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LEAF STRUCTURE OF MANGROVE SPECIES TO UNDERSTAND THE SPECTRAL RESPONSES

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Abstract

The preservation of ecosystems such as mangroves plays a key role in mitigating the negative effects arising from climate change, especially for the capture of atmospheric carbon dioxide, the main agent of degradation of the ozone layer. The remote sensing application studies aim to develop that allows the preservation of ecosystems such as mangroves. This study aims to evaluate the anatomical structure of three species in a mangrove established at Pernambuco State as an aid in understanding the spectral responses shown by these species. Mature leaves of *Rhizophora mangle*, *Laguncularia racemosa* and *Avicennia schaueriana* were collected in the estuary of Maracaípe, in the district of Ipojuca-PE, and cross-sections of leaf lamina and epidermis dissociation were performed, following usual procedures in plant anatomy. Individuals of *R. mangle* showed the highest values of thickening of the cuticle and epidermis. *A. schaueriana* detached through the highest values for the thickness of palisade and *L. racemosa* showed the highest values for the thickening of the spongy parenchyma. The species showed different structural characteristics with different action related to the reflectance, absorptance, and transmittance, allowing the use of remote sensing techniques for proper assessment of vegetation conditions for the preservation of the environment.
Key words: Climate conditions, remote sensing, mangrove, leaf anatomy.

1. Introduction

Climate change is often associated with human activities, and one of the main aspects that contribute to the appearance of these climatic variations is related to changes in natural vegetation covertures, together with the burning of fossil fuels, releasing large quantities of carbon dioxide to the atmosphere (Ayodya, 2003).

This ecosystem plays an important role when it is related to carbon sequestration from the atmosphere. Some attempts were made to minimize the negative effects of the accumulation of carbon dioxide in the atmosphere, highlighting the reforestation, including the coastal vegetation (Fonseca & Drummond, 1998). These authors evaluated the practice of reforestation with native species in areas with mangroves in the Rio de Janeiro State, aiming to reduce the damage caused by the greenhouse effect. It is clear the importance of preserving the mangrove ecosystem, since these regions have environmental conditions conducive to the development of several species of fish and crustaceans (Lacerda, 2003).

The monitoring of environments such as mangroves is performed efficiently through the use of remote sensing techniques, it is possible to manage and monitor information from the temporal and spatial variables and carry out a preliminary assessment of problems in different areas, using simulations and mathematical models (Petersen et al. 1991; Vaiphasa et al., 2005, Wang et al. 2004; Giri et al., 2007), the space-time mapping is a way of monitoring.

The understanding of information recorded on a sensor needs the knowledge of the spectral features of the object under study (Fonseca et al. 2002; Rooster et al., 2002). Considering the vegetation, the main target that interacts with radiation is the leaf. Features commonly associated with radiation in leaves are: the cuticle, mesophyll and distribution of parenchyma, palisade and spongy, and the density of trichomes and stomata (Fanh & Cutler, 1992; Ourcival et al. 1999; Silva et al., 2006).

Initial work involving mapping of mangroves in Brazil was carried out by Herz (1991). In Pernambuco, Lacerda et al. (2006) identified 11 regions of mangroves in 2001, which corresponds to a total area of approximately 161.38 km².

Since a long time the mangrove is becoming an important source of economic resources used by those people which lives in the coastal regions of tropics, one of the reasons that qualifies as one of the most important wetland ecosystems (Dugan, 1992).

In Brazilian mangrove we found tree mainly species belonging to four genera: *Rizophora*, *Aviccenia*, *Laguncularia* and *Conocarpus*. Other genera, such as *Hibiscus*, *Acrostichum* and *Spartina* can also be found, however enocntradas are often associated with other species (Herz, 1991; Schaeffer-Novelli, 2002; Fao, 2007).

