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Compartmentalization and efficiency biological of nitrogen utilization in dry tropical forest

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ABSTRACT: Studies of nutrient efficiency and compartmentalization of nutrients in dry forests can contribute to the understanding of the nutrition of these forests because significant nutrient depositions come from leaf and branch fractions and are mostly derived from leguminous species, emphasizing the importance of nitrogen in cycling of these environments. This work aimed to determine the compartmentalization and efficiency biological of nitrogen utilization of the forest species with the highest importance value in a fragment of Caatinga hiperxerófila in Pernambuco. In the species was estimated the leaf biomass, using allometric equations. Leaves and stem parts were sampled for determination of nitrogen content. The biological utilization efficiency was calculated for each species. The biomass of the stem was 10.12 kg plant^{-1} and of the leaf was 0.99 kg plant^{-1}. Higher N contents were observed in the leaves and stem of *Poincianella bracteosa*, associated to the high biomass of the species. The most efficient species to use nitrogen were *Myracrodruon urundeuva* and *Bauhinia cheilantha*, which could be indicated for areas with low levels of organic matter.

Key words: forest nutrition; forest biomass; nitrogen content

Compartimentalização e eficiência de utilização biológica de nitrogênio em floresta tropical seca

RESUMO: Estudos de eficiência nutricional e compartimentalização de nutrientes em florestas secas podem contribuir para compreensão da nutrição dessas florestas porque deposições significativas de nutrientes são oriundas das frações folhas e galhos e são provenientes, em sua maioria, de espécies leguminosas, ressaltando a importância do nitrogênio na ciclagem nutricional desses ambientes. Este trabalho objetivou determinar a compartimentalização e eficiência de utilização biológica de nitrogênio das espécies florestais com maior valor de importância em fragmento de Caatinga hiperxerófila em Pernambuco. Nas espécies foi estimada a biomassa foliar, utilizando-se equações alométricas. Foram amostradas folhas e partes do caule para a determinação do teor de nitrogênio. A eficiência de utilização biológica foi calculada para cada espécie. A biomassa do caule foi de 10,12 kg planta^{-1} e da folha de 0,99 kg planta^{-1}. Maiores conteúdos de N foram observados nas folhas e caule da *Poincianella bracteosa*, associado à elevada biomassa da espécie. As espécies mais eficientes em utilizar nitrogênio foram *Myracrodruon urundeuva* e *Bauhinia cheilantha* podendo ser indicadas para áreas com diagnóstico de baixos teores de matéria orgânica.

Palavras-chave: nutrição florestal; biomassa florestal; conteúdo de nitrogênio

Introduction

There are large amounts of nutrients stored in the biomass above the soil of a native or planted forest. The accumulation of nutrients in the biomass of the trees varies from nutrient to nutrient depending on the characteristics of each species, age, and different levels of soil fertility (Salvador et al., 2016).

In general, the soils of the semi-arid region of the Northeast of Brazil are deficient in N, and the mineralization of organic matter is the main source of this nutrient for the plants. This condition is aggravated by the degradation of vegetation, where most of the semi-arid environments are submitted. In this scenario, legume species stand out due to their biological N fixing capacity and high litter production (Nogueira et al., 2012). Native legumes, adapted to the conditions of high temperatures and low availability of semi-arid water, may be able to grow and potentially fix N advantageously over other species (Freitas et al., 2011).

The selection of species that adapt to low available soil nutrient contents has been a permanent concern, and the species that best use them and have a greater capacity to absorb nutrients from the soil are desirable (Fontes et al., 2013). From the nutritional point of view, a more efficient species is able to develop and have a good production under unfavorable conditions of soil fertility, having the ability to absorb the necessary nutrients in a smaller quantity, and/or distribute them in a more efficient in the various components of the plant, without compromising productivity (Batista et al., 2015).

Biomass quantification is the basis for knowledge of the stock and nutrient dynamics in the forest and it is of great importance for decision making for the sustainable management of forest resources and forest restoration (Mensah et al., 2016). In the recovery of degraded soils with the use of 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 in the semi-arid region.

