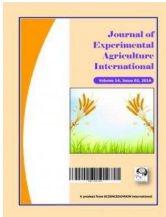

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Nitrogen Nutrition in Dry Tropical Forest at Different Times of Regeneration

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Authors' contributions

This work was carried out in collaboration between all authors. Authors AMOS, FJF, MDB, RLCF and MF designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors FTAJ, CSF and ACFS managed the analyses of the study. Authors CSF and AMOS managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The management of forest species requires the quantification of various nutrients flows in the ecosystem. Specifically for N this aspect is even more important because many species in dry forests, as Brazilian Caatinga, are legumes and in symbiotic association with diazotrophic bacteria, fix N_2 from the atmosphere. This study aimed to evaluate the N nutrition of forest species in Caatinga fragments with different regeneration times in the semi-arid region of Brazil. The study areas had different historical uses: the first one (53 ha) had no exploitation in the last 44 years; the second (32 ha) was in regeneration for 25 years; and the third (25 ha) had been in regeneration for five years. Four common tree species were evaluated in the three evaluated areas. Leaves were

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collected from each species to determine N contents. The legume species in the preserved area presented higher N content, decreasing with the regeneration time. The results showed a greater ecological balance in the most preserved sites, favoring the biological N fixation. N acquisition by legumes was not influenced by the disturbance of the site, suggesting the recommendation of these species as restorers of degraded areas.

Keywords: Caatinga; forest nutrition; N cycling; leguminous forest species.

1. INTRODUCTION

The mineralization of vegetal residues is the main route of nutrients supply to maintain soil fertility in forest ecosystems. Leaf compartment has already been shown to have greater contribution to the biomass supply in the soil and to the highest concentration of nutrients, particularly N, in different forest ecosystems [1-2].

In dry forest environments, such as Caatinga, a high number of deciduous species occurs, which confirms the high potential for nutrient cycling via foliar deposition. In general, the soils of the semi-arid region present low levels of N, and the mineralization of organic matter is the main source of this nutrient for the vegetation [3]. This condition is increased by vegetation degradation, in which most semi-arid environments are subject to [4].

Nutrient content in leaves of trees may be influenced by internal and external factors, as site conditions, physiological age of leaves, position of leaves in the canopy, time of year [5]. In soils deficient in some nutrients there is a greater demand for these, making the internal cycling inside the plants more active, as for N in soils from Brazilian semi-arid region.

Native leguminous species, adapted to the conditions of high temperatures and low water availability in semi-arid, may represent potential species to recover these adverse environments, mainly due to the biological N fixing capacity and high production of litter [6].

The management of forest species requires the quantification of various nutrients flows in the ecosystem. According to Bündchen [7], nutrient mobility and conservation in the forest ecosystem may be an important attribute and related, in part, to the ability of trees to occupy low fertility soils.

In the recovery of degraded soils with native forest species, the greatest difficulty has been the lack of studies involving the acquisition of nutrients and the nutritional requirements of these species, mainly for environments such as the semi-arid region [3]. Studies of this nature in disturbed ecosystems are important as a basis for understanding changes in the nutrient cycling process caused by anthropogenic interference and as a basis for assessing its recovery.

Thus, the objective of this study was to evaluate the N nutrition of forest species in three fragments of hyperxerophilic Caatinga with different times of regeneration after cutting for wood exploitation.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out on Caatinga fragments located in the municipality of Floresta, Pernambuco, Brazil (Fig. 1).

Three areas presenting different use histories and were selected to the study. The first one (Preserved), with 53 ha, had not been explored in the last 44 years; the second place had been in regeneration for 25 years after the cutting, and it is approximately 32 ha (Regeneration 25 years); and the third site was cut five years ago (Regeneration 5 years) and it is 25 ha extension (Fig. 2). Currently the regeneration areas have been managed for the exploitation of firewood for charcoal and/or wood. The areas in regeneration for five and 25 years are distanced by about 200 m and are distant from the preserved area at about 2,000 m.

According to Köppen's classification, the climate in this municipality is BSh ' semi-arid, with well-defined dry season, and the rainfall is concentrated mainly in the summer. The annual average rainfall is 431.8 mm and the annual temperature is between 24 and 26°C, providing high evaporation rate and low relative humidity [8].

The vegetation is deciduous thorny woodland [9], characterized by shrub-tree vegetation. The soil is classified as Chromic Luvisol, shallow and sandy to medium texture in the surface [10].

Four tree species common in these three studied areas were evaluated. These species were defined as having the highest importance value (IV) in the forest fragments in a floristic and structural study carried out by Alves Júnior [11] (Table 1).