In addition to the light in the mangroves be intense throughout the day, other environmental factors such as high levels of soil salinity and water available to plants, low levels of oxygen available and periodically flooded soils, make the plant species established there to develop functional and morphological adaptations that allow survival and remain in these environments (Soares, 1997; Lee & Yeh, 2009, Silva et al., 2005). All these environmental factors may be responsible for low diversity of plant species found in mangroves (Tomlinson, 1986). It is common to find roots developing in the horizontal direction, or stems that grow toward the surface, known as pneumatophores, which act in the capture of oxygen to the tissues that are immersed in the soil, and excretory glands, which eliminate the excess of salt absorbed by the roots (Olmos & Silva, 2003). The adjustments related to the anatomical structure of the leaf, as thick cuticle, epidermis and chlorenchyma, alter the scattering of radiation inside the leaf and, consequently, its spectral response (Jones et al., 2004, Todd et al., 2011).

This study aims to describe and to evaluate the anatomical structure of leaves of three plant species of the mangrove ecosystem, to assist in understanding the spectral specific response.

2 Material and methods

The plant material was collected in the Maracaípe estuary on the southern coast of Pernambuco State, Ipojuca in the coordinates 08°31'48"S and 35°01'05" W (Figure 01).

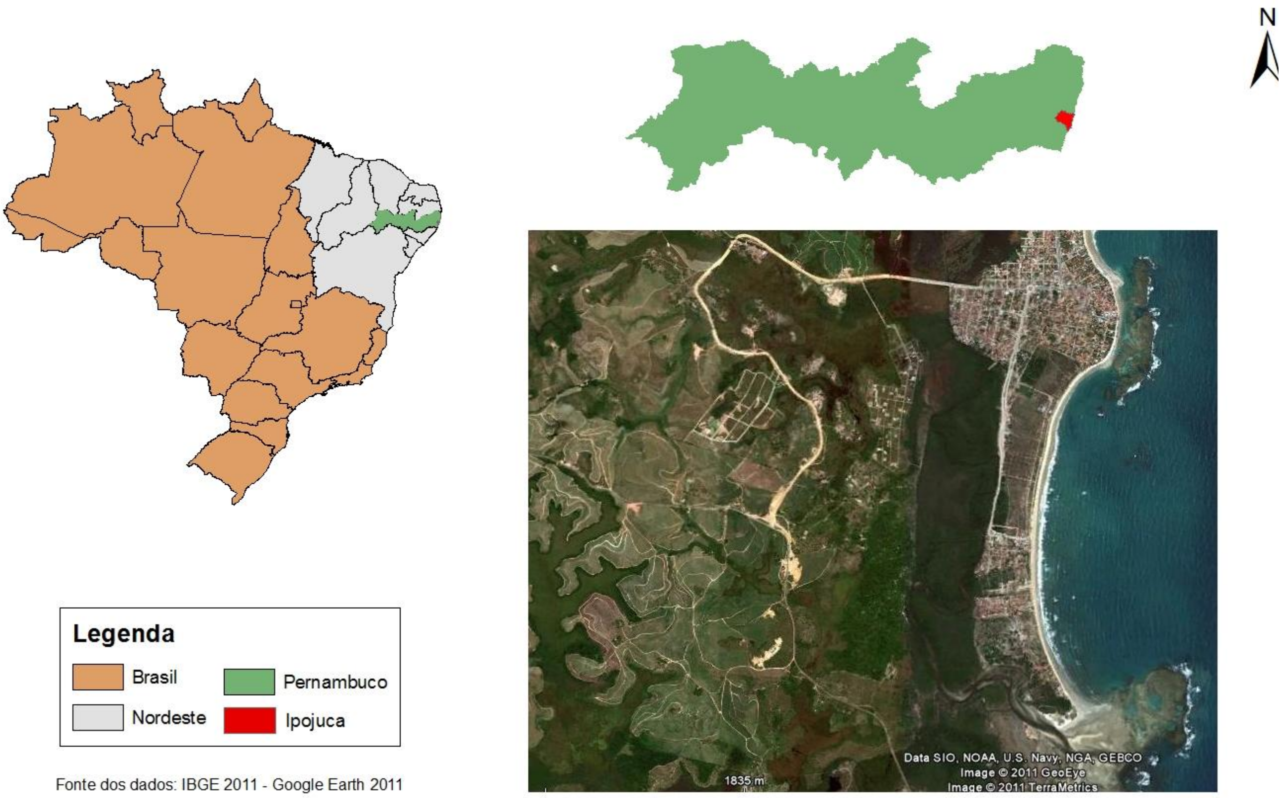

Figure 1. Aerial view of Maracaípe estuary, Ipojuca-PE.

The mangrove vegetation occupies an area of approximately 15.24 ha. The approximate distance from mangrove to the sea is 5 km. The region shows a flat landscape, slightly undulate and Quartzarenic Neosol.

The annual rainfall is 2,000 mm and, according to Köppen (1948), the climate type is tropical rain.

According to Silva et al. (2011), Maracaípe estuary is under a coastal plain area formed during the Holocene marine transgression, flooding the river valleys, this process of flooding was greater than those of sedimentation, allowing the current topography of estuaries was similar to the river valley. They are generally shallow, rarely exceeding 30 m deep, in cross section; in most cases, increases toward the outfall.