Studies of nutrient efficiency and compartmentalization of nutrients in dry forests can contribute to the understanding of the nutrition of these forests because significant nutrient depositions come from leaf and branch fractions and are mostly derived from leguminous species, emphasizing the importance of N in cycling of these environments.

In this context, this work aimed to determine the compartmentalization and efficiency of biological utilization of N of the forest species with the highest importance value in a fragment of the hyperoxerophilic Caatinga in Pernambuco.

Material and Methods

Study area

The study was carried out in a fragment of hyperoxerophilic Caatinga located in the city of Floresta, Pernambuco (Figure 1).

The study area is located at latitude of 08°30’37’ South and 37°59’07” West and with approximately 53 ha without anthropogenic exploitation at 45 years. According to the classification of Köppen, the municipality has the BSh’

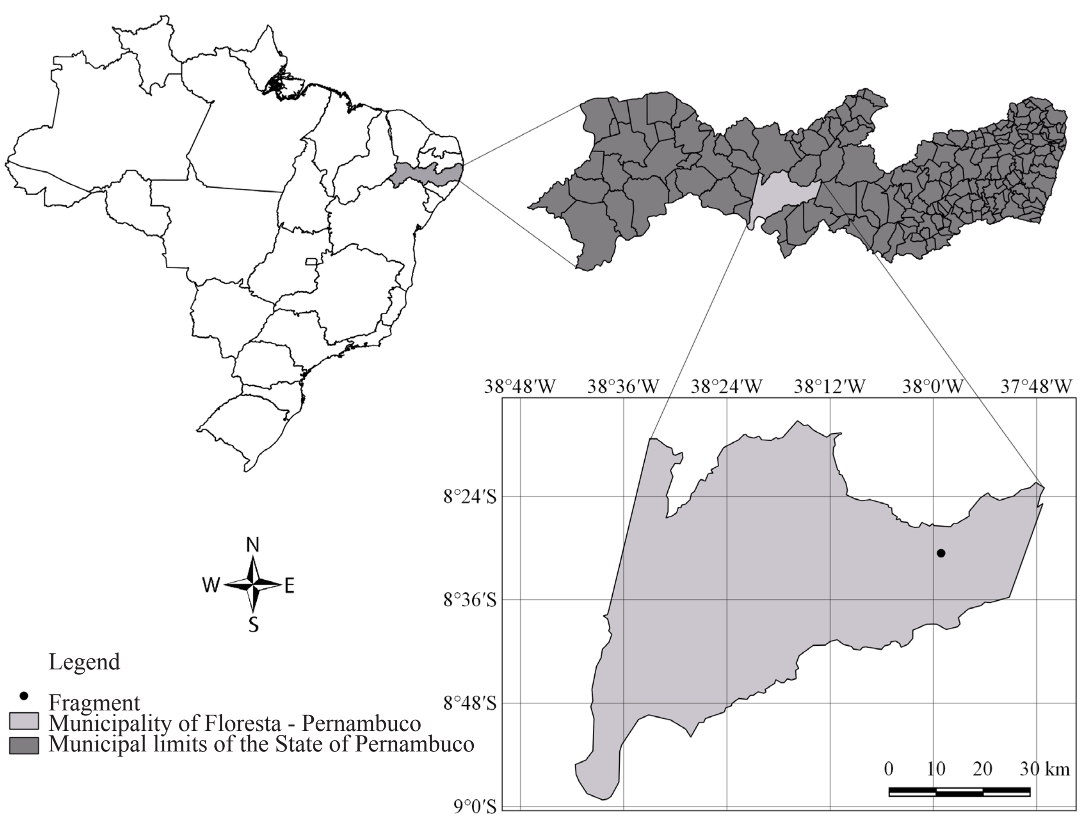

Figure 1. Location of the study area in the municipality of Floresta, Pernambuco.

semi-arid climate, with a well-defined dry season and with concentrated rainfall, mainly in the summer, with annual average rainfall of 431.8 mm and mean annual temperature between 24 and 26ºC, providing high evaporation rate and low relative humidity (Embrapa, 2010).

