REVISTA ELETRÔNICA
CIENTÍFICA DA UERGS

Propriedades da madeira de *Eucalyptus urophylla* em diferentes locais de plantio no Nordeste do Brasil

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ISSN 2448-0479 Submetido em: 10 ago. 2020. Aceito: 17 jun. 2021.
DOI: http://dx.doi.org/10.21674/2448-0479.72.203-211

Resumo

A variabilidade das condições ambientais no Brasil influencia no crescimento das árvores, por isso esses fatores são fundamentais no estudo das propriedades da madeira visando ao seu processamento. Objetivou-se avaliar a influência das condições edafoclimáticas em dois locais de cultivo de *Eucalyptus urophylla* quanto aos seus parâmetros dendrométricos, densidade básica da madeira, densidade básica da casca e morfologia de fibras. Em cada local de plantio, abateram-se três árvores, das quais retirou-se discos das posições 0, 25, 50, 75 e 100% da altura comercial ao longo do fuste das árvores para obtenção dos parâmetros físicos e anatômicos. Os parâmetros dendrométricos não foram influenciados pelas condições edafoclimáticas. Na densidade da madeira e da casca, registrou-se acréscimo de 13,95% e 7,69% no sítio da região com menor precipitação. O comprimento da fibra e a espessura da parede celular não foram afetados pela condição de sítio, por outro lado, no diâmetro da fibra e diâmetro do lúmen houve acréscimos de 7,21% e 26,46%, respectivamente, na região em que se observou maiores precipitações pluviométricas anuais. Os parâmetros dendrométricos de *Eucalyptus urophylla* foram menos sensíveis ao local de plantio em relação aos parâmetros tecnológicos da madeira. A avaliação da madeira, com base no local onde foi produzida, permite classificar a matéria-prima visando às exigências do mercado dos produtos madeireiros.

Palavras-chave: anatomia; casca; densidade básica; fibras; índice de sítio.

Abstract

Wood properties of *Eucalyptus urophylla* at different planting sites in the Northeast region of Brazil

The variability of environmental conditions in Brazil influences the growth of trees, so these factors are fundamental in the study of the properties of wood with a view to its processing. The objective of this study was to evaluate the influence of edaphoclimatic conditions in two *Eucalyptus urophylla* cultivation sites regarding their dendrometric parameters, basic wood density, basic bark density and fiber morphology. At each planting site, three trees were cut, from which disks were removed from positions 0, 25, 50, 75 and 100% of the commercial height along the shaft of the trees to obtain physical and anatomical parameters. The dendrometric parameters were not influenced by the edaphoclimatic conditions. An increase of 13.95% and 7.69% in the density of wood and bark was registered at the site of the region with the lowest rainfall. The length of the fiber and the thickness of the cell wall were not affected by the site condition, on the other hand, there were increases of 7.21% and 26.46% in the diameter of the fiber and diameter of the lumen, respectively, in the region in which greater annual rainfall was observed. The dendrometric parameters of *Eucalyptus urophylla* were less sensitive to the planting site in relation to the technological parameters of the wood. The evaluation of the wood based on the place where it was produced allows us to classify the raw material aiming at the demands of the market of wood products.

Key words: anatomy; bark; basic density; fiber; site index.

Resumen

Propiedades de la madera de *Eucalyptus urophylla* en diferentes sitios de plantación en la región Noreste de Brasil

La variabilidad de las condiciones ambientales en Brasil influye en el crecimiento de los árboles, por lo que estos factores son fundamentales en el estudio de las propiedades de la madera con miras a su procesamiento. El objetivo de este estudio fue evaluar la influencia de las condiciones edafoclimáticas en dos sitios de cultivo de *Eucalyptus urophylla* en cuanto a sus parámetros dendrométricos, densidad básica de la madera, densidad básica de la corteza y morfología de las fibras. En cada sitio de plantación, se cortaron tres árboles, de los cuales se sacaron discos de las posiciones 0, 25, 50, 75 y 100% de la altura comercial a lo largo del fuste de los árboles para obtener parámetros físicos y anatómicos. Los parámetros dendrométricos no fueron influenciados por las condiciones edafoclimáticas. Un aumento de 13,95% y 7,69% en la densidad de madera y corteza fue registrado en el sitio de la región con menor precipitación. La longitud de la fibra y el espesor de la pared celular no se vieron afectados por la condición del sitio, por otro lado, en el diámetro de la fibra y el diámetro del lumen hubo incrementos de 7,21% y 26,46%, respectivamente, en la región donde se observaron mayores precipitaciones anuales. Los parámetros dendrométricos de *Eucalyptus urophylla* fueron menos sensibles al sitio de plantación en relación a los parámetros tecnológicos de la madera. La evaluación de la madera en función del lugar donde se produjo permite clasificar la materia prima atendiendo a las demandas del mercado de productos de madera.

