

Morphofunctional Characteristics of Seedlings of 30 Woody Species From a Tropical Coastal Vegetation (Restinga Forest), Area of Northeastern Brazil

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ABSTRACT

The morphology of seedlings provides important information. It can be used in studies of regeneration and succession in natural ecosystems. This work was guided by the following issues: The morphofunctional characteristics of the cotyledons allow inference about the group successional species? Is there any relation between the morphofunctional types of seedlings and some ecological characteristics? Mature fruits from restinga forest, southern coast of Pernambuco, were randomly collected from the 30 woody species. The fruits were measured (length x width) and the seeds were weighed (g), and then allowed to germinate. The correlation about the morphofunction of seedlings and ecological characteristics were determined using the Pearson correlation test and chi-square. As a result, the species were subdivided into four categories: 13 phanero-epigeal-foliaceous (PEF), 3 phanero-epigeal-reserve (PER), 4 phanero-hypogeal-reserve (PHR) and 10 crypto-hypogeal-reserve (CHR). There were significant correlations between the morphofunctional types of the species with successional groups, seed weight, dispersal syndrome and place of occurrence. When considering pioneer species with cotyledons, PEF mostly had small lightweight seeds. While most of those with cotyledons CHR showed larger seeds and a high number of reservations, which were considered secondary species. The results showed that, at least in the initial stage, the morphology of seedlings can be used as a parameter-level succession, contributing data for the projects management and conservation of areas of Restinga forest.

Key Words: Cotyledon Morphology, Ecological Succession, Pernambuco.

INTRODUCTION

Among the diverse Brazilians ecosystems, the restingas are one of the most threatened, mainly because it is

located in the littoral and these areas are often a target of estate speculation and cultivation in general. (Zickel et al. 2004). The restingas feature high biological richness and strong ecological importance (Sacramento et al.

2007) whose variations found in its geomorphological and climatic aspects may help with the manifestation of the plants phenological plasticity (Chagas et al. 2008). Despite that, edaphic factors, like low nutrients concentration, low water retention capacity, salinity, associated with high temperatures and high luminous incidence (Henrique et al. 1986) influence the development and the growth of the vegetal species (Bray et al. 2000). Considering the importance of recovering studies and injured areas management, knowledge about the morphology and establishment of seedlings, associated with ecological processes support the more appropriate selection of species to recover these areas (Moraes and Paoli 1999).

Based on the position, texture, exposition and function of the cotyledons, various authors (Duke 1965 and 1969, Ng 1978, Vogel 1980, Miquel 1987, Garwood 1996, Ressel et al. 2004, Montoro 2008) highlighted the seedlings importance as allowance for dynamic of vegetation and natural areas recovery researches. These studies provide parameters to characterize the ecological successions periods, once that it is in the seedling phase that the individual can reveal its environment adaptability (Souza and Válio 2003).

Nevertheless, the classification of species in ecological groups is an essential tool to understand the ecological succession. However, due to the high plasticity presented by vegetal species, there is a difficulty related to the determination of the criteria to its classification (Paula et al. 2004). Faced with this problem, information about seedling morpho-functionality may help with the strengthening of criteria used for species classification in successional groups.

In this context, the aim of this work is to test the hypothesis that cotyledons morphofunction, of wooden species, may be used as an indicative of successional group of forest areas. Therefore, this study intends to answer the following questions: (i) Do the morpho-functional characteristics of seedlings allow to indicate which successional group of wooden species present in the restinga? (ii) Is there a connection between the seedling morphofunctional types and seeds weight, occurrence area and dispersion type, and can it be used to characterize successional groups from restinga?

MATERIALS AND METHODS

This study was developed in a 76.2 ha restinga forest area located in the Natural Heritage Private Reserve

(RPPN) Nossa Senhora do Outeiro de Maracaípe, Pernambuco south coast (Duke 1965 and 1969, Ng 1978, Vogel 1980, Miquel 1987, Garwood 1996, Ressel et al. 2004, Montoro 2008), Ipojuca, Pernambuco, Brazil. The area of study presents, in general, a good state of conservation and occurring few individuals with cut evidence, in the forest shape besides the local population walk through the area (Souza and Válio 2003).

