northern Sertaneja Depression (GIULIETTI et al., 2004; LOPES-SILVA et al., 2019).

Some inselbergs are found in this area, which exhibits specific edaphic and microclimate conditions, including higher temperatures, water retention in crevices or pools, and pronounced wind action, composing ravishing landscapes (ARAÚJO; OLIVEIRA; LIMA-VERDE, 2008; TOLKE et al., 2011).

According to Lucena et al. (2015), plants in inselbergs are challenged by water deficits, small amounts of available substrate, and high solar radiation levels, but vegetation is found in different altitude layers; additionally, they pointed out the lack of studies for the region. This denotes the importance of research involving seed banks in these areas, as the results may contribute to a better understanding of the representation of vegetation communities and the occupation by other species from nearby areas. Moreover, they contribute to a better understanding of the behavior of species and to describe their survival and colonization, mainly the herbaceous stratum, which is often overlooked. In this regard, this information can support local managements and the conservation of Caatinga biodiversity.

Considering the need for studies in this biome regarding floristic diversity of seed banks, the objective of this study was to evaluate the seed bank composition and floristic diversity, as well as the degree of similarity of this vegetation, at different altitudes (base, middle, and top layers) of the Espinho Branco Inselberg, in Patos, PB, Brazil.

MATERIALS AND METHODS

Characteristics of the study area

The study was conducted in the Espinho Branco Inselberg (EB), located in the municipality of Patos, PB, Brazil (Figure 1), which has an estimated area of 506.5 km^2. The municipality of Patos belongs to the State Immediate and Intermediate Region, in the Northern Sertaneja Depression, with an average altitude of 250 m, presenting undulating and slightly undulating relief (BRASIL, 2005). The climate of the region is BSh, semiarid, according to the Köppen classification (ALVARES et al., 2014), and the predominant vegetation is characterized as open shrubby Caatinga (LOPES -SILVA; LUCENA; GOMES-SILVA, 2017).

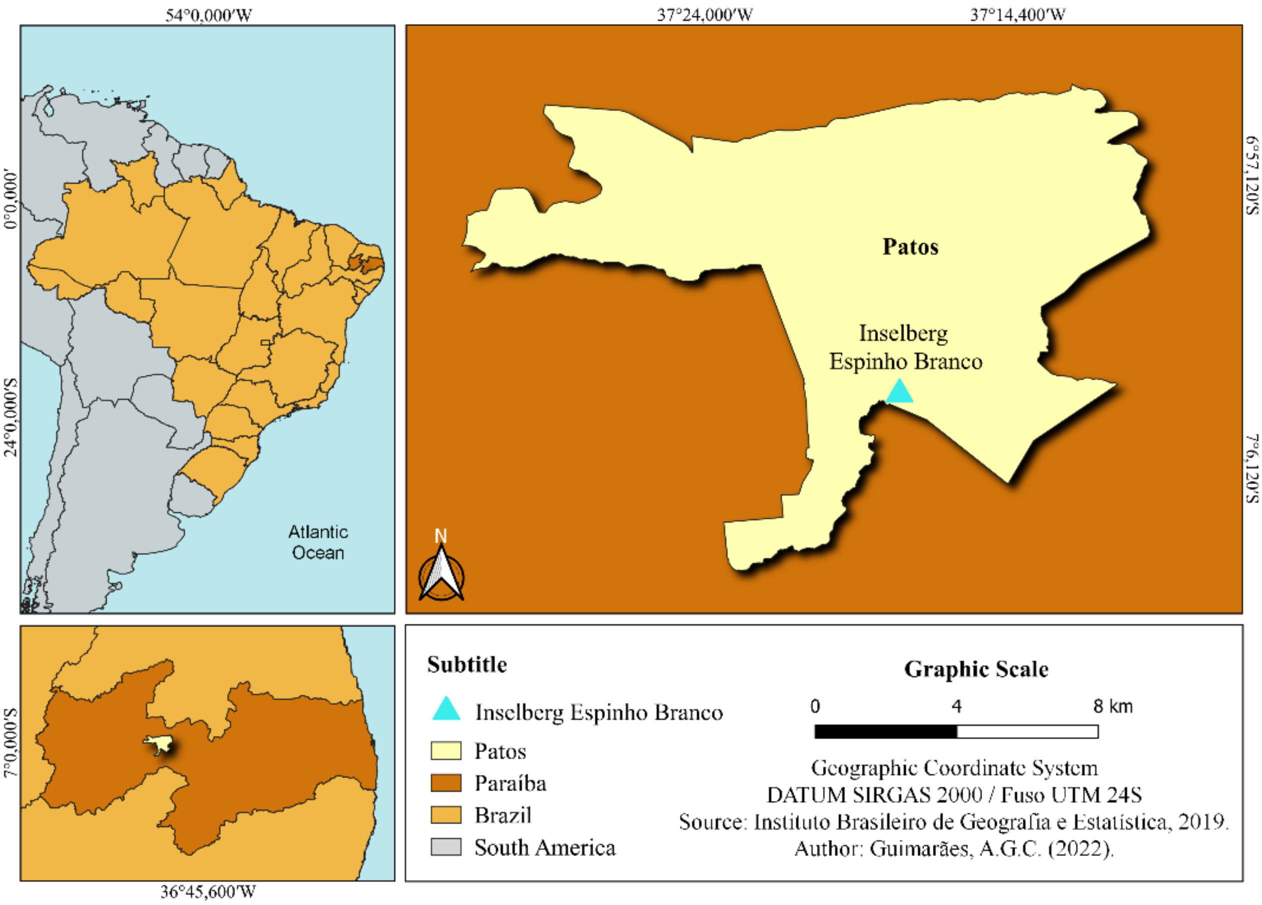

Figure 1. Geographical location of the Espinho Branco Inselberg in Patos, PB, Brazil.