Palabras Clave: anatomía; corteza; densidad básica; fibras; índice del sitio.

Introduction

Presenting a fast growth and a species variety that are adapted to the most diverse climatic conditions, the gender *Eucalyptus* L'Héritier (Myrtaceae) represents the main group of tree species planted in Brazil, and according to Brazilian Tree Industry (IBÁ, 2019) the planted area reached approximately 5.7 million ha in 2018, with 73% being legally certified.

Due to its adaptability in different environments and high productivity, the *Eucalyptus* culture is consolidated in the Brazilian forest sector, as one of the main sources of renewable raw materials and derived products. However, the viability of cultivation depends on the productive capacity of the site and the management applied (CASTRO *et al.*, 2019).

According to Gonçalves *et al.* (2016), the *Eucalyptus* production areas present an ecological scenario with several environmental mosaics, where natural strata can be recognized by climatic differentiation as edaphic, physiographic, biotic and sustainable soil use. The productive capacity of national logs of *Eucalyptus* is directly influenced by this variety of conditions. Therefore, to ensure the production of a more homogeneous raw material, it is important that the clones suffer the least effect on their technological characteristics due to the environment (GOUVÊA *et al.,* 2012).

Besides all advantages attributed to their trees in general, the species *Eucalyptus urophylla* which occurs in wide distribution throughout Brazil (IBÁ, 2019), presents in its technological properties a huge development potential for industrial use. Because of this, it is also connected to breeding, for obtaining fast-growing genetic materials and wood of superior technological quality.

The relationship between anatomical features of xylem and environment conditions has been known for a long time, especially due to water availability, soil fertility, temperature variations and wind influences. These aspects are related to the productive capacity of the place and affect the decisions of forest management, silvicultural activities, production costs, quality of the wood and the growth of the tree (TONINI; SCHNEIDER; FINGER, 2004; PUHLICK; KUEHNE; KENEFIC, 2018; LOMBARDINI; ROSSI, 2019).