The soils are classified as Quartzarenic Neosols, sandy, with the sand percentage varying between 98% and 100% in the forest (Embrapa 1999). The climate in the area is As' type (Koppen 1948), rainy tropical with dry summer and less than 600mm of rain in the driest month, and high total annual rainfall and around 2000 mm (Medeiros et al. 2007).

Based on phenological (Medeiros et al. 2007) and fitossociological studies (Almeida Jr. et al. 2009), 30 woody species were selected, representative from this restinga, among trees and bush, with diameter at breast height (dbh) equal or upper to 10 cm, to fruits collect (Table 1). The seeds were obtained from 100 mature fruits, by monthly collect in the period between June/2009 and July/2010, which were forwarded to Laboratório de Florística e Ecossistemas Costeiros (LAFLEC) where it as weighed and measured with digital caliper gauge and analytical balance, respectively. Following, fruits were pulped out and the seeds were sterilized in NaOCl 1% solution for 15 minutes, followed by triple rinse in running water. The seeds were stored in a cool and dry place, protected from the sunlight, then its size (length and width) and the weight (g) were measured according to methodology described as before. The seeds were submitted to germination standard process according to methodology described in Ranal and Santana (2006). The fresh seeds mass was obtained based on the average of 100 seeds according to seed analysis international rules (Rajjou et al. 2007). For the analysis of these seeds it was used three different classes of fresh mass: (1) $S < 0.1$ g; (2) $0.1 \text{ g} > S < 1.4$ g and (3) $S > 1.5$ g (Ressel et al. 2004).

After this processing and according to the specie, the seeds were sown in plastic trays (28 x 15 x 8 cm), with sandy soil and kept in the greenhouse in ambient temperature. The seed that showed difficulties in germination were submitted to different treatments of germination induction. These seeds were, left to germinate in box made of acrylic model gerbox® 11 x 11 x 3.5 cm in germination chamber model BOD with temperature adjusted for 25 ± 2 °C and photoperiod of 12 hours provided by lamps type daylight (Sylvania cool-white

fluorescent lamps) doing a luminous intensity of 40 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$.

For the characterization of germination in greenhouse, it was considered the seedlings emergency as a germinability criterion, while that for the experiments in BOD the root protrusion was the characteristic analyzed (Ranal and Santana 2006). For morphological characterization of seedlings, the method proposed by Feliciano (1989) was used where the individuals with completely formed eophylls are recognised as seedlings.

The morphofunctional characterization of seedlings was done based on observations of three cotyledons characteristics: (i) exposition (phanero or crypto); (ii) position (epigeal or hypogean) and (iii) function (phanero or reserve) (Ng 1978, Vogel 1980, Miquel 1987, Garwood 1996) which constitute five morphofunctional types of seedlings: (i) phanero-epigeal-foliaceous (PEF) i.e., exposed cotyledons, above the soil level and photosynthetic; (ii) phanero-epigeal-reserve (PER) i.e., exposed cotyledons, above the soil level and stoker;

Table 1. Woody species of forest physiognomy of RPPN Nossa Senhora do Outeiro - Maracápe - PE classified according to four types morphofunctional (Mp) and their ecological data dispersion (Dis), successional groups (Gs), seed weight classes (Ws) and Place of occurrence (Po). Sorting in alphabetical order by family and species following APG III (2009).