2.2 Species Sampling and Chemical Analysis

A sampling of leaves was performed to estimate the N content. Four individuals of each species were sampled, having as criterion of selection the similarity in the size, vegetative development and phytosanitary status of the individuals sampled. There were collected randomly 25 newly mature leaves at the four cardinal points in a total of 100 leaves in each plant (400 leaves by plot).

The sampled leaves were packed in paper bags and stored in coolers containing ice. Subsequently, the samples were placed in an oven with forced air ventilation and maintained at 65°C until constant weight. They were then crushed and stored in previously cleaned and dried flasks for N analysis [12]. For N-total determination, the samples were digested in sulfur solution and analyzed by the Kjeldahl method [13].

2.3 Statistical Procedures

The statistical procedure for the study of N content data was the analysis of variance (ANOVA) and averages comparison by Scott-Knott test ($p<0.05$), when the main effects and/or interactions were significant by F-test ($p<0.05$).

The orthogonal contrast technique was used to analyze differences of the averages between legume and non-legume species groups and for the groups of preserved versus in regeneration areas. The difference between the means of contrast was evaluated by the t-test ($p<0.05$).

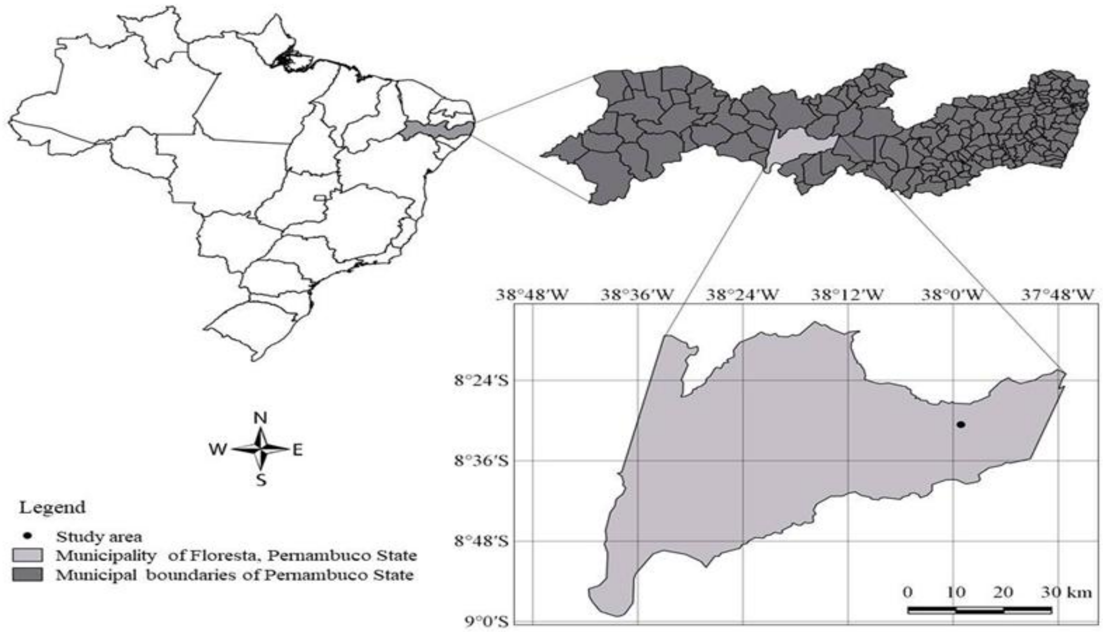

Fig. 1. Geographic location of the study area, Brazil

Table 1. Forest species of natural regeneration of higher value importance (HVI)) and botanical family in fragments of the Caatinga, Brazil

Species	Botanical family
Poincianella bracteosa (Tul.) L. P. Queiroz	Caesalpiniodeae
Mimosa ophtalmocentra Mart. ex Benth	Fabaceae Mimosoidae
Cnidoscolus quercifolius Pohl	Euphorbiaceae
Mimosa tenuiflora (Willd.) Poir	Fabaceae Mimosoideae