The vegetation of the area is the savannah-esthetic type (Ferraz et al., 2014), characterized by shrub-tree vegetation. The soil is classified as shallow *Luvissolo Crômico*, with sandy to medium surface texture (Santos et al., 2013).

Horizontal structure of the forest fragment

The study of the horizontal structure of the fragment was carried out through a phytosociological survey of 40 plots of 400 m² distant 80 m between them. In each plot, all adult arboreal individuals with diameter at chest height at 1.30 m (DAP) ≥ 6.0 cm were measured and identified (Ferraz et al., 2014).

From these data, the estimates of the phytosociological parameters were obtained, such as density, frequency, basal area, and dominance. These estimates were calculated according to the following expressions:

$DA = ni/A$ and $DR = ni/N \times 100$, where DA is the absolute density (ind. ha^{-1}); DR is the relative density (%); ni is the number of individuals of species i; A is the area (ha); and N is the total number of individuals sampled in the area.

$FA = U/UT \times 100$ and $FR = FA/\Sigma FA \times 100$, where FA is the absolute frequency (%); FR is the relative frequency (%); U is the number of sample units in which the species i occurred, and UT is the total number of sample units.

$DoA = AB/A$ and $DoR = AB/ABT \times 100$, where DoA is the absolute dominance ($m^2\ ha^{-1}$); DoR is the relative dominance (%); AB is the basal area of species i (m^2), and ABT is the total basal area of all species (m^2).

The value of importance (VI) was calculated according to the following expression:

$VI = DR + FR + DoR$ defining seven species of higher VI (%) used in this study.

Biomass, level, content, and efficiency of biological nitrogen use

From the phytosociological survey, seven forest species of higher VI were determined (Table 1). The DAPs of all individuals of each species were added to obtain the average DAP by species, due to the number of individuals of the species.

The foliar biomass of the species was determined according to a methodology developed by Silva & Sampaio (2008). To estimate individual leaf biomass (kg $plant^{-1}$) of arboreal habit species, the following equation was used:

$\hat{Y} = 0.0681 \times DAP^{1.5829}$, where $\hat{Y}$ is the foliar biomass (kg); 0.0681 is a parameter of the model; DAP is the diameter at the height of the chest at 1.30 m from the ground (cm); 1.5829 is another parameter of the model.

To estimate the biomass of the stem (kg $plant^{-1}$) of the individuals of the species of arboreal habit was used the equation:

$\hat{Y} = 0.2255 \times DAP^{1.7212}$, for stems between 1.1 and 5.0 cm in diameter, where $\hat{Y}$ is the biomass (kg); 0.2255 is a parameter of the model; DAP is the diameter at the height of the chest at 1.30 m from the ground (cm); 1.7212 is another parameter of the model.

$\hat{Y} = 0.1497 \times DAP^{1.7876}$, for stems between 5.1 and 10.0 cm in diameter, where $\hat{Y}$ is the biomass (kg); 0,1497 is a parameter of the model; DAP is the diameter at the height of the chest at 1.30 m from the ground (cm); 1.7876 is another parameter of the model.

$\hat{Y} = 0.0064 \times DAP^{1,733}$, for stems greater than 10.0 cm in diameter, where $\hat{Y}$ is the biomass (kg); 0.0064 is a parameter of the model; DAP is the diameter at the height of the chest at 1.30 m from the ground (cm); 1.733 is another parameter of the model.

In order to estimate the biomass of the total aerial part (kg plant-1) of the species of arboreal habit, the equation was used:

$\hat{Y} = 0.2368 \times DAP^{2,2219}$ where $\hat{Y}$ is the biomass (kg); 0.2368 is a parameter of the model; DAP is the diameter at the height of the chest at 1.30 m from the ground (cm); 2.2219 is another parameter of the model.

Then, the biomass was multiplied by the number of individuals per hectare to transform the biomass of each species by area (kg ha^{-1}).

For the determination of the N level, a sampling of leaves and the stem of the species of greater VI was carried out. Four individuals of each species were sampled, having the size similarity (H = 4.12 ± 0.55 cm) and vegetative development of the species sampled as similarity criterion. Fresh leaves were collected randomly at the four cardinal points and at the median third of the crown of each plant, 25 leaves were

Table 1. Total number of individuals (Nt), absolute density (DA), importance value (VI), mean diameter at chest height at 1.30 m of soil (DAP) and family of forest species in the hyperoxerophilous Caatinga fragment in the municipality of Floresta, Pernambuco.