Three plant species were selected and analyzed for the anatomical features related to the spectral response, they are: *Rhizophora mangle* L. (red mangrove), *Avicennia schaueriana* Stapf & Leechman (black mangrove) and *Laguncularia racemosa* L. (white mangrove). Two plots were established on the margin of the mangrove, the first nearest the outfall and the second on the middle of the mangrove, far from 1 km between them. From each species were selected five adults ones, randomly distributed in the plots. From each specimen was collected ten adult leaves, exposed to the sun in the middle third of the crown, being considered adult leaves those located between the fifth and sixth nodes, with maximum development of the leaf blade, compared with other leaves from the same branch. These samples were taken to the Laboratory of Functional Fitomorfologia at the Federal Rural University of Pernambuco and fixed in FAA 50 (Johansen, 1940) to maintain the integrity of the cellular structures until processing (Kraus & Arduin, 1997).

The histological slides were hand-made from cross sections in the middle portion of the leaf blade with the aid of common steel blade. The sections were cleared in sodium hypochlorite 10%, following usual procedures in plant anatomy (Johansen, 1940). The epidermis analysis used fragments of 1 cm^2 from leaves immersed in sodium hypochlorite 20% until dissociation. The period of immersion in this solution was variable for some species with exchange at intervals over 24 hours (Sasser, 1951).

The cross sections and epidermal fragments were stained with safranin 1%and astra blue 1% (1:1), and mounted in aqueous glycerin 50% (Sass, 1951).

The anatomical structure has been described and characterized using digital images. Digital images were obtained under an optical microscope coupled with a digital camera. The anatomical structures were measured using image analysis program Image Tool (Wilcox et al., 2002). The anatomical features classification followed Metcalfe & Chalk (1972ab, 1988). The traits evaluated were: thickness of cuticle, upper and lower epidermis, palisade and spongy parenchyma and the total thickness of leaf blade.

3 Results and discussion

In front view, individuals of *Rizophora mangle* showed fundamental cells of epidermis ranging from square to circular, on both sides (Fig. 2AB). The anticlinal walls of these cells are straight and the stomata are anomocytic (Fig. 2C), founded exclusively on the abaxial surface (Fig. 2B).

Fundamental cells of epidermis in *Laguncularia racemosa* showed rounded outline and rarely rectangular on both surfaces (Fig. 2AB). The cells wall are classified as straight and the stomata are anomocytic (Fig. 3C), found on both surfaces (Fig. 3AB).