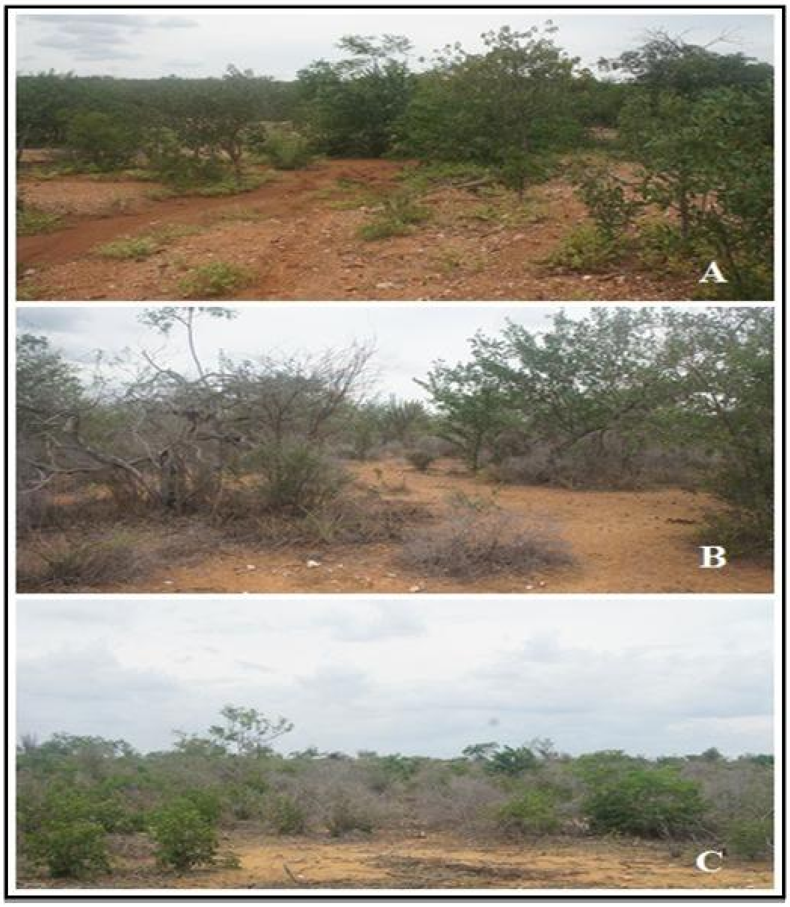

Fig. 2. Fragments of Caatinga where the studies were carried out. Preserved Caatinga area (A); Caatinga area in regeneration 25 years (B); and the regenerating Caatinga area 5 years (C)

3. RESULTS AND DISCUSSION

N contents of the plant leaves in the hyperoxerophilic Caatinga fragment differed between regeneration times only for the species *Cnidoscolus quercifolius* and *Mimosa tenuiflora*. *Cnidoscolus quercifolius* had the highest N content in the area at 25 years of regeneration, while Mimosa tenuiflora showed the highest content in the area in 5 years under regeneration (Table 2).

Although *Poincianella bracteosa* and Mimosa ophthalmocentra had no difference in N content in the area of higher equilibrium (preserved) or in regenerating environments, these species presented higher N levels in the preserved area. The acquisition of N by these legumes is higher because they are associated with N-fixing bacteria. On the other hand, the legume Mimosa tenuiflora showed to be more demanding in this nutrient presenting higher contents in the areas in regeneration (Table 2).

Cnidoscolus quercifolius presented high levels of N in relation to legume species regardless of the regeneration time, which shows a high requirement in N, since this species is the only non-legume. All this strategy of survival can cause this species to regenerate much more slowly than the others. This may indicate that regeneration of leguminous species is faster and more balanced.

The results obtained showed that the evaluated species had N contents similar to those found in studies in other forests in Brazil. Bündchen [7] obtained N levels between 23.85 and 35.56 g kg-1 in a study with five species in subtropical forest in southern Brazil. In decidual seasonal forest in Rio Grande do Sul, Vogel [14] found average N contents in the leaves of 24.20 g kg-1. Mendes

[15], evaluating ten native species in Central Amazonia observed N contents in leaves varying between 15.70 and 22.40 g kg-1. In Atlantic Forest, Cunha [2], studying two fragments of Montana Forest in Rio de Janeiro observed average N contents in leaves of 25.80 and 26.66 g kg-1. In area of Caatinga in regeneration, Alves [3] obtained average N contents in the leaves of five species ranging from 18.00 to 23.10 g kg-1.

N contents in leaves of legume species were lower than that of non-legume species in all evaluated environments (Fig. 3). These results demonstrated the highest N requirement for the only non-leguminous species (*Cnidoscolus quercifoilius*) and especially it was verified that there was an increase of this species occurrence in less balanced areas, with shorter times of regeneration.

There was certain homogeneity of the average content of N in the leaves of legume species in the different studied sites, varying between 17.36 and 20.98 g kg-1 in the regenerating area for five years and the preserved area, respectively (Fig. 3). It was also verified that in the preserved area, the leguminous species presented higher N content in the leaves, decreasing with the reduction of the regeneration time of the areas. This may be related to the greater ecological balance in the most preserved sites and with a longer regeneration time, favoring the biological N fixation.