Species	Family	Tn (unity)	AD (ind ha^{-1})	IV (%)	MDH mean (cm)
Poincianella bracteosa (Tul.) L. P. Queiroz	Fabaceae	1032	644	34.30	3.98
Mimosa ophtalmocentra Mart. ex Benth	Fabaceae	330	206	11.99	3.30
Myracrodruon urundeuva Allemão	Anacardiaceae	65	41	5.82	7.14
Cnidoscolus quercifolius Pohl.	Euphorbiaceae	66	41	5.57	6.50
Anadenanthera colubrina var. cebil. (Griseb.) Altschul	Fabaceae	101	63	5.35	5.15
Bauhinia cheilantha (Bong.) Steud	Fabaceae	135	83	4.64	2.43
Mimosa tenuiflora (Willd.) Poir	Fabaceae	45	28	3.59	5.17

removed, as well as sampling of the stem surface in part of the sapwood, soon after the bark by the largest circulation and concentration of nutrients in this region. Four replicates of each compartment (leaves and stem) were performed, totaling eight samples per species. The collection of the vegetal material was carried out in February of 2015 in hot and humid period that in the region usually corresponds to January, February, March, and April.

The leaf and stem samples were packed in paper bags and stored in styrofoam boxes containing ice. Subsequently, the samples were taken to a greenhouse with forced air ventilation and maintained at 65 °C until constant weight. Then, they were crushed and stored in previously cleaned and dried flasks for N level analysis (Embrapa, 2009).

To determine the N-total, the samples were digested in sulfur solution and analyzed by the Kjeldahl method (Embrapa, 2009). The content of N in leaf biomass of the species in kg ha^{-1} was obtained by multiplying the level (g kg^{-1}) by leaf biomass (kg ha^{-1}). The biological use efficiency of N was determined by the ratio between the leaf biomass of the species and the N content stored in the biomass (Bündchen et al., 2013).

Statistical procedures

The data of the levels, contents, and efficiency of use of N had a normal distribution and the statistical procedure used was analysis of variance (ANOVA) and means comparisons by the Scott-Knott test at 5% probability, when the main effects and/or the interactions were significant by the F test at the 5% probability level, considering the homoscedasticity of the variances.

The orthogonal contrast technique was used to analyze differences in means between legume and non-legume species. The difference between the means of contrast was evaluated by the F and t-tests up to the 5% probability level.

Results and Discussion

Biomass of forest species

Estimates of stem biomass per plant were more than ten times greater than the leaf compartment, ranging from 0.29 to 1.89 kg plant^{-1} (Table 2). The species *Anadenanthera colubrina, Myracrodruon urundeuva* and *Cnidoscolus quercifolius* exhibited the highest foliar biomasses, while *Mimosa ophthalmocentra* and *Bauhinia cheilanta* were the smaller (Table 2).

The stem biomass of the species varied between 1.92 and 19.81 kg plant^{-1}. The species *A. colubrina* presented larger biomass of the stem, followed by *M. urundeuva* and *C. quercifolius*. The species *M. ophthalmocentra* and *B. cheilanta* showed the smallest biomasses of the stem (Table 2).

The results obtained for biomass of the stem are related to the predominance of stems with diameter greater than 10 cm in the species *A. colubrina, M. urundeuva* and *C. quercifolius* than other species, contributing to the increase of the biomass of this compartment.

The growth in diameter of a tree can be influenced by several factors, such as climatic (temperature, precipitation, wind and insolation), pedological (physical, chemical and biological characteristics of soils), topographic (inclination, altitude and exposure), biological (pests and diseases), genetic and by the competition of the species with other shrub-arboreal individuals and other types of vegetation (Benin et al., 2014).