The inselberg is located at the geographic coordinates 07º03’50.3” S and 37º18‘2.35” W, 8 km from the Patos city center, reaching heights of 415 m in altitude at its highest point and 165 m at its lowest point, occupying an area of approximately 12.94 ha (AQUINO, 2012). Some images of the environment under study are shown in Figure 2 for a better visualization of its characteristics.

Figure 2. Images of the Espinho Branco Inselberg in Patos, PB, Brazil.

This rocky outcrop is made up of granite, with the presence of herbaceous, shrub, and tree species, as well as some climbing species. In its surroundings, there are two dams in private properties and an intermittent river, Rio da Cruz, that are used for irrigation and animal watering (Figure 3).

Figure 3. Intermittent reservoirs present around the study area in Patos, PB, Brazil.

The base of the Espinho Branco inselberg can be characterized as a narrow stretch of riparian forest, where some native tree species predominate, including *Anadenanthera colubrina* (Vell.) Brenan, *Bauhinia cheilantha* (Bong.) Steud., *Combretum leprosum* Mart., *Handroanthus impetiginosus* (Mart. ex DC.) Mattos, *Microdesmia rigida* (Benth.) Sothers & Prance, *Mimosa tenuiflora* (Willd.) Poir., and *Sarcomphalus joazeiro* (Mart.) Hauenshilde (LUCENA et al., 2015).

Seed bank composition and floristic diversity

The inselberg was divided into three altitude levels, considering access conditions: base layer (245-290 m), middle layer (290.1-360 m), and top layer (360,1-415 m). Litterfall-soil samples (litterfall plus 5 cm of soil) were collected from each layer during the dry season (December 2021) using a metal frame of 30 × 50 cm (Figure 4).

Figure 4. Frame used to collect the litterfall-soil samples.

Forty-seven litterfall-soil samples were collected in the 0-5 cm soil layer: 32 from the base, 12 from the middle, and 3 from the top layer, according to the availability of litterfall and soil in each layer (Figure 5). These samples were labeled and taken to the forest nursery at the Federal University of Campina Grande (UAEF/CSTR/UFCG, Patos, PB, Brazil) to analyze the seed bank composition and floristic diversity.