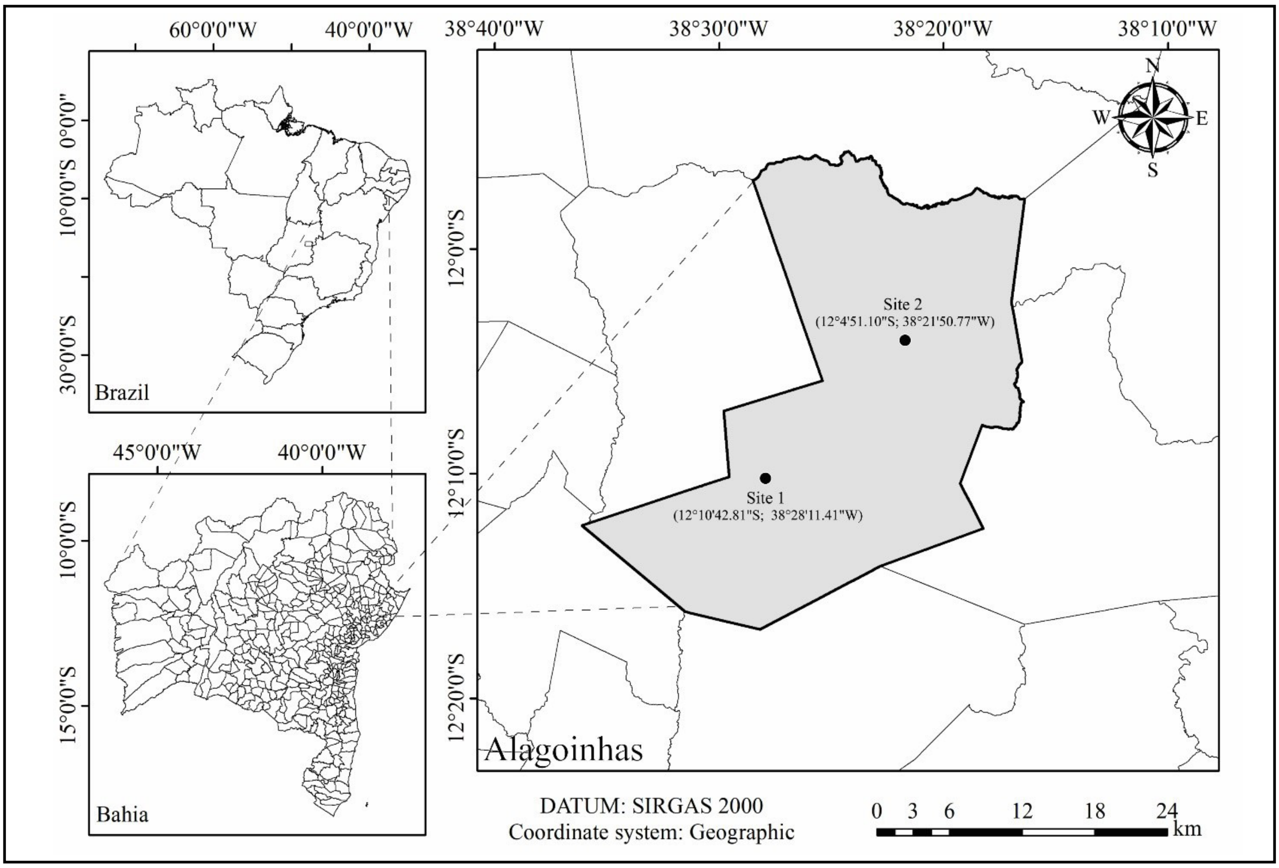
The scientific research of wood properties has helped the forest sector to improve the quality on their final products. However, a better understanding of the effects of planting conditions in the northeast region of Brazil and their implications on the timber features is lacking. This work aimed to study the effect of different conditions of planting site on the fiber's morphology, bark and physical properties of *Eucalyptus urophylla* wood.

Material and methods

Study area

The work was developed in Alagoinhas city, northeast of Bahia state, Brazil (154 meters of altitude, 12°8'2.29"S e 38°25'16.4"W) (Figure 1).

Figure 1: Location of *Eucalyptus urophylla* plantations (site 1 and site 2) in the municipality of Alagoinhas, state Bahia, Brazil.



Source: Elaborated by the authors (2020).

According to the Köppen-Geiger climatic classification carried out by Alvares *et al*. (2013) for Brazil, the municipality of the study region has two climatic classifications: in the far north (site 2) there is the Am climate type (tropical monsoon) with average annual temperature of 26 °C, from May to July is the coldest season with temperatures around 20 °C, and the average relative humidity is 75%. In the center-south (site 1) there is the Af climate, the predominant typology in the city, with an average annual temperature of 24 °C, and in the coldest months the minimum temperature is 18 °C, with an average relative humidity of 80%.

In site 1, the average annual rainfall is 900 mm and the soil type is yellow argisol with sandy/medium texture. Whereas, on site 2 there is an average annual rainfall of 1300 mm and the soil type is quartzarenic neosol of sandy texture. Rainfall values were recorded by the plantation owner company and database of National Institute of Metereology (INMET, 2020), and the soils were classified based on Santos *et al*. (2018).

A commercial plantation of *Eucalyptus urophylla* clones with eight years of age, cultivated in the 3x3 m spacing (1,111 trees ha^{-1}) for the soluble cellulosic pulp (dissolving pulp) production is located in this city. The cultivation area includes different soil conditions and rainfall locations.

According to information from the proprietary company, to meet the minimum nutritional parameters of *Eucalyptus* during implantation in both locations, liming was carried out in a total area at a dose of 2 t ha^{-1} and the base fertilization in the furrow consisted of maintaining N, P levels and K, in the order of 15, 1.5 and 10 g kg^{-1}, respectively. The doses of N and K were divided into three applications every 20 days to avoid excessive losses due to volatilization and leaching. The cover fertilization was carried out by applying N and K in the doses of 4.5 and 3 g kg^{-1}, respectively, every 10 months in the first two years of cultivation.