Individuals of *Avicennia schaueriana* showed fundamental epidermal cells with quadrangular and rectangular outline on both leaf surfaces (Fig. 4AB); the anticlinal walls are straight. Stomata are diacytic (Fig. 4C), and are limited to the abaxial surface (Fig. 4B).

The epidermal cells show square and circular outline in *Rizophora mangle* (Fig. 2AB), rectangular in *Laguncularia racemosa* (Fig. 3AB) and square in *Avicennia schaueriana* (Fig. 4AB). The anomocytic stomata were found in *R. mangle* (Fig. 2C) and *L. racemosa* (Fig. 3C) and diacytic one in *A. schaueriana* (Fig. 4C). The epidermis is uniseriate in all species and the hypodermis was observed in *R. mangle* (Fig. 2E), with six layers of cells, and in *A. schaueriana* (Fig. 4F) it showed three layers of cells.

The mesophyll is dorsiventral in all species and the number of layers of palisade parenchyma ranged between one layer in *R. mangle* (Fig. 2D), and four in *L. racemosa* (Fig. 3E) and *A. schaueriana* (Fig. 4E); the number of layers of spongy parenchyma ranged from ten in *R. mangle* (Fig. 2D) and *L. racemosa* (Fig. 3D) and nine in *A. schaueriana* (Fig. 4D).