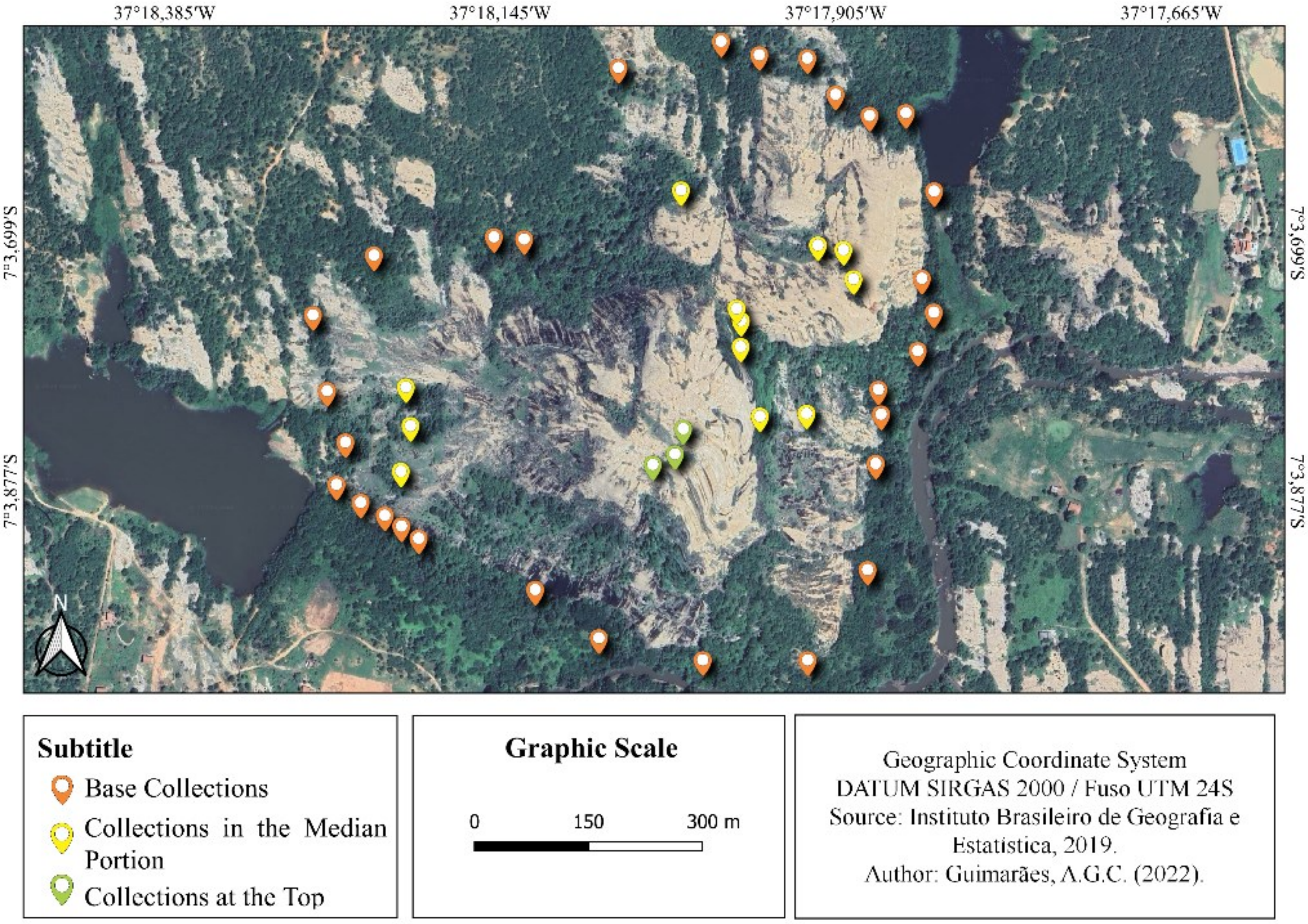

Figure 5. Map of the spatial distribution of collections at the Espinho Branco in Patos, PB, Brazil.

Seed bank activation

The samples collected from the different altitude layers (base, middle, and top) of the inselberg were placed in plastic trays (33 × 24 × 5 cm), which were perforated to drain excess irrigation water, labeled, and distributed on benches in a shaded area in the forest nursery at the Federal University of Campina Grande (UAEF/CSTR/UFCG), with a solar reduction factor of 50%.

The samples were then manually irrigated to evenly moisten the material. This was done every day until the end of the experiment, except in raining days. The trays were rotated weekly to reduce environmental heterogeneity and prevent one tray from having more water than the other.

Data of seedling emergence were recorded daily and entered onto specific forms for later analysis.

Species identification

The seedlings were quantified by counting the number of seedlings of each species and the density was expressed as individuals m^{-2}, as defined by Baskin and Baskin (1998).

The species were counted and identified after producing fertile material, and at least two individuals of the same species were collected for identification, herborization, and deposition in the Rita Baltazar de Lima Herbarium at the Federal University of Campina Grande, Patos, PB, Brazil.

The plants were identified by common name, botanical family, genus, species, and plant type (herbaceous, sub-shrub, shrub, tree, and climber), according to the characteristics of each plant (VIDAL; VIDAL, 2003). Morphological characteristics of seedlings (leaves and stems) of tree species were compared with other individuals exhibiting the same characteristics in similar vegetative conditions, and then confirmed by experts in the field and by people who recognize the species at this stage.

A list of species was organized in alphabetical order by family, according to the Angiosperm Phylogeny Group classification system (APG IV, 2016). Scientific names and authors of the species were described according to the Flora do Brasil (2020) species list.

Plant type was determined according to the Flora do Brasil (2020) catalog, following Vidal and Vidal (2003): herb or herbaceous plants are those with an annual life cycle, limited development, and low consistency due to little or no lignification; sub-shrubs are small shrubs that can reach one meter in height, with a woody base and herbaceous tender branches; shrubs have an average size of less than five meters, branch out from the base, close to the ground, and do not have a predominant stem, i.e., they are resistant and woody at the base and tender and flexible at the top; trees are larger than five meters, their trunk is clearly visible and bare of branches at the ground level, and the branched part corresponds to the crown; and vines or lianas are plants that can reach many meters in length, commonly with structures (tendrils) to attach to other plants.

Species richness, abundance, and similarity indices

Species richness and abundance were assessed using the Shannon-Weaver diversity index (H') and the Pielou equitability index (J'). The similarity of the species found in the three altitude layers was assessed by qualitative comparison using the Jaccard Similarity Index (Sj'), which is based on the presence or absence of species (SOUZA; SOARES, 2013).

RESULTS AND DISCUSSION

Study of the seed bank floristic composition

The seed bank was activated on February 4, 2022. The first emergence occurred about 24 hours after the beginning of irrigation in the experiment and was a Lily (*Zephyranthes cearensis* (Herb.) Baker), a monocotyledon from the family Amaryllidaceae, with rapid growth and development. This species is very common in the Semiarid region of Brazil following the first rains (Figure 6). After 48 hours, there was a progressive emergence of individuals of other species in all samples collected. This shows the rapid germination of Caatinga species found in the study environment under favorable moisture, temperature, and light conditions.