Family	Species	Mp	Dis	Gs	Ws	Po
Anonaceae	<i>Rollinia pickelii</i> Diels.	CHR	1	2	1	2
Apocynaceae	<i>Himatanthus phagedaenicus</i> (Mart.) Woodson	PEF	2	1	2	1
	<i>Hancornia speciosa</i> Gomes	PHR	1	1	2	1
Burseraceae	<i>Protium heptaphyllum</i> (Aubl.) Marchand	CHR	1	3	2	3
Celastraceae	<i>Maytenus impressa</i> Reissek	CHR	1	2	1	2
Elaeocarpaceae	<i>Sloanea guianensis</i> (Aubl.) Benth.	PER	3	3	2	3
Euphorbiaceae	<i>Pera glabrata</i> (Schott) Poepp. ex Baill.	PEF	3	1	1	3
Fabaceae	<i>Abarema filamentosa</i> (Benth.) Pittier	PER	2	2	2	3
	<i>Chamaecrista ensiformis</i> (Vell.) H.S. Irwin & Barneby	PHR	3	2	2	3
	<i>Inga capitata</i> Desv.	PHR	3	2	2	3
	<i>Inga flagelliformis</i> (Vell.) Mart.	PHR	3	2	2	3
Lauraceae	<i>Andira fraxinifolia</i> Benth.	CHR	1	3	3	2
	<i>Ocotea gardneri</i> (Meisn.) Mez	CHR	1	2	1	1
Lecythidaceae	<i>Eschweilera ovata</i> (Cambess.) Miers	CHR	1	2	3	3
Malpighiaceae	<i>Byrsonima gardneriana</i> A. Juss.	PEF	2	1	2	1
	<i>Byrsonima sericea</i> DC.	PEF	2	1	1	1
Moraceae	<i>Ficus guianensis</i> Desv. ex Ham.	PEF	1	1	1	1
Myrtaceae	<i>Eugenia puniceifolia</i> (Kunth) DC.	PEF	1	2	1	3
	<i>Myrcia bergiana</i> O. Berg	PEF	1	2	1	3
	<i>Myrcia guianensis</i> (Aubl.) DC.	PEF	1	2	1	1
	<i>Marlierea regeliana</i> O. Berg	PEF	1	2	2	1
	<i>Psidium guineense</i> Sw	PEF	1	1	1	1
	<i>Eugenia hirta</i> O. Berg	CHR	1	2	2	2
Nyctaginaceae	<i>Guapira nitida</i> (Schmidt) Lundell	PEF	1	1	2	1
Ochnaceae	<i>Ouratea fieldingiana</i> (Gardner) Engl.	PER	1	2	2	3
Olacaceae	<i>Ximenia americana</i> L.	CHR	1	2	3	2
Polygonaceae	<i>Coccoloba laevis</i> Casar.	PEF	1	1	1	1
Rubiaceae	<i>Guettarda platypoda</i> DC.	PEF	1	1	1	1
Salicaceae	<i>Casearia javitensis</i> Kunth	CHR	1	2	1	1
Simaroubaceae	<i>Simaba cuneata</i> A. St.-Hil. & Tul.	CHR	1	2	3	2

Mp/ morphofunctional: PEF (phanero-epigeal-foliaceous), PER (phanero-epigeal-reserve), PHR (phanero-hipogean-reserve), CHR (crypto-hipogean-reserve); Dis/dispersal: (1) zoochorous, (2) anemochoric, (3) autochoric; Gs/ successional groups: (1) pioneer, (2) early secondary, (3) late secondary (climax); Ws/ seed weight class: (1) $S \leq 0.1$ g; (2) $0.1 \text{ g} < S < 1.5$ g; (3) $P \geq 1.5$ g; Po/ Place of occurrence: (1) sunny area, (2) shadow area and (3) neutral.

(iii) phanero-hypogean-reserve (PHR) i.e., exposed cotyledons, same soil level stoker; (iv) crypto-hypogean-reserve (CHR) i.e., occult cotyledons, under soil level and reserve and; (v) crypto-epigeal-reserve (CER) i.e., occult cotyledons, above soil level and reserve.

The seedlings morphological characteristics were associated with ecological characteristics of each species like a successional group, seeds weight, shade tolerance and dispersion syndrome (Ressel et al. 2004), with the objective to integrate the seedlings' morphofunction data and the successional group indication in restinga forest area.

The characterization of woody species in successional groups was made by the location of the species in the study area, considering light availability. From this piece of information and based on the characteristics described by Gndolfi et al. (1995), the plant species were classified into three main groups: (i) pioneer species; (ii) early secondary and (iii) late secondary (climax).

The woody species were classified according the occurrence area in: (i) non-tolerant to shade species, present in areas with 70-100% of solar energy transmittance; (ii) tolerant to shade species, present in areas with solar energy transmittance under 70% e; (iii) neutral species, that can occur in both systems.