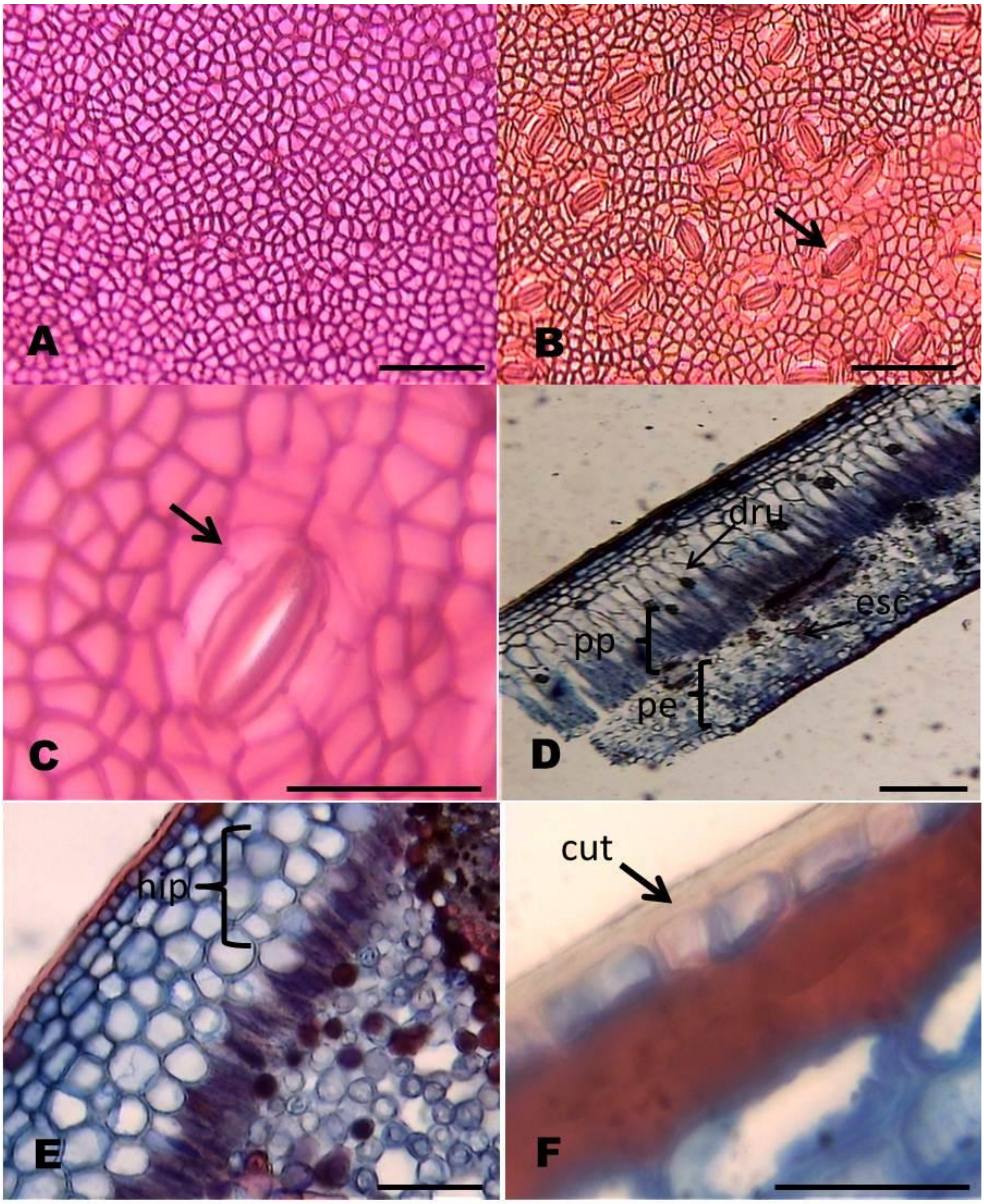

Figure 2. *Rhizophora mangle* L. A-C. Front view of leaf epidermis. C-F. Cross-sectional view of the leaf lamina. A. Adaxial surface. B. Abaxial surface with anomocytic stomata (arrow). C. Detail of anomocytic stomata (arrow). D. Dorsiventral mesophyll with crystals (druse) and sclereid. E. Detail of hypoderm. F. Detail of cuticle. pp. Palisade parenchyma; pe. Spongy parenchyma; dru. Druse; esc. Sclereid; hip. Hypoderm; cut. Cuticle. Bars: A,B,E = 100µm; C,F = 50µm; D = 200µm.