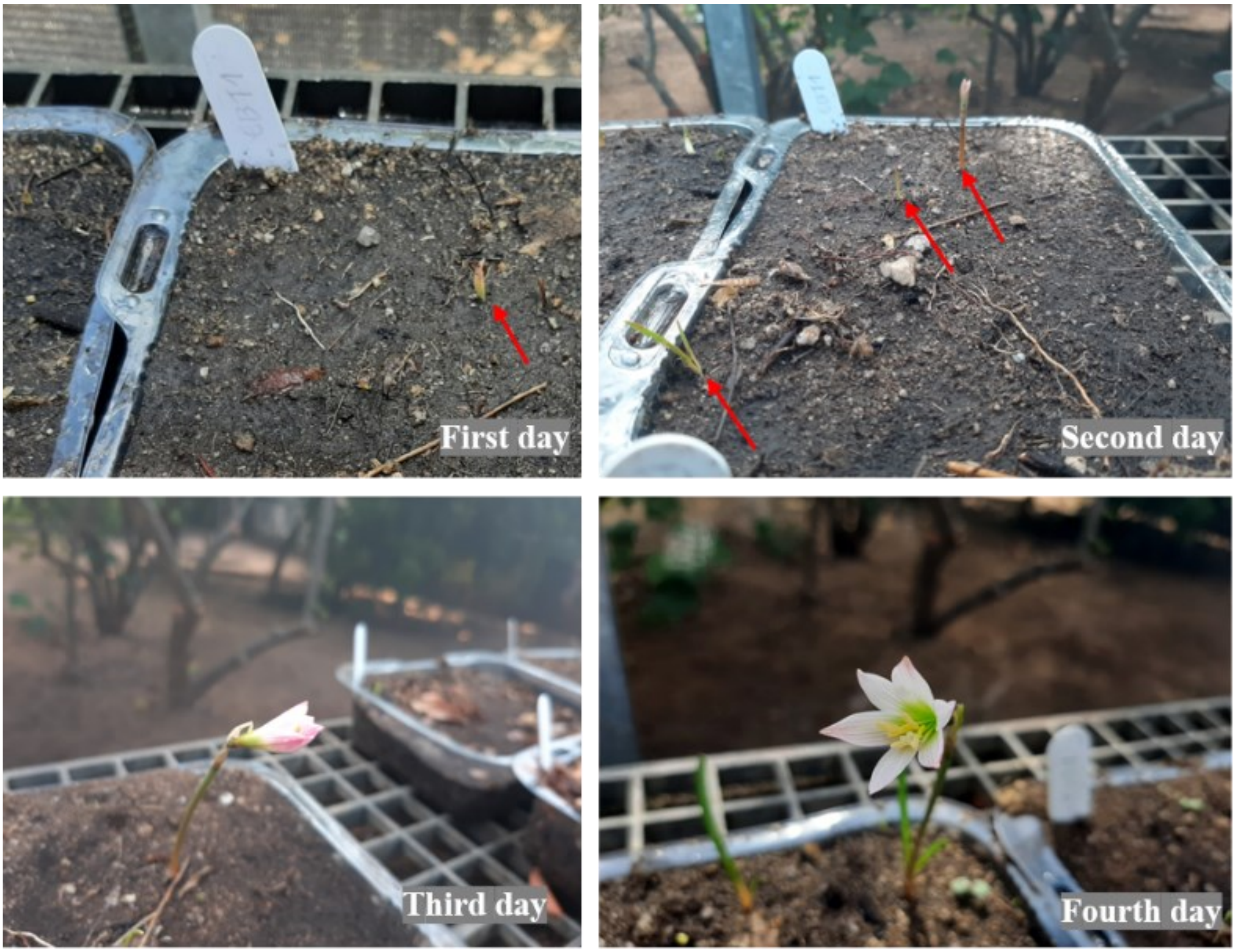

Figure 6. Rapid growth and development of a lily in the experiment.

The floristic composition of the 47 litterfall-soil samples collected in the Espinho Branco Inselberg showed 4,616 individuals form 40 families, 96 genera, and 111 species. This information is shown in Table 1, considering the altitude layers studied.

These results complement the work of Lucena et al. (2015), who studied the vascular flora of this same inselberg by collecting botanical material, recording 45 families, 84 genera, and 101 species. Comparing the species identified by them with the floristic list found in the seed bank, only 41 are similar between the studies. This shows that the plant richness of the inselberg is greater than that found in the two studies.

Table 1. Number of families, species, and individuals in the 47 litterfall-soil samples collected at the Espinho Branco Inselberg.

Families/Species/Individuals	Base	Middle	Top
Families by altitude layer	35	27	13
Families in the 3 altitude layers		40	
Species by altitude layer	97	59	19
Species in the 3 altitude layers		111	
Individuals by altitude layers	2.614	1.370	632
Individuals in the 3 altitude layers		4.616	

Despite not having studied the seed bank, Lopes-Silva et al. (2019) found 120 species when carrying out a floristic survey on the rocky outcrop Morro do Carioca, in the middle region of Patos, PB, Brazil, with a maximum altitude of 376 m. A similar result was found by Tolke et al. (2011), even though it was not a seed bank, in Puxinanã, PB, Brazil, which has an altitude of 711 m; the floristic richness comprised 97 species. These studies were carried out in the Semiarid region of Brazil under similar soil and climate conditions (low rainfall rates and high wind speeds) and relatively similar elevations to the present study, which explains the verisimilitude of the results.