In this study, as the species are under the same edaphoclimatic and topographic conditions, the differences in stem diameter growth may be related, besides to the genetic factors of each species, to the competition in the fragment. Also, there are historical cultural, social and economic factors that may also be responsible for greater or lesser competition among species. In this case, *A. colubrina, M. urundeuva,* and *C. quercifolius* presented a higher competitive performance in the acquisition and/or use of environmental resources, generating a greater production of stem biomass. Remaining individuals of *A. colubrina* and *M. urundeuva* in areas of Caatinga are a reflection of exposure to many years of disorganized and unsustainable exploitation, but even so, the stem diameter of these species differed and presented higher biomass.

Regarding the biomass per hectare, *P. bracteosa* presented the highest biomass of the aerial part, while the species B. cheilanta had the lowest biomass. The results found in this study for the biomass per hectare of the aerial part of the species *P. bracteosa* and *B. cheilanta* were higher

Table 2. Estimation of biomass by individual and area of the most important forest species in a hyperoxerophilous Caatinga fragment in the city of Floresta, Pernambuco.

Species	Biomass by plant (kg plant^{-1})			Biomass by área (kg ha^{-1})		
	Stem	Leaf	Aerial part	Stem	Leaf	Aerial part
Poincianella bracteosa	6.96	0.67	7.63	2,851.03	688.92	3,539.95
Mimosa ophtalmocentra	1.92	0.47	2.40	591.67	156.82	748.49
Myracrodruon urundeuva	17.68	1.89	19.57	850.15	122.69	972.84
Cnidoscolus quercifolius	14.80	1.55	16.35	560.68	102.38	663.06
Anadenanthera colubrina	19.81	1.09	20.90	581.60	110.39	691.99
Bauhinia cheilantha	2.60	0.29	2.89	144.82	39.16	183.97
Mimosa tenuiflora	7.10	0.98	8.08	157.48	44.18	201.66
Total	70.87	6.94	77.81	5,737.43	1,264.53	7,001.96
Average	10.12	0.99	11.12	819.63	180.65	1,000.28

to 2,302 and 26 kg ha^{-1}, respectively, estimated by Amorim et al. (2005) when studying the vegetation in the Caatinga area preserved in Rio Grande do Norte, which may be related to the lower number of individuals per hectare found by the authors.

However, Cabral et al. (2013) found higher results than this study for biomass of the Caatinga aerial part of the city of Santa Terezinha in Paraíba for *P. bracteosa, A. colubrina, C. quercifolius* and *M. tenuiflora*, despite the lower number of individuals per unit of area.

The legumes *P. bracteosa, M. ophthalmocentra, A. colubrina, B. cheilanta* and *M. tenuiflora* were responsible for more than 76% of the total biomass of the aerial part of the species studied. It is worth mentioning that *C. quercifolius* and *M. urundeuva* are not legumes of the studied species. According to Nogueira et al. (2012), most leguminous species present a high production of biomass with significant leaf contribution, providing a significant improvement in soil fertility.

Nitrogen levels in forest species

N levels in leaves of forest species varied between 17.87 g kg^{-1} in *P. bracteosa* and 29.96 g kg^{-1} in *C. quercifolius* (Table 3), which was the highest N level among the species, indicating that the nutritional demand of *C. quercifolius* by N was high. This may be related to the particularities of the species, which is a pioneer (Maker & Andrade, 2007). In general, high N level is associated with the high rate of photosynthesis that may reflect the increase in biomass and leaf area (Garrone et al., 2016).

The *M. tenuiflora* species had the highest N level in the leaves, among the legumes studied (*A. colubrina, B. cheilantha, M. ophthalmocentra* and *P. bracteosa*) and *C. quercifolius* among non-leguminous species (Table 3). These results showed that the leaves of *C. quercifolius* and *M. tenuiflora* are important for N cycling, demonstrating the potential of these species for use in areas in the process of forest recovery.