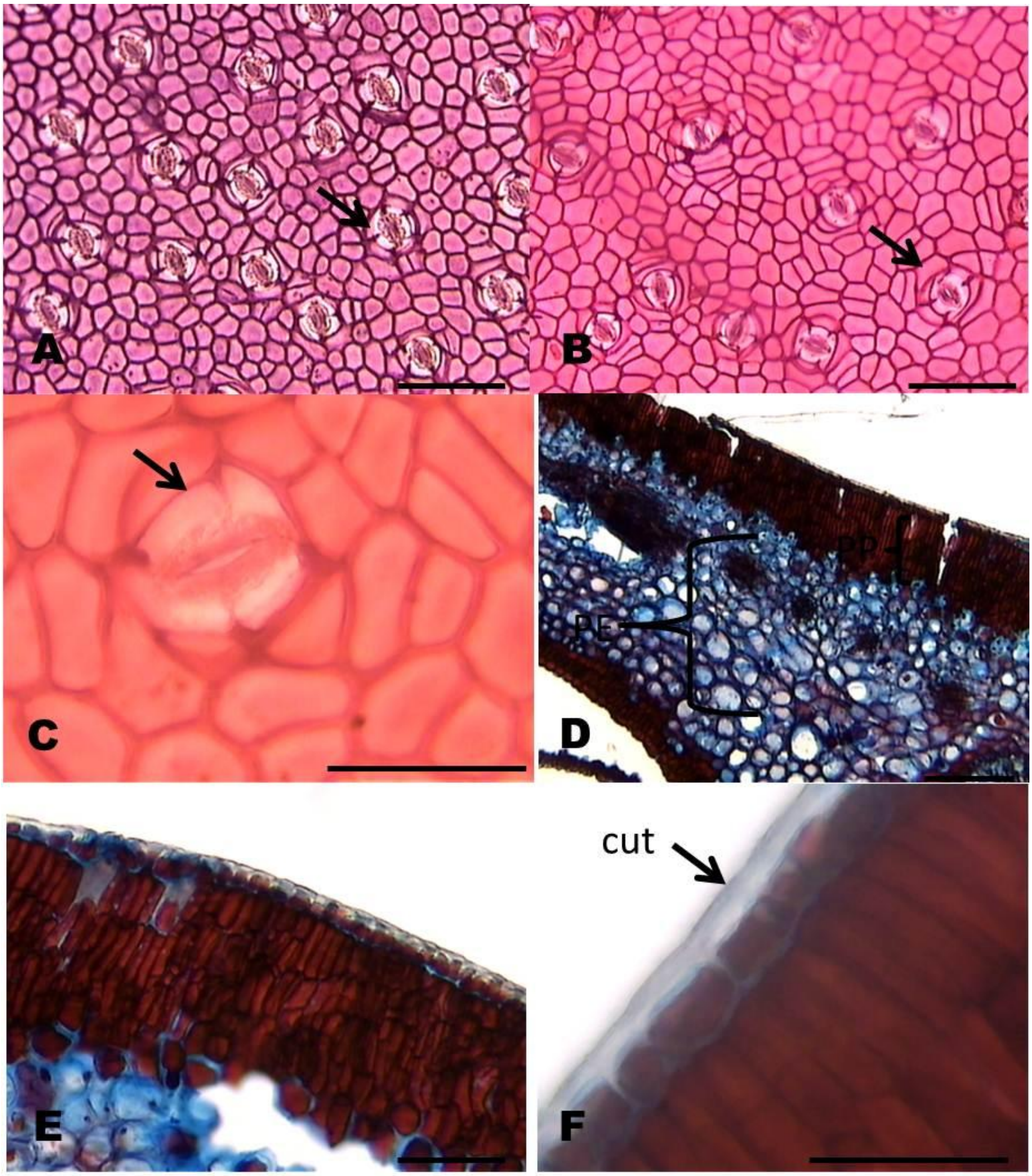

Figure 3. *Laguncularia racemosa* (L.) Gaerten. A-C. Front view of leaf epidermis. D-F. Cross-sectional view of the leaf lamina. A. Adaxial surface with anomocytic stomata (arrow). B. Abaxial surface with anomocytic stomata (arrow). C. Detail of anomocytic stomata. D. Dorsiventral mesophyll. E. Palisade mesophyll showing accumulating phenolic compounds. D. Detail of the cuticle. pp. Palisade parenchyma; Fr. Spongy parenchyma; cut. Cuticle. Bars: A, B, E = 100µm, C, F = 50µm. D = 200µm.