In relation to dispersion syndrome was classified into two categories: (i) abiotic (e.g., anemochoric or autochory) and (ii) zoochoric, based on the descriptions of van der Pijl (1982).

The morphofunctionality and ecological characteristics (e.g., successional stage, seeds weight, occurrence area and dispersion syndrome) were correlated by test G and the relation between species and morphofunction were made by Chi-square Test for a sample of expected ratios equal (Bio Estat 5.0) (Ayres et al. 2007).

RESULTS

The 30 woody species present in the restinga forest of Maracaípe may be classified in four morphofunctional types (Table 1), with type PEF, more often, with 44% of studied species. The morphofunctional types CHR, PER and PHR, represent 33%, 10% and 13% of studied species, respectively.

The number of woody species from restinga of Maracaípe was significantly different between functional groups ($\chi^2 = 9,20$; $p = 0.0267$), being important the relation between cotyledons and successional groups (Test-G 20.73; $p < 0.0021$) and occurrence area (Test-G

24.79 $p < 0.0004$). The relation among seedlings morphofunction and seeds weight and dispersion syndrome (Test-G 5.55; $p < 0.1356$) was not statistically expressed.

The PEF morphofunctional type was the one with bigger abundance (90%) among the species classified as pioneers. Besides that, the group of the beginners secondary (47%) and the climax species (67%), the morphofunctional type with bigger abundance was CHR (Figure 1).

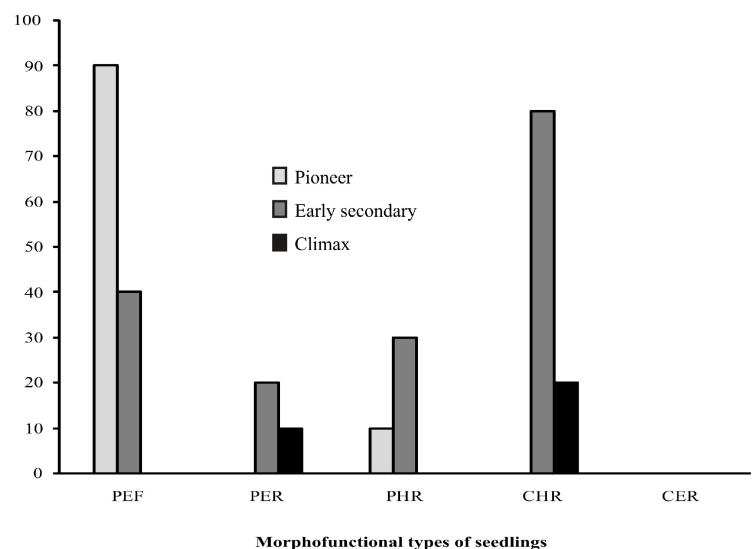


Figure 1. Percent distribution of seedlings' morphofunctional types in successional groups of woody species of RPPN Nossa Senhora do Outeiro de Maracaípe – PE, Brazil. PEF (Phanero-epigeal-foliaceous), PER (Phanero-epigeal-reserve), PHR (Phanero-hypogean-reserve), CHR (Crypto-hypogean-reserve) and CER (Crypto-epigeal-reserve).

In the total of PEF seedling, 77% were found in well-lightened areas (i.e. $> 70\%$ of transmittance), while that, CHR and PER total of seedlings. 86% and 100% respectively, occurred in shady areas, exclusively. Individuals with seedlings type PHR are found in areas sunny (33%), or even in areas shady (33%).

Around 69% of the seeds were classified as lighter ($S < 0.1$ g) and relate to type PEF, predominant of species in starter stage of ecological succession. While that 33% of the studied species present heavy seeds ($S > 1.5$ g), characterized for present CHR cotyledons, predominant in species in final succession stage.

The incidence of fruits with anemochoric and autochory dispersion (14%) was prevailed by the presence of carnosic fruits (86%) or with something attractive to zoochoric dispersion. Among these, it is

possible to highlight the species *Himatanthus phagedaenicus*, *Sloanea guianensis*, *Abarema filamentosa* and *Eschweilera ovata*, being the first, the only one of anemochoric type that was observed in this study. The following two species were type autochory and the last with two types of dispersion (i.e., zoochoric and abiotic), because the diverse animals that disperse it, it presents autochory dispersion too (Table 2).