The levels of N in the leaves of *P. bracteosa* and *C. quercifolius* as confirmed by Alves et al. (2017) in preserved Caatinga area were 18.0 ± 2.1 g kg^{-1} and 22.1 ± 2.4 g kg^{-1}, respectively. In general, these results were close to those found in this study (Table 3). This similarity can be explained by analogous soil and climatic conditions because they were carried out in the same municipality of Pernambuco. According to Vitousek (1984) in tropical forests, the values considered adequate of N levels vary from 5.00 to 19.00 g kg^{-1}. Therefore, the N levels found in this study on average exceeded the adequate range, which may have been due to a higher concentration of N for a low production of biomass, typical of dry tropical forests (Chazdon, 2012). In fact, Barbosa (2012) found average levels of 25 g kg^{-1} of N in dry forest in the municipality of Arcoverde in Pernambuco.

The group of species *A. colubrina, C. quercifolius, M. ophthalmocentra, M. tenuiflora* and *P. bracteosa* presented higher levels of N in the stem than the *B. cheilantha* and *M. urundeuva* species (Table 3).

The N levels of the species were larger on average in the leaves than in the stem (Table 3). For example, in *Myracrodruon urundeuva* the N level in the leaves (19.39 g kg^{-1}) was more than four times higher than the stem level (4.34 g kg^{-1}). In general, the mean nutrient levels are higher in the leaves than in the branches, with the exception of Ca (Caldeira et al., 2014). This is because nutrients, especially N, are much needed in the physiologically more physiologically active fraction of the plant (Nunes et al., 2013).

Nitrogen content in forest species

The N content in the stem was higher than in the leaf in the species *Anadenanthera colubrina, Cnidoscolus quercifolius* and *Poincianella bracteosa* (Table 4).

Table 3. Nitrogen levels in the leaves and stems of the most important forest species in a hyperoxerophilous Caatinga fragment in the city of Floresta, Pernambuco.

Species	Compartment		Average
	Leaf	Stem	
	g kg^{-1}		
Poincianella bracteosa	17.87 cA	10.92 aB	14.40
Mimosa ophthalmocentra	20.27 cA	9.38 aB	14.82
Myracrodruon urundeuva	19.39 cA	4.34 bB	11.87
Cnidoscolus quercifolius	29.96 aA	12.43 aB	21.19
Anadenanthera colubrina	19.95 cA	9.31 aB	14.63
Bauhinia cheilantha	20.41 cA	5.79 bB	13.10
Mimosa tenuiflora	24.82 bA	14.81 aB	19.81
Average	21.81	9.57	
	F calculated		
Specie	10.511*		
Compartment	229.208*		
Specie x Compartment	2.874*		
CV (%)	19.29		

Mean values followed by the same lowercase letter in the column and upper case in the row did not differ statistically by the Scott-Knott test at 5% probability. *Significant at 5% probability.

Table 4. Nitrogen content in the leaves and stems of the most important forest species in a hyperoxerophilous Caatinga fragment in the city of Floresta, Pernambuco.

Species	Compartment		Average
	Leaf	Stem	
	g kg^{-1}		
Poincianella bracteosa	12.31 aB	31.13 aA	21.72
Mimosa ophthalmocentra	3.18 bA	5.55 bA	4.36
Myracrodruon urundeuva	2.38 bA	3.69 cA	3.03
Cnidoscolus quercifolius	3.07 bB	6.97 bA	5.02
Anadenanthera colubrina	2.20 bB	5.42 bA	3.81
Bauhinia cheilantha	0.80 bA	0.84 cA	0.82
Mimosa tenuiflora	1.10 bA	2.33 cA	1.71
Average	3.576	7.989	
	F calculated		
Specie	108.031*		
Compartment	71.397*		
Specie x Compartment	22.026*		
CV (%)	33.79		

Mean values followed by the same lowercase letter in the column and upper case in the row did not differ statistically by the Scott-Knott test at 5% probability. *Significant at 5% probability.

The highest N contents observed in the stem of the species were mainly due to the large accumulation of biomass in this compartment, demonstrating the importance of this compartment for the cycling of N.

Higher N contents were observed in the leaves and stem of *P. bracte*osa (Table 4), which is associated with the high biomass per hectare of the species (Table 2). Alves et al. (2017) found similar results with *P. bracteosa* in his study in hyperoxerophilic Caatinga.