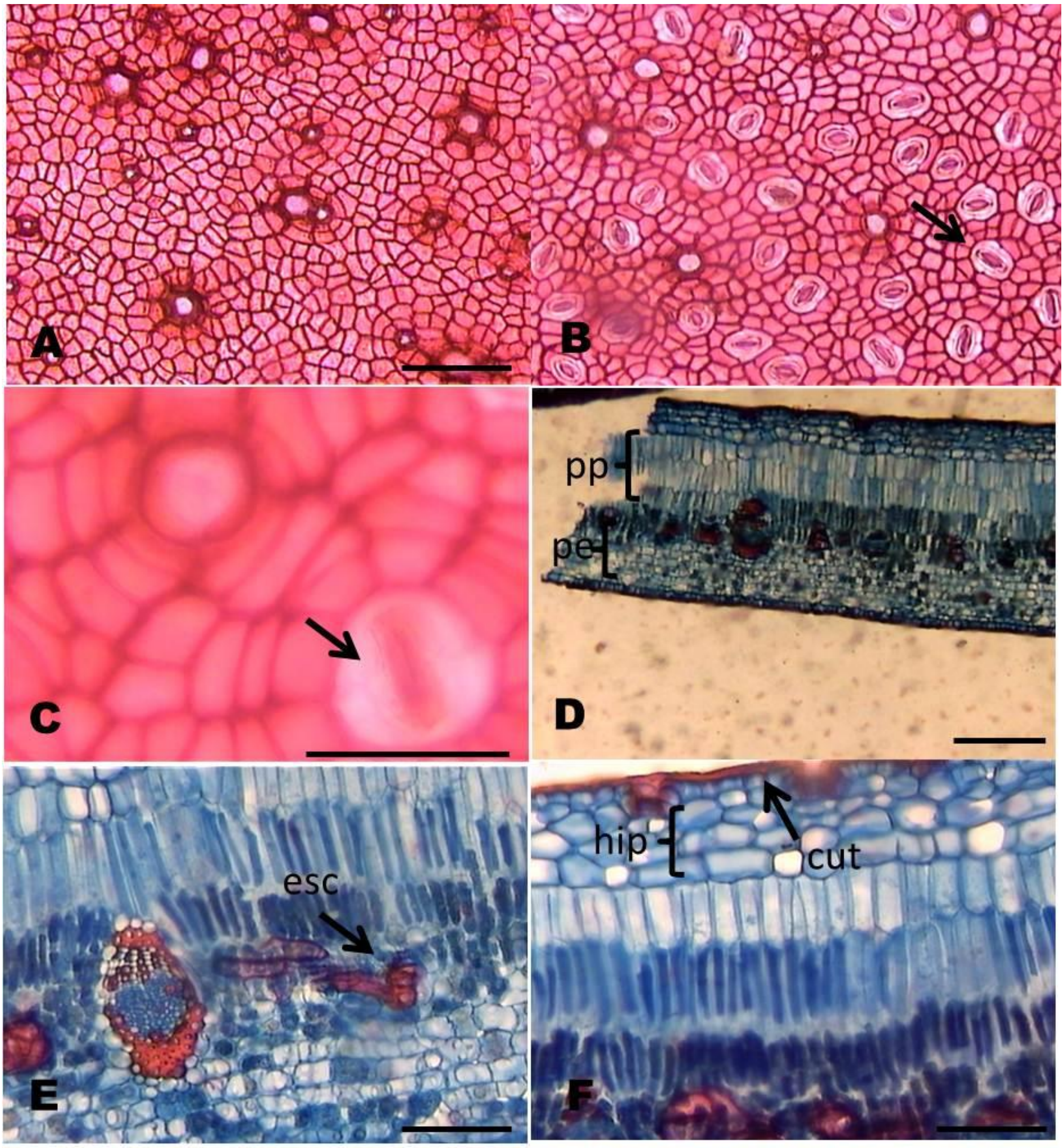

Figure 4. *Avicennia schaueriana* Stapf & Leechman. A-C. Front view of leaf epidermis. D-F. Cross-sectional view of the leaf lamina. A. Adaxial surface showing secretory structures. B. Abaxial surface showing diacytic stomata (arrow). C. Detail of diacytic stomata. D. Dorsiventral mesophyll. E. Sclereid in the mesophyll. F. Detail of hypodermis and cuticle. pp. Palisade parenchyma; pe. Spongy parenchyma; esc. Sclereid; hip. Hypodermis; cut. Cuticle. Bars: A, B, E, F = 100µm; C = 50µm; D = 200µm.

Inclusions of druse were found into the hypodermis and palisade and spongy parenchyma cells (Fig. 2D). The frequency of idioblasts was lower in *L. racemosa* related to *R. mangle*.

In general, there was no significant difference between the average values related to anatomical structures in all individuals (Table 1). The epidermal cells showed similar sizes on both sides, for *R. mangle* and *L. racemosa* (Table 1).

The thickening of palisade showed a higher average value for *L. racemosa* with the same number of cell layers compared to *A. schaueriana* (Table 1). These cells in *R. mangle* showed greater diameter (Fig. 2D).