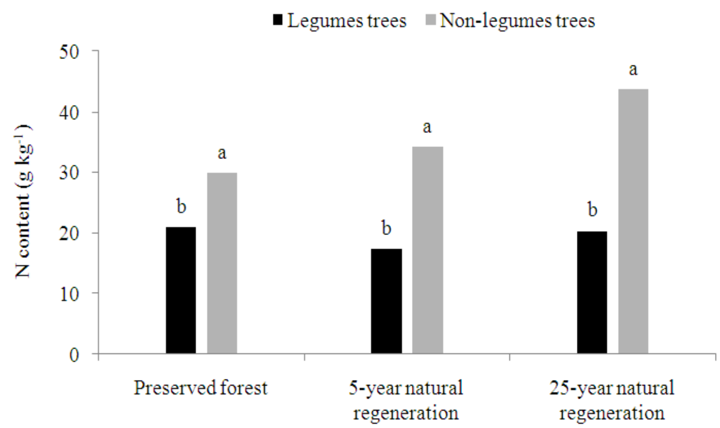

Fig. 3. Orthogonal contrast of N content in leaves of legumes versus non-legumes forest species, separately for each time of regeneration in the Caatinga fragments, Pernambuco, Brazil. Means followed by different lowercase letters at each regeneration time differ statistically by the t test (p<0.05)

Table 2. N content in leaves of forest species in Caatinga fragments at different times of regeneration, Pernambuco, Brazil

Forest species	**Time of regeneration (years)**			**Average**
	Preserved	**5**	**25**	
		g kg-1		
Cnidoscolus quercifolius	29.96 aB	34.30 aB	43.65 aA	35.97
Mimosa ophthalmocentra	20.27 bA	17.36 bA	16.54 cA	18.05
Mimosa tenuiflora	24.82 aA	18.73 bB	27.34 bA	23.63
Poincianella bracteosa	17.87 bA	16.01 bA	17.22 cA	17.03
Average	23.23	21.60	26.18	
	F test			
Species			37.220*	
Time			3.547*	
Species x Time			2.823*	
CV (%)[1]			20.86	

*[1]Coefficient of variation = Standard deviation/average X 100. Averages followed by the same letter, uppercase in the row and lowercase in the column, do not differ statistically by the Scott-Knott test (P<0.05). *Significant by F test (P<0.05)*

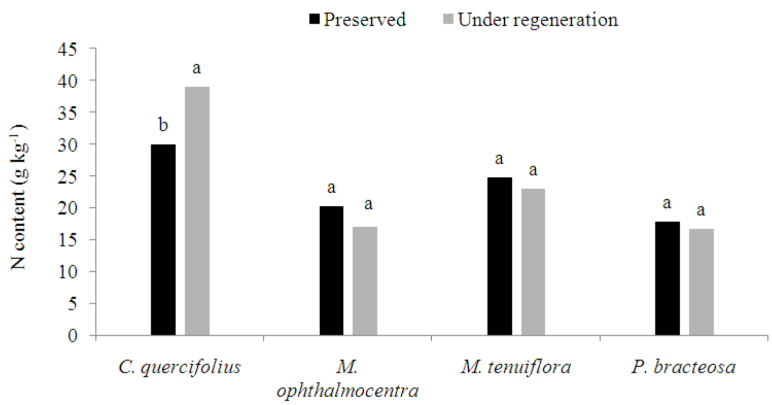

Fig. 4. Orthogonal contrast of the N content in leaves of forest species in the preserved versus regenerated areas, separately for each forest species in the Caatinga fragments, Pernambuco, Brazil. Means followed by different lowercase letters in each forest species differ statistically by the t test ($p<0.05$)

Concerning the contrast between the N levels in the leaves of the species and the regenerated and preserved environments, it was verified that the legume species presented similar results in these environments (Fig. 4). It emphasizes the advantage of N biological fixation for the recovery of degraded environments, legume species can be used in the recovery of degraded areas, since the acquisition of N was not influenced by the disturbance of the site.

Regarding to *Cnidoscolus quercifolius*, the levels of N in the regenerated and preserved environments were inversely related to what occurred with the leguminous species, with higher levels in the regeneration sites. This may indicate that in less balanced environments *Cnidoscolus quercifolius* tends to store more N and favor its internal cycling, because there is higher demand for N by plants in these places, greater soil limitation and there is no competitive advantage such as biological N fixation.

Moreover Cnidoscolus quercifolius showed higher average N contents in the evaluated environments than legume species.

4. CONCLUSION

The legume species in the preserved area showed higher N content decreasing with the regeneration time, which it could be related to greater ecological balance in the most preserved sites, favoring biological N_2 fixation. The acquisition of N by legumes was not influenced by the disturbance of the site, suggesting the recommendation of these species as restorers of degraded areas.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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