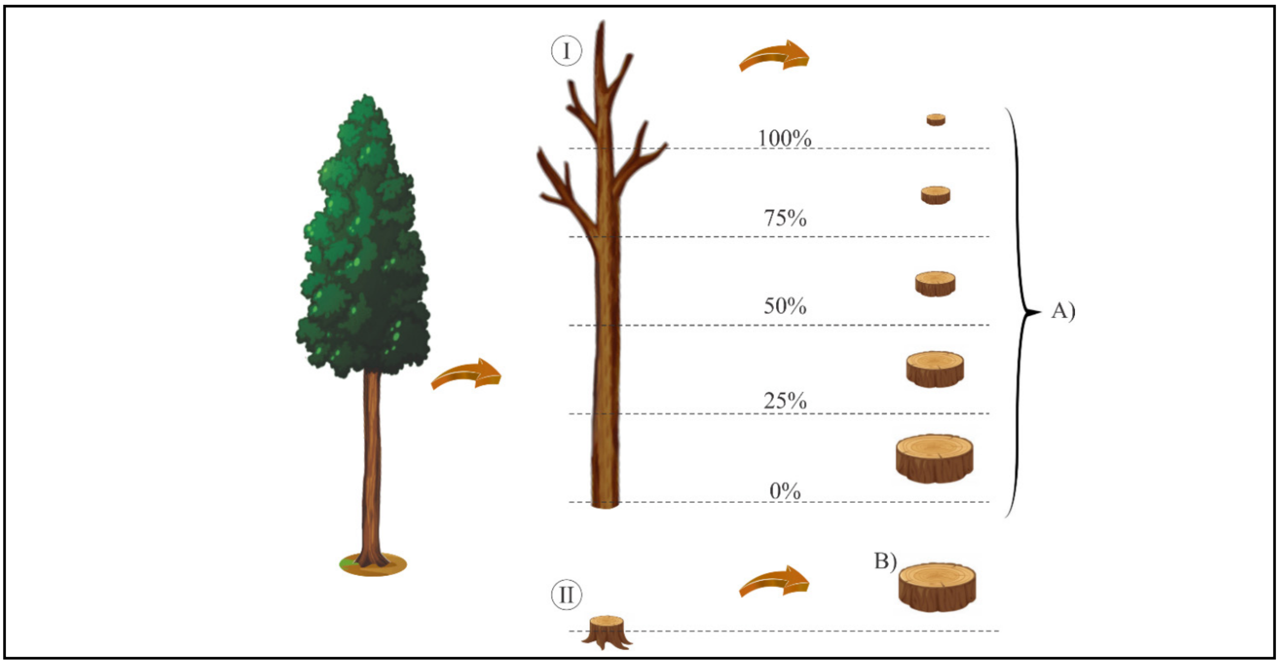
Trees selection

The *Eucalyptus* trees used for this research were obtained according to the guidelines indicated in ASTM D 5536 (ASTM, 2015). Three representative trees were sampled at random, free of diseases, bifurcations, tortuosity and large trees. Using sutures, the diameter at breast height (DBH) was obtained and the commercial height (CH) was obtained from trees felled without branches, considering a minimum useful diameter of 6 cm.

Wood sampling and characterization

In this stage, disks were removed along the shaft at positions of 0, 25, 50, 75 and 100% of the commercial height of the tree to calculate the weighted basic densities of the wood and bark, while anatomical characterization of the wood collected disks in the basal region of the trunk (Figure 2). Then, the discs were identified and stored in plastic bags to maintain moisture. The circumferences of the discs were measured with and without bark, to determine the percentage of bark, taking into account the commercial heights and the volumes of the trees.

Figure 2: **Sampling scheme for *Eucalyptus urophylla* stem, being: I - A) Discs sampled in different positions, height and commercial height to determine the basic density of wood and bark; II - B) Disc obtained from the stump for anatomical characterization of the wood.**



Source: Elaborated by the authors (2020).

Following the NBR 11941 standard (ABNT, 2003), the basic densities of wood and bark were determined. Taking into account the methodology proposed by Oliveira *et al.* (2012), wood particles from three radial positions were produced from the base of the trunk, near the core, between the core and the bark and close to the bark. To remove the particles, a carpenter's chisel was used. Each sample was macerated in a 30% hydrogen peroxide solution and glacial acetic acid in the proportion (1:2), keeping the material in an oven at 60ºC until the individualization of the fibers.