Table 2. Dispersal syndrome and seed weight (WS - average weight of seeds) of 30 species of woody RPPN Maracaípe, Pernambuco.

Species	WS (g)	Dispersal syndrome
<i>Rollinia pickelli</i>	0.08	zoochorous
<i>Hancornia speciosa</i>	0.28	zoochorous
<i>Himatanthus phagedaenicus</i>	0.14	abiotic/ anemocory
<i>Protium heptaphyllum</i>	0.20	zoochorous
<i>Maytenus impressa</i>	0.03	zoochorous
<i>Sloanea guianensis</i>	0.53	abiotic/ autochory
<i>Pera glabrata</i>	0.01	zoochorous
<i>Andira fraxinifolia</i>	11.87	zoochorous
<i>Abarema filamentosa</i>	0.14	abiotic/ autochory
<i>Inga capitata</i>	0.64	zoochorous
<i>Inga flagelliformis</i>	0.64	zoochorous
<i>Chamaecrista ensiformis</i>	0.62	zoochorous / ornithochory
<i>Ocotea gardneri</i>	0.16	zoochorous
<i>Eschweilera ovata</i>	1.91	zoochorous / autochory
<i>Byrsonima gardneriana</i>	0.10	zoochorous
<i>Byrsonima sericea</i>	0.07	zoochorous
<i>Ficus guianensis</i>	0.001	zoochorous
<i>Eugenia hirta</i>	0.09	zoochorous
<i>Eugenia puniceifolia</i>	0.23	zoochorous
<i>Marlierea regeliana</i>	0.12	zoochorous
<i>Myrcia bergiana</i>	0.06	zoochorous
<i>Myrcia guianensis</i>	0.04	zoochorous
<i>Psidium guineense</i>	0.006	zoochorous
<i>Guapira nitida</i>	0.10	zoochorous
<i>Ouatea fieldingiana</i>	0.15	zoochorous
<i>Ximenia americana</i>	4.39	zoochorous
<i>Coccoloba laevis</i>	0.83	zoochorous
<i>Guettarda platypoda</i>	0.04	zoochorous
<i>Casearia javitensis</i>	0.03	zoochorous
<i>Simaba cuneata</i>	10.9	zoochorous

Source: Adapted from Medeiros et al. (2007)

DISCUSSION

The RPPN of Maracaípe presents a morphofunctional distribution that looks like other five tropical forests studied (Table 3). Where the PEF morphofunctional type

is more often, varying from 39% to 51% of total species, while the CER morphofunctional type has varied between 1 and 8% (Ng 1978, Miquel 1987, Ressel et al. 2004); this type though was not observed in the present study. Garwood (1996), comparing the similarity in the abundance of seedlings morphofunctional types between different tropical forests, suggested that similar selective pressure may act on the seedlings morphology determination and that ecology morphofunctional studies may be very interesting to the understood of the forest developments present in the tropics as one.

It is verified in RPPN of Maracaípe a predominance of seedling with cotyledons type PEF (90%) (Figure 1) among the species classified as pioneers. In the successional group of pioneers species, the main characteristic is the fast growth, what makes possible these plants competition for light. Therefore, the photosynthesizing cotyledons presence inside the pioneers group, present an additional advantage when it makes possible these plants photosynthesize right after its emergence (Ng 1978). On the other hand, 47% of the species with cotyledons type CHR may be classified as secondary beginners. In general, these species form a seedling bank and may survive in sub woods for long periods of time (Schiavini et al. 2001), once its cotyledons have nutritive substances stored and relatively protected (i. e., in general, the seed tegument works as a protection barrier) (Ressel et al. 2004).