The media average of thickness of the spongy parenchyma was highlighted in *A. schaueriana*, 494.06 μm, followed by *R. mangle* and *L. racemosa* (Table 1).

The total thickness of the leaf showed higher mean values for *A. schaueriana* and similar values for the other two species (Table 1).

Table 1. Mean values (μm) of structural parameters in leaves of mangrove species.

Especie	***Rhizophora mangle***	***Laguncularia racemosa***	***Avicennia schaueriana***
Cuticle	9.00 ± 0.84	6.50 ± 0.41	6.48 ± 0.90
Epiderm			
Adaxial surface	11.31 ± 2.21	10.34 ± 1.61	8.80 ± 1.56
Abaxial surface	10.26 ± 0.91	10.45 ± 1.71	9.70 ± 2.20
Parenchyma			
Palisade	129.20 ± 14.67	239.60 ± 7.80	161.30 ± 4.31
Spongy	218.30 ± 11.10	191.10 ± 13.10	494.06 ± 26.21
Total thickness of leaf	581.23 ± 20.70	584.90 ± 15.30	742.41 ± 21.50

Leaves covered by a uniseriate epidermis showed greater ability to absorb light energy, essential for photosynthesis. The cuticle thickening which recover these cells is a barrier against water loss through evapotranspiration, thereby reducing the risk of dehydration and problems in the metabolism of these cells (Korndörfer, 2006). Depending on the degree of cuticle thickening, greater will be the amount of reflection of solar rays' incident on the leaf (Valeriano, 2003). In order, *R. mangle* showed best response for protection against strong radiation and its harmful effects due to its greater height and cuticle cells of the adaxial epidermis.

However, these structures do not interact so strongly significant with the radiation, because only a small part of the incident radiation is reflected by the leaf cuticle (Valeriano, 2003).

The incident light on the leaves is important for the maintenance of photosynthesis, allowing the plant to synthesize organic substances that maintain the cells functioning and enable the production of new cells during plant development (Chazdon & Kaufmann, 1993).

The region of the leaf that interacts more effectively with the radiation is the mesophyll, since much of the sunlight crosses the cuticle and epidermis. It is also into the mesophyll where are the tissues specialized in the photosynthesis (Fahn & Cutler, 1992).

Although the palisade tissue is considered the main to conduct this process, photosynthesis can also be held by the spongy parenchyma. Thus, the cells of these two tissues generally have high amounts of chlorophyll, the main photosynthetic pigment. In the palisade, the pigment is fundamental to the absorption and light reflectance in the visible spectrum, while the spongy parenchyma absorption and reflectance occur more intensely near the infrared spectrum (Carvalho Junior et al., 2005).

Laguncularia racemosa showed the greatest thickening values to the palisade, while *Avicennia schaueriana* showed the highest values to the spongy parenchyma. The interference in the spectral response are higher in mature tissues, and the scattering of radiation inside the leaf tends to increase the reflectance indices on those individuals with cellular structure more developed (PONZONI, 2001).

Idioblasts, containing druse inside, frequently found in individuals of *R. mangle*, contribute to the reflection and guiding of light inside the leaf, optimizing, often, the photosynthetic performance (Fahn & Cutler, 1992).

4 Conclusions and suggestions

Thicker leaves, with greater development of palisade parenchyma, found in *Avicennia schaueriana*, indicate that this species, compared to *R. mangle* and *L. racemosa*, shows a more adapted structure to better use of incident light radiation at greater likelihood of absorbance and transmittance, respectively.

Leaves of *Rizophora mangle*, which shows higher values of cuticle thickening and greater height of the cells of the adaxial epidermis, may have higher reflectance values compared to the other two species.

The leaf anatomical structure characteristic for each species defines the spectral response of these plants and allows the identification of them through remote sensing technique, which can contribute to the development of research aimed at the preservation of this ecosystem and the mitigation of environmental impacts from the degradation.

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