Then, using the guidelines presented by the International Association of Wood Anatomist (IAWA, 1989), slides were made to measure the fibers in an optical microscope adapted with a measurement system. The lumen diameters were calculated by the difference between the diameter of the fiber and twice the thickness of the cell wall.

Data analysis

For the density and wood values, 3 samples were produced per disk from each position, totaling 45 samples for each evaluated site. For fiber biometrics, three slides from each radial region were produced, in which at least 25 fibers were measured.

A completely randomized design (CRD) was used with the treatments being the different planting locations. The data were submitted to the Tukey test ($p < 0.01$) in order to verify differences in at least one pair of means of the evaluated parameters, for these analyzes the statistical package R version 3.3.1 (R CORE TEAM, 2016) was used.

Results and discussion

Dendrometric characterization

Among the planting sites, there were no differences observed regarding dendrometric parameters (Table 1).

Table 1 - Means and standard deviations from diameter at breast height (DBH), commercial height (CH), bark volume (Bv), without bark volume (Wbv) and bark percentage of *Eucalyptus urophylla* trees grown in two sites.

Place	DBH (cm)	CH (m)	Bv (m³)	Wbv (m³)	Bark (%)
Site 1	17.74±0.76^{ns}	26.07±1.45^{ns}	0.34±0.04^{ns}	0.30±0.04^{ns}	13.77±1.41^{ns}
Site 2	17.94±0.55^{ns}	26.77±0.51^{ns}	0.38±0.02^{ns}	0.33±0.02^{ns}	13.01±0.06^{ns}

Means followed by distinct letters in the same column differ by the Tukey test (p<0.01), while means followed by "ns" do not differ.
Source: Elaborated by the authors (2020).

There are features that do not undergo major changes with environmental variations (TONINI; SCHNEIDER; FINGER, 2004), and in the present study this occurred because, probably, in the planting sites there was an equivalent attendance to the metabolic demand of the trees. Despite the soils being of different classifications, soil preparation and fertilization management were similar between plantations.

Nicolodi *et al*. (2008) studies assist in this understanding, by explaining that soil fertility is not a static characteristic but a highly dynamic process, which expresses the ability to supply nutrients in an appropriate quantity and proportion to plants, in the absence of toxic elements for their development and productivity. In other words, soils with forestry aptitude, even if different from each other, with a proper management can present similar fertility properties. Another point is that even though there are differences in the average annual rainfall between the sites, in both places the amount of water met the requirements of the *Eucalyptus* culture, which is between 800 mm and 1200 mm (CARNEIRO *et al*., 2008).

For dendrometric parameters, the average DBH, height and volume are in accordance with what was expected for *Eucalyptus urophylla* at the age of 8 years, as can be seen in the study of Trugilho *et al*. (2010). Regarding the bark percentage, the results are in harmony with the studies obtained by Ramalho *et al*. (2019) who found values for *Eucalyptus urograndis* between 10 and 18%. In a general way, according to Neiva *et al*. (2018) bark percentages for *Eucalyptus globulus* plantations reach about 18% in relation to the commercial volume.

Physical and anatomical characterization of wood

Analyzing Table 2, it was found that the variation of the planting environment influenced the densities, because in site 1 the values were 13.96% and 7.70% higher for the density of wood and bark, respectively. Despite this, based on Evangelista *et al*. (2010) research, the results are in accordance with the species expectation and there was no influence on the wood classification, whereas in both sites it fits as a light-wood (<0.50 g cm^{-3}). Ramalho *et al*. (2019) explain that the basic density of wood can significantly vary depending on age, origin, forestry treatments, spacing and growth rate.

Table 2 - Means and standard variation of basic density wood and basic density bark of *Eucalyptus urophylla* trees grown in two sites.

Place	Basic density wood (g cm^{-3})	Basic density bark (g cm^{-3})
Site 1	0.49±0.02 a	0.28±0.01 a
Site 2	0.43±0.01 b	0.26±0.01 b

Means followed by distinct letters in the same column differ by the Tukey test (p<0.01), while means followed by "ns" do not differ.
Source: Elaborated by the authors (2020).

As there were no variations in dendrometric and genotypic aspects, the differences observed can be attributed to external factors such as temperature, direction and speed of the winds that causes changes in the tree's cells promoting substantial modification in the density of the wood and production of reaction wood (BRAZ *et al*., 2014).