Biological efficiency of nitrogen utilization

In general, the biological use efficiency of N of the species was higher in the stem and differed in the species only in that compartment. *Myracrodruon urundeuva* did not allocate much N in this compartment (Tables 3 and 4), but it was more efficient in using the nutrient to produce stem biomass (Table 5). *Mimosa tenuiflora* was very demanding in N (Table 3) and not very efficient in the production of stem biomass (Table 5). It was observed that the species with the highest N content were the least efficient species.

The biological efficiency of N in the stem compartment presented the following decreasing order: *Myracrodruon urundeuva* > *Bauhinia cheilantha* > *Anadenanthera colubrina* > *Mimosa ophthalmocentra* > *Poincianella bracteosa* > *Cnidoscolus quercifolius* > *Mimosa tenuiflora.*

Increased nutrient efficiency presented by one species correlates with a lower nutrient requirement, becoming a relevant criterion in the selection of species to be used in reforestation, especially in nutrient deficient soils (Bündchen et al., 2013).

In this study, the most efficient species to use N was *M. urundeuva*, which can be used in areas where there is a low nutrient content, such as in semi-arid soils that are commonly deficient in N and chemical fertilization is inaccessible to most of the rural producers, making the availability of this nutrient even more dependent on the mineralization of organic matter (Freitas et al., 2011).

Table 5. Efficiency of nitrogen utilization of forest species of higher importance value in leaves and stems in a fragment of hyperoxerophilic Caatinga in the city of Floresta, Pernambuco.

Species	Compartment		Average
	Leaf	Stem	
	g kg^{-1}		
Poincianella bracteosa	61.25 aB	93.57 cA	77.42
Mimosa ophthalmocentra	51.61 aB	108.39 cA	79.99
Myracrodruon urundeuva	51.93 aB	242.70 aA	147.32
Cnidoscolus quercifolius	33.77 aB	83.06 dA	58.42
Anadenanthera colubrina	50.24 aB	113.37 cA	81.81
Bauhinia cheilantha	49.48 aB	176.58 bA	113.03
Mimosa tenuiflora	41.01 aA	67.61 dA	54.31
Average	48.470	126.472	
	F calculated		
Specie	19.029*		
Compartment	190.921*		
Specie x Compartment	15.953*		
CV (%)	24.15		

Mean values followed by the same lowercase letter in the column and upper case in the row did not differ statistically by the Scott-Knott test at 5% probability. *Significant at 5% probability.

On the other hand, *C. quercifolius* should not be recommended for re-vegetate areas with restricted N availability due to the low efficiency of this species in the production of biomass, mainly stem. The recommendation of using *Mimosa tenuiflora* in these environments could also be restricted by the low efficiency of this species in the production of biomass. However, it is a legume fixer of atmospheric N_2, which favors its pioneering character, of fast growth, very adapted to adverse abiotic conditions and tending to form homogeneous stands in the early stages of secondary succession.

Nitrogen nutrition of legumes versus non-legumes

The N level in the leaf compartment of the non-leguminous species was higher than in the leguminous species, not differing in the stem compartment (Figure 2A). It may be that the symbiotic relationship between N-fixing bacteria and leguminous forest species in the Caatinga is less efficient and nitrogen nutrition is more balanced in the species because the N level in legume species was similar than the non-leguminous species *Myracrodruon urundeuva* (Table 3).

Also, the high levels of N in the leaf presented by the non-legume species *Cnidoscolus quercifolius* (Table 3) may also indicate that the biological fixation of the leguminous species in the Caatinga was slower and more balanced, while the nitrogen nutrition of the *C. quercifolius* species depended basically of the soil as N source (biogeochemical cycling). The water availability as well as the species' perenniality interferes in the biological fixation of N, presenting different behaviors for N metabolism, requiring further studies to better elucidating this behavior (biochemical cycling). It is possible that in wet periods, the *C. quercifolius* species increases its N uptake, taking advantage of the higher mineralization of the organic matter in this period and the biological N fixation is not so high, because the legumes will also have more N available in the soil by greater mineralization of organic matter.

In general, in the soils of the Caatinga, N is one of the nutrients found in low levels, limiting growth and forest production. The legumes have an advantage over the acquisition of this nutrient since they have the capacity to establish symbiosis with diazotrophic bacteria. Therefore, they are important ecologically to maintain the nutritional balance (Freitas et al., 2011).