The base of the inselberg had higher number of families, species, and individuals compared to the other altitude layers. This is due to the lower altitude, which contributes to a greater litterfall and soil accumulation, providing favorable microclimate conditions, especially temperature and humidity, for the development of species. There are also more interactions between plant and animal species in this layer, as there are no considerable physical obstacles (slopes) like in the other classes, favoring the emergence of more species through the seed dispersal process. Additionally, the base is affected by the two intermittent reservoirs and the Rio da Cruz River, which flows around the inselberg. These water sources provide suitable temperature and humidity conditions and cycling and decomposition of organic matter for plant species.

The higher the altitude of an environment, the higher the tendency of the amount of litterfall and soil to decrease and concentrate in specific places, such as rock recesses. A study carried out by Wen et al. (2022) shows that this parameter directly and indirectly affects the height and diameter of tree vegetation and the floristic composition of the seed bank, as the seeds are deposited in the substrate, which provides suitable conditions for plant development, depending on its quantity and accumulation.

Despite the lower number of families, species, and individuals in the middle and top layers, compared to the base, the values obtained in the experiment are significant. The presence of litterfall and soil in these environments is the result of natural phenomena, such as weathering, and anthropogenic actions. Seeds reach these higher layers by wind (anemochory dispersal); these diaspores are light and some have winged seeds, facilitating dispersal. There is also zoochory (dispersal by animals), in which seeds are carried by birds, reptiles, and other small animals that frequent the environment in search for food and/or shelter.

The density of the seed bank, including the three altitude layers, was estimated in approximately 655 individuals m^{-2}, with 545 individuals m^{-2} in the base, 761 individuals m^{-2} in the middle, and 1,404 individuals per square meter in the top layer. The higher number of plants m^{-2} in the top layer of the inselberg may be explained by the topographical conditions of the outcrop, which has a higher concentration of litterfall and soil in specific places, such as rock recesses. Moreover, the litterfall-soil collection was restricted to a few points due to these conditions, increasing the density of plants per square meter. The accumulation of litterfall and soil in these depressions occurs because they prevent organic matter, diaspores, seeds, and other debris from being carried to the lower layers, creating favorable microclimate conditions for plant development, especially herbaceous species, which are less demanding.

The base and middle layers of the outcrop presented lower plant density than the top due to a greater litterfall and soil availability in different parts in the top layer, which made it possible to sample more points. In this sense, there is a greater distribution and dispersion of propagules at the base, which decreases along the other altitude layers.

According to Pereira et al. (2001), forest environments that had been affected by anthropogenic interferences commonly present increases in density of young individuals. Porto et al. (2008) also reported that anthropized ecosystems have a greater floristic diversity and form more microhabitats. Theis argues for the need of studies on biogeography of rocky outcrops, especially in the Northeast region of Brazil, to better understand the distribution patterns, behavior, and richness of species to devise effective conservation strategies.

Seed bank studies in inselbergs are rare, as many people choose to study their floristic composition by collecting botanical material. This methodology is important, but it is necessary to look for other possibilities to obtain further results, such as studies of soil seed banks. These studies make it possible to understand diverse phenomena, including seed rain and its extent, providing indications of tolerance, intra- and interspecific behavior, colonization, and ecological succession, and presence or absence of pollinators and dispersers (ALMEIDA, 2016; RIBEIRO et al., 2017).

Regarding plant types, herbaceous plants stood out with 3,092 individuals (67%), followed by shrubs with 1,156 individuals (25%), sub-shrubs with 311 individuals (7%), climbers with 50 individuals (0.9%), and trees with seven individuals (0.1%).

Herbaceous plants stood out in terms of number of individuals compared to other plant types because they are less demanding in water, light, soil, and nutrients and have a fast life cycle and high seed production (RIBEIRO et al., 2017), often with dormancy, allowing seeds to spread over time and space and germinate when conditions are favorable for their development. Inselbergs stood out in floristic surveys carried out by Lucena et al. (2015) and Tolke et al. (2011) in the semiarid region of Paraíba, under similar conditions of altitude, wind intensity, and rainfall. The natural conditions of the inselberg, including limited availability of litterfall and soil, shallow depth due to rocks, and high temperature leading to high evapotranspiration, contribute to the emergence of smaller plants, such as herbaceous species.

The species *Cyperus* sp. (Cyperaceae), *Ludwigia octovalvis* (Jacq.) P.H.Raven (Onagraceae), and *Panicum trichoides* Sw. (Poaceae) had the highest number of individuals: 1,238, 625, and 401, respectively. The species *Cyperus sp*. was present in all altitude layers and its large number of individuals was expected, as it is an exotic genus with a high invasive potential, grows rapidly, and reproduces vegetatively. The other two species are native according to the Flora of Brazil Catalog (2020), but are considered weeds (LORENZI, 2008).

Many species of the family Cyperaceae are highly invasive, both on land and in water (GIL; BOVE, 2004). Although they are usually associated with places with greater water accumulation, as river banks, they also occur on hilltops, outcrops, and more drained environments, constituting an important floristic element in the ecological succession of areas exposed to human actions. It is considered a cosmopolitan family with more than 5,000 species (TREVISAN; FERREIRA; BOLDRINI, 2008). These findings are consistent with the results found in this study, considering the large number of individuals recorded and their distribution in all parts of the inselberg.