The averages of the density bark varied significantly from one site to another, the values of 0.28 g cm^{-3} (site 1) and 0.26 g cm^{-3} (site 2) are similar to those observed by Juízo, Lima and Silva (2017), which evaluated the bark of nine species of *Eucalyptus* for the charcoal production.

Calculating the difference in rainfall between the two planting sites (400 mm), taking into account the INMET (2019) climatological database for the region, the results indicate that the lower availability of water in site 1, may have stimulated the trees to develop defense mechanisms against dehydration. Following this logic, Vergílio (2015) explains that in environments with less resources for plant growth, the development of bark properties in tissues, such as cell wall thickness, sclerenchyma, cuticle, tannins, terpenes, suberin and resins can occur, which may explain the greater density at site 1.

As for physical properties, there was an environmental influence on the anatomical characteristics of *Eucalyptus* wood, except for fiber length and cell wall thickness (Table 3). However, the standard deviation shows that the material has good homogeneity. Thus, the anatomical characteristics and basic density of these species favor the lignin impregnation and removal from the chips in the cooking processes. Consequently, in the formation of the paper there will be a better connection between fibers, increasing the quality of the paper.

Table 3 - Means and standard deviations of fiber length, cell wall thickness, fiber diameter and lumen diameter of the wood of *Eucalyptus urophylla* trees grown in two sites.

Place	Fiber length (mm)	Cell wall thickness (μm)	Fiber diameter (μm)	Lumen diameter (μm)
Site 1	1.04 ± 0.07^{ns}	6.27 ± 0.27^{ns}	22.3±0.70 a	9.75±0.78 a
Site 2	0.99 ± 0.05^{ns}	5.79 ± 0.40^{ns}	23.91±0.39 b	12.33±1.03 b

Means followed by distinct letters in the same column differ by the Tukey test ($p<0.01$), while means followed by "ns" do not differ.
Source: Elaborated by the authors (2020).

On the other hand, the highest values of fiber diameter and lumen diameter were recorded on site 2; in this case it is evident that the greater amount of rain in this environment probably promoted changes in the morphology of the fibers.

This characteristic was observed by Barboza (2018), when studying the wood *Vochysia tucanorumi* (Vochysiaceae) demonstrated that the relationship between the anatomical characteristics of the wood and the environmental factors is determinant in the alterations of the xylem due to water availability. The author found that between the cerrado and the dense forest he found that in the forest, where there is greater water availability, there was an increase in the diameters of the vascular pits and the vessel elements, pointing to greater metabolic investment in the conduction of xylem fluids (RODRIGUES-ZACCARO *et al*., 2019).

Therefore, the results obtained also help to elucidate the wood basic density results, because in site 1 there are narrower fibers, smaller lumens and the cell wall thickness did not vary, thereby there is a greater amount of fibers per unit of volume increasing the basic density.

Among the anatomical elements, the fibers are responsible for the wood resistance to mechanical efforts. The biometric characteristics of this cell are fundamental in the cellulose production, as the wood quality depends on the length and thickness of its walls (OLIVEIRA *et al*., 2012). To ensure the production of a more homogeneous raw material it is important that the clones suffer the least effect on their technological properties due to the used site (GOUVÊA *et al*., 2012). In the present study it was observed that the site influenced the wood properties, this fact is not desirable for forestry companies since it may cause need for changes in production processes.

Final considerations

Under the study conditions, it was found that the dendrometric parameters of *Eucalyptus urophylla* are less sensitive to the planting site than the technological parameters of the wood. Where the precipitation was lower, the bark and wood densities were higher and the fiber and lumen diameters were lower.

The evaluation of these parameters according to the location of growth of the trees, allows to classify the raw material in batches based on the market requirements of wood-based products, ensuring homogeneity and quality.

Acknowledgements

The authors are particularly grateful to the Wood Technology Laboratory at the Federal University of Recôncavo da Bahia (UFRB) for the experimental support and to Bracell Celulose S/A for providing the plant material. This study was promoted by the Research Support Foundation of the State of Bahia (FAPESB), National Council for Scientific and Technological Development (CNPq, Brazil) and Higher Education Personnel Improvement Coordination (CAPES, Brazil).

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