Concerning the N content, it was found that legume species had higher stored amounts of N in both leaves and branches (Figure 2B). These results are related to the higher biomass per area of legume species (Table 2) and also because they presented a larger number of individuals in the fragment (Table 1). The vegetation of Caatinga is rich in leguminous species (Barbosa et al., 2012), but there are few studies about the potential of biological N fixation in these species (Freitas

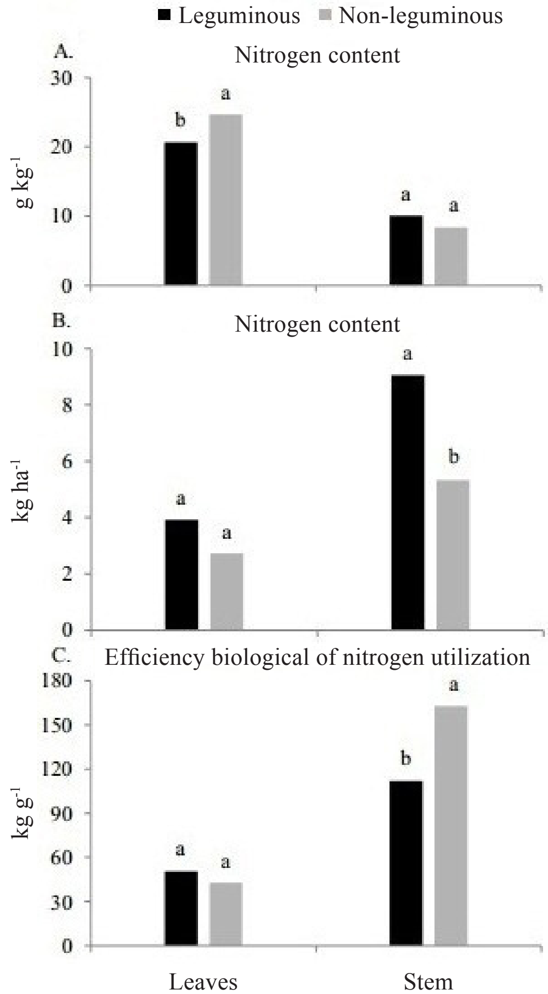

Figure 2. Orthogonal contrasts of level (A), content (B) and efficiency of biological nitrogen utilization (C) in leaves and stems of leguminous versus non-leguminous forest species.

et al., 2011). Amorim et al. (2005) stated that the abundance of species of the Leguminosae family in the Seridó of Rio Grande do Norte is responsible for the large availability of N.

Regarding the efficiency of N use, legume species were less efficient in the production of stem biomass per unit of N absorbed and accumulated in this compartment (Figure 2C). Biological use efficiency is the ability of species to produce biomass in nutritionally restrictive environments (Bündchen et al., 2013). In the stem, the N levels did not differentiate between legumes and non-legumes (Figure 2A), that is, there was no greater requirement of N by legumes. However, N accumulated more in legume stem biomass (Figure 2B) without converting this larger accumulation into more biomass (Table 1), compromising the nutritional efficiency of these species (Figure 2C).

In the leaf compartment, the non-leguminous species were more demanding in N because they had higher levels than the leguminous species (Figure 2A), but did not compromise their efficiencies of biological N use, because they were as efficient as legume species (Figure 2C). On the other hand, legumes did not accumulate much N in leaf biomass, able to also be efficient in the production of leaf biomass per N unit, suggesting that the nitrogen nutrition of the legumes was more balanced, providing sustainability in the nutrition of the fragment.

Conclusions

The species *Myracrodruon urundeuva* and *Bauhinia cheilantha* used the N for biomass production more efficiently and may be alternatives for reforestation of areas in the Brazilian semi-arid region where there are low levels of organic matter.

The leaves were the room where the N was more leased, independent of the species, emphasizing that the senescence and the fall of leaves, with their later decomposition, interfere in the nutritional dynamics of the Caatinga.

Legume species were less demanding in N in the leaf compartment and accumulated more N in the stem compartment, reducing their nutritional efficiency.

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