Some shrub and tree species that did not emerge from the seed bank were found in the Espinho Branco inselberg, including *Commiphora leptophloeos* (Mart.) J.B.Gillett (Umburana-de-cambão), *Luetzelburgia auriculata* (Allemão) Ducke (Pau pedra), *Microdesmia rigida* (Benth.) Sothers & Prance (Oiticica), *Aspidosperma pyrifolium* Mart. & Zucc. (Pereiro), *Cnidoscolus quercifolius* Pohl (Faveleira), *Croton blanchetianus* Baill. (Marmeleiro), a *Anadenanthera colubrina* (Vell.) Brenan (Angico), *Handroanthus impetiginosus* (Mart. ex DC.) Mattos (Ipê-roxo), *Vitex gardneriana* Schauer (Jaramataia), *Schinopsis brasiliensis* Engl. (Baraúna).

The lack of germination of these species can be explained by the lack of viable seeds available at the time of collection, loss of viability, predation, possible dormancy, or need for direct light to germinate. This may have occurred because the seeds were not subjected to the necessary stress for germination, and the soil was not disturbed, which would have exposed the seeds to sunlight. Other factors may be associated with the lack of emergence of these species during the period of fruiting and seed dispersal, which generally occurs between August and December, the month of collection. This is common for Caatinga species in the Semiarid region, as the rainy season usually begins in January or February, providing suitable conditions for the emergence of seeds; herbaceous plants usually complete their cycle, and larger species, such as trees, develop to endure the dry season.

SILVA et al. (2013) point out that there are periodic variations in diversity of species in seed banks in Caatinga areas, influenced by the rainfall regime, i.e. the amount and spatial distribution of rainfall affect soil seed stocks.

Regarding the families, Fabaceae was the most representative with 18 species, especially *Chamaecrista pilosa* (L.) *Greene*, which had 188 individuals distributed in all altitude layers. Most plants from this family were found at the base and middle layers of the rocky outcrop. Second place was occupied by the families Euphorbiaceae, Malvaceae, and Poaceae, which presented ten species each. The families Convolvulaceae and Rubiaceae presented six species each. The genera with the highest number of species were *Mimosa* (3), followed by *Cyperus, Chamaecrista, Digitaria, Euploca, Herissantia, Ipomoea, Jacquemontia, Oxalis, Panicum, Portulaca, Sida, Tetraulacium*, and *Waltheria,* which presented two species each.

Although some floristic surveys are carried out without studying the seed bank, they can provide the plant composition of the environment. This can be seen in the work carried out by Cordeiro, Souza, and Felix (2018) in Serra da Raiz, PB, Brazil, under a hot and humid climate (As'), vegetation classified as Seasonal Deciduous Forest, and altitude of approximately 350 m, in which the family Fabaceae was the most representative (20 species), followed by Poaceae (9), and Euphobiaceae and Asteraceae (8 species each). A study carried out by Sales-Rodrigues, Brasileiro and Melo (2014) in Puxinanã, PB, Brazil, under an altitude of over 650 m and high relative humidity; although it was not a seed bank study, the family Fabaceae was also the most representative with 13 species. According to Gomes and Alves (2010), Fabaceae and Euphorbiaceae on rocky outcrops are very important in terms of diversity of species for the Semiarid region of Brazil.

Representative species of Euphorbiaceae were found mainly at the base and middle layers, with herbaceous, shrubby, sub-shrubby, and arboreal species. The species labeled indeterminate 1 had the highest number of individuals (250).

Malvaceae is another well-represented family, with herbaceous, shrubby, and sub-shrubby species, mainly at the base and middle layers of the rocky outcrop. The species *Sida galheirensis* Ulbr. presented the highest number of individuals (45) and was found only at the base. *Corchorus argutus* Kunth presented 32 individuals and was found at the three layers.

The family Poaceae presented 10 species; *Panicum trichoides* Sw. stood out with 401 individuals and *Panicum* *stramineum* Hitchc. & Chase with 213 individuals. The species occurred in the three layers, with the lowest number of individuals found at the top. According to Araújo, Oliveira, and Lima-Verde (2008), high diversity of Poaceae is associated with inselbergs in dry climates.

Convolvulaceae had six species, with some herbaceous climbers, including *Ipomoea minutiflora* (M.Martens & Galeotti) House, which presented the highest number of individuals (19), distributed in all altitude layers. *Jacquemontia evolvuloides* (Moric.) Meisn. was the second with ten individuals and, unlike the first species, it was found only at the base layer.

Lucena et al. (2015) evaluated the floristic composition of this same rocky outcrop by collecting botanical material and recorded six species of the family Convolvulaceae, the same number found in this study, but only one species was common to both studies, *Jacquemontia gracillima* (Choisy) Hallier f., which was found at the base and middle layers. This shows that the richness of this family in the environment is greater than that found in the present study. Lopes-Silva et al. (2019) carried out a survey in an inselberg area in Patos, PB, Brazil, although not considering the seed bank, and identified nine species of Convolvulaceae, indicating that the diversity in the intermediate region is expressive.