Species with seedlings type PEF, in general, invest in a huge quantity of light seeds, with a few or no storage capacity. Besides that, species with seedlings type CHR, invest its reserves on the production of less seeds, usually with bigger biomass and full of nutritive reserves (Ressel et al. 2004). In Maracaípe, the obtained results in this study accord others studies results for tropical forest. Studying 172 species in a tropical forest in Gabão, Hladik and Miquel (1990) describe that shot seeds, with leafy cotyledons, usually occur in pioneers species. Nevertheless, these seeds were registered, in low frequency, for other morphofunctionals seedlings types. A alike result was found by Ibarra-Marínquez et al. (2001) at Los Tuxtlas forest in Mexico, where 210 studied species among trees, shrubs and lianas, those which presented small seeds were represented by seedlings with cotyledons type PEF. The late secondary or climax, with heavier seeds, were represented by morphofunctional type CHR. On the other hand, seedlings PHR, CHR and CER did not differ in mass. The results found in restinga forest of Maracaípe tie with those obtained by Hladik and Miquel (1990) and Ibarra-

Table 3. Percentage distribution (%) of morphofunctional types of seedlings of six tropical forests (Adapted from Ressel et al. 2004).

Forest type	N° species	PEF	PER	PHR	CHR	CER	Reference
Equatorial tropical	300	64*	10	18	8		Ng (1978) (Malaysia)
Tropical rain	206	43	16	41@			Garwood (1983) (Panama)
Tropical rain	102	51	16	31#	2		Rousteau (1983) (Guadalupe)
Equatorial tropical	210	39	25	9	22	5	Miquel (1987) (Gabon)
Cerrado	122	51	17	8	23	1	Ressel (2004) (MG - Brazil)
Restinga	30	13	3	4	10	0	This study (PE - Brazil)

* seedlings PEF+ PER; @ seedlings PHR + CHR + CER; # seedlings PHR + CHR

Marínquez et al. (2001), though on the present study the criteria used for classification was the seed cool mass instead its size.

The species with PEF seedlings also presented a variety of comportment to react with morphofisiologic contrasts under different quantity of light (Kitajima 1992), though this type of seedling is often associated with light dependent species (Ibarra-Manríquez et al. 2001). In Maracaípe RPPN, PEF seedlings also occur in species which established and grown-up under shade (sub woods), e. g., *Pera glabrata* (Euphorbiaceae) and *Myrcia bergiana* (Myrtaceae). These points were also observed by Ibarra-Manríquez et al. (2001) in a tropical forest in Mexico, where some taxons of Melastomataceae, Moraceae and Rubiaceae were found species with PEF seedlings in shady areas.

In Maracaípe, 86% of the species with bigger seeds and seedlings type CHR developed in shady areas, as Kelly and Purvis (1993) had already related, suggesting that this kind of cotyledon is adapted to shady areas or with little light. In this environment seedlings survival seems being linked to size and the storage capacity of seeds nutritive substances, besides that, bigger seeds result in vigorous seedlings which have more efficient mechanisms to tolerate various biotic and abiotic agents (Ibarra-Marínquez et al. 2001).

The seedlings predominance (PEF and CHR) in restinga of Maracaípe may suggest that these two specific morphofunctionals types give extra advantages for survival and growth of seedlings in the forest in recover fase. This fact may be confirmed by proportion of morphofunctional types in relation to dispersion syndrome. In Maracaípe was observed a predominance of fruits with zoochoric dispersion (i.e., PEF 60% and CHR 96%), including some species with anemochory used zoochory to disperse its fruits. Therefore, it suggests that zoochoric dispersion seems to assure a

bigger reproductive success for the vegetal individuals which present it. Griz and Machado (1998) analyzing 29 dicotyledons species, in an Atlantic forest in Pernambuco, Brazil, reported predominance of zoochoric dispersion. Also, Silva and Tabarelli (2000), verified zoochoric species predominance among 428 tree species in an Atlantic forest area at north São Francisco river.

It was observed in Maracaípe RPPN that seedlings functional morphology seems to be involved firstly to the successional stage of the area, once that seedling of pioneer species present, in its majority, photosynthesizing and exposed cotyledons (PEF) being responsible for nitrite the plant in development. On the other hand, the majority of the secondary species presented seedlings with cotyledons type CHR, which presents bigger storage capacity and protection during germination process and plant establishment. The relevant relation between seedlings morphology and occurrence area, contribute in the data group which indicate different successional groups, and then make stronger the criteria of characterization of the different resting physiognomies.

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