The family Rubiaceae also presented six species, mainly *Staelia virgata* (Link ex Roem. & Schult.) K.Schum. which had the highest number of individuals (236), distributed in all layers. The second species with the highest number of individuals (58) was identified to the genus level, *Spermacoce* sp., which was found at the base and middle layers of the rocky outcrop.

Floristic diversity and similarity

The base layer had the highest diversity of species according to the Shannon-Weaver index (H'= 2.95) and Pielou's evenness (J'= 0.65), followed by the middle layer, H'= 2.48 and J'= 0.61, and the top layer of the inselberg, H'= 1.56 and J'= 0.53. Considering all altitude layers together, the diversity of species was H'= 2.92 and the equitability index was J'= 0.62.

The diversity of species was highest at the base of the inselberg and decreased along the other layers. This result was expected, as this layer has better conditions for plant development, including greater availability of litterfall and soil, lower incidence of solar radiation, and greater soil water retention, whereas the opposite occurs in the middle and upper layers.

Similarly, the Pielou's evenness index indicated that the base layer presented not only had greater diversity, but also species with more evenly distributed individuals. A lower number of species and individuals was found in the middle and top than in the base layer, and their distribution was concentrated at points with higher concentration of organic matter and soil. The distribution of plants was more restricted in the top layer; however, the species need to be more specialized and/or adapted to more stressful environments, especially in terms of temperature and humidity, to survive at the top of the outcrop.

Floristic similarity was determined by Jaccard's index considering the three altitude layers of the rocky outcrop (Figure 7).

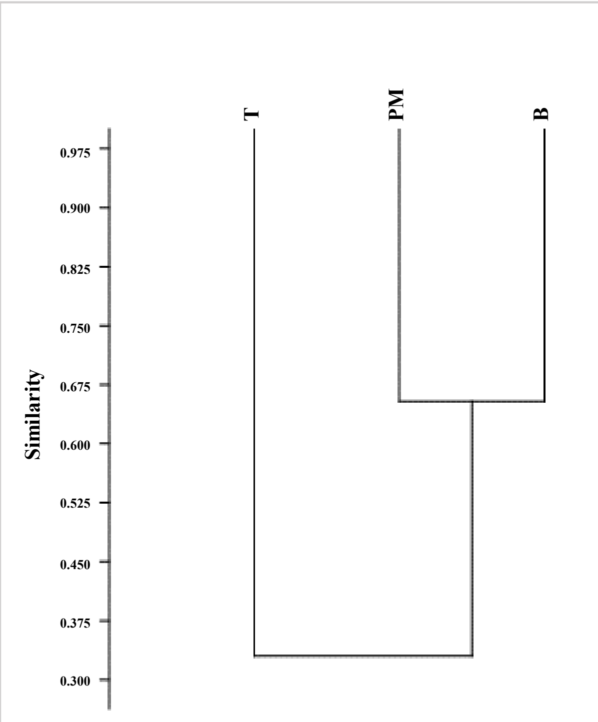

Figure 7. Dendrogram of similarity between the altitude layers (B = base; PM = middle; T = top) of the Espinho Branco Inselberg, defined by the UPGMA clustering criterion, based on the average Jaccard Index.

Considering the presence and absence of species, the Jaccard index was 0.93. Thus, the diversity of species between the base and the middle is similar, and 46 species is common to both layers. This was expected, as the middle layer has microclimate and soil conditions similar to the base layer, and is more affected by plant and animal species through ecological interactions.

The top layer showed less similarity to the other layers; the species *Z. cearensis* (Herb.) Baker was only found in this layer. This result was also expected due to the outcrop topographical conditions, lower availability and concentration of litterfall and soil, and high temperature and wind intensity. Therefore, species need to be resilient and less demanding to adapt to environments like these.

CONCLUSIONS

The seed bank floristic composition of the Espinho Branco Inselberg, Patos, PB, Brazil, at the different altitude layers differs in terms of number and diversity of species; the greatest floristic richness was found at the base layer. The floristic diversity of the inselberg (Shannon and Pielou indices), and the similarity of the altitude layers (Jaccard index) were considered significant for the Semiarid region of Brazil.

Thus, this work contributes to studies on seed banks in inselberg areas, with a view to conserving species exclusive to these environments, and represents a gain for society and the scientific community by promoting further research.

REFERENCES

ALMEIDA, D. S. **Recuperação ambiental da mata atlântica**. Ilhéus, BA: Editus, 2016. 200 p.

AQUINO L. L. **Geografia Patos**: Bases para a compreensão do espaço. Patos, PB: Gráfica e Editora Real, 2012. 96 p.

ARAÚJO, F. S.; OLIVEIRA, R. F.; LIMA-VERDE, L. W. Composição, espectro biológico e síndromes de dispersão da vegetação de um inselberg no domínio da Caatinga, Ceará. **Rodriguésia**, 59: 659-671, 2008.

APG IV. The Angiosperm Phylogeny Group: An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants. Botanical Journal of the Linnean Society, **Botanical Journal of the Linnean Society**, 181: 1-20, 2016.

ALVARES, C. A. et al. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, 22: 11-728, 2014.

BASKIN, C. C.; BASKIN, J. M. **Seeds, ecology, biogeography, and evolution of dormancy and germination**. New York: Academic Press, 1998.

BRASIL. Ministério das Minas e Energia, Secretaria de Geologia, Mineração e Transformação Mineral; CPRM – Serviço Geológico do Brasil. **Diagnóstico do Município de Patos, Estado da Paraíba**. Recife, PE: CPRM/PRODEEM, 2005.

CORDEIRO, J. M. P.; SOUZA, B. I.; FELIX, L. P. Levantamento florístico em afloramento rochoso no piemonte da Borborema, Paraíba, Brasil. **Geosul**, 33: 214-228, 2018.

CÓRDULA, E.; QUEIROZ, L. P.; ALVES, M. Checklist da flora de mirandiba, pernambuco: leguminosae. **Rodriguésia**, 59: 597-602. 2008.

FERNANDES, A. **Fitogeografia brasileira**. 2. ed. Fortaleza, CE: Multigraf, 2000. 341 p.

FLORA DO BRASIL. **Flora e Funga do Brasil**. 2020. Jardim Botânico do Rio de Janeiro. Disponível em: <http://floradobrasil.jbrj.gov.br/>. Acesso em: 17 abr. 2023.

GIL, A. S. B.; BOVE, C. P. O gênero *Eleocharis* R. Br. (Cyperaceae) nos ecossistemas aquáticos temporários da planície costeira do Estado do Rio de Janeiro. **Arquivos do Museu Nacional**, 62: 131-150, 2004.

GIULIETTI, A. M. et al. Diagnóstico da vegetação nativa do bioma Caatinga. In: SILVA, J. M. C. et al. (Eds.). **Biodiversidade da Caatinga:** áreas e ações prioritárias para a conservação. Brasília, DF: Ministério do Meio Ambiente, 2004. v. 1, cap. 2, p. 48-90.

GOMES, P.; ALVES, M. Floristic diversity of two crystalline rocky outcrops in the Brazilian northeast semi-arid region. **Revista Brasileira de Botânica**, 33: 661-676, 2010.

LOPES-SILVA, R. F.; LUCENA, M. F. A; GOMES-SILVA, F. Espécies vegetais exóticas dos inselbergs da cidade de Patos, Paraíba, Nordeste do Brasil. **Cientec**, 9: 75-84, 2017.

LOPES-SILVA, R. F. et al. Composição florística de um inselberg no semiárido paraibano, nordeste brasileiro. **Rodriguésia**, 70: e02812017, 2019.

LORENZI, H. **Plantas daninhas do Brasil**: terrestres, aquáticas, parasitas e tóxicas. 4 ed. Nova Odessa, SP: Instituto Plantarum, 2008. 678 p.

LUCENA, D. S. et al. Flora vascular de um inselberg na mesorregião do sertão paraibano, nordeste do Brasil. **Scientia Plena**, 11: 1-11, 2015.

MAIA, R. P. et al. Geomorfologia do campo de inselbergues de Quixadá, Nordeste do Brasil. **Revista Brasileira de Geomorfologia**, 16: 239-253, 2015.

PEREIRA, I. M. et al. Regeneração natural em um remanescente de caatinga sob diferentes níveis de perturbação, no agreste paraibano. **Acta Botanica Brasilica**, 3: 413-426, 2001.

PORTO, P. A. F. et al. Composição florística de um inselberg no agreste paraibano, município de Esperança, Nordeste do Brasil. **Revista Caatinga**, 21: 214-223, 2008.

RIBEIRO, T. O. et al. Diversidade do banco de sementes em diferentes áreas de caatinga manejadas no semiárido da Paraíba, Brasil. **Ciência Florestal**, 27: 203-213, 2017.

SALES-RODRIGUES. J.; BRASILEIRO, J. C. B.; MELO, J. I. M. Flora de um inselberg na mesorregião agreste do estado da Paraíba-Brasil. **Polibotânica**, 37: 47-61, 2014.

SILVA, K. A. et al. Spatio-temporal variation in a seed bank of a semi-arid region in northeastern Brazil. **Acta Oecologica**, 46: 25-32, 2013.

SOUZA, A. L.; SOARES, C. P. B. **Florestas nativas**: estrutura dinâmica e manejo. Viçosa: Editora UFV, 2013.

SOUZA, D. D. A Caatinga. In: SOUZA, D. D. (Ed.). **Adaptações de plantas da caatinga**. São Paulo, SP: Oficina de textos, 2020. v. 1, cap. 1, p. 10-22.

TOLKE, E. E. A. D. et al. Flora vascular de um inselbergue no estado da Paraíba, Nordeste do Brasil. **Biotemas**, 24: 39-48. 2011.

TREVISAN, R.; FERREIRA, P. M. A.; BOLDRINE, I. I. A família Cyperaceae no Parque Estadual de Itapuã,Viamão, Rio Grande do Sul, Brasil. **Revista Brasileira de Biociências**, 6: 217-244. 2008.

VIDAL, W. N.; VIDAL, M. R. R. **Botânica – Organografia**: quadros sinóticos ilustrados de fanerógamos. 4. ed. Viçosa, MG: UFV. 2003. 124 p.

WEN, Z. et al. Tropical forest strata shifts in plant structural diversity-aboveground carbon relationships along altitudinal gradients. **Science of The Total Environment**, 838: 155907, 2022.