

Pharmacobotanical characterization of common arrowroot (*Maranta arundinacea* L.)

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ABSTRACT

Maranta arundinacea L., belonging to the Marantaceae family, has traditionally been valued for its food and medicinal uses, but it still lacks technical-scientific studies to support its widespread application. This work aimed to characterize the external morphology, anatomy, and histochemistry of the species, contributing to its safe identification and functional appreciation. The plant material was collected from an agroecological cultivation in Rio Formoso (Pernambuco), herbarium-prepared, and analyzed using classical botanical and histochemical techniques under optical microscopy. Morphological results revealed fusiform rhizomes rich in starch, leaves with a prominent pulvinus, and panicle-type inflorescences. Anatomically, the presence of sclerenchyma in the rhizome and polypodal roots, amphistomatic leaf blades with prismatic crystals, as well as the absence of trichomes in the pulvinus and petiole, stood out. Histochemistry showed the presence of alkaloids, phenolic compounds, starch, mucilages, pectins, proteins, and lipids, mostly in the storage and conduction tissues. Tests for tannins, triterpenes, and steroids were negative. These results confirm distinct diagnostic features compared to related species, like *Maranta pilosissima*, and support the traditional uses of the species as easily digestible food and a therapeutic agent. In conclusion, the pharmacobotanical and metabolic characterization of *M. arundinacea* supports its inclusion in public policies focused on Non-Conventional Food Plants, helps standardize its production chain, and strengthens its potential as a strategic functional resource for food security, family farming, and herbal medicine.

RESUMO

Maranta arundinacea L., pertencente à família Marantaceae, é tradicionalmente valorizada por seus usos alimentícios e medicinais, mas ainda carece de estudos técnico-científicos que embasem sua ampla aplicação. Este trabalho teve como objetivo realizar a caracterização da morfologia externa, anatomia e histoquímica da espécie, contribuindo para sua identificação segura e valorização funcional. O material vegetal foi coletado em cultivo agroecológico em Rio Formoso (Pernambuco), herborizado e analisado por meio de técnicas botânicas clássicas e histoquímicas em microscopia óptica. Os resultados morfológicos revelaram rizomas fusiformes ricos em amido, folhas com pulvino proeminente e inflorescências paniculadas. Anatomicamente, destacou-se a presença de esclerênquima no rizoma e na raiz poliarca, lâmina foliar anfistomática com cristais prismáticos, além da ausência de tricomas em pulvino e pecíolo. A histoquímica evidenciou a presença de alcaloides, compostos fenólicos, amido, mucilagens, pectinas, proteínas e lipídios, majoritariamente nos tecidos de reserva e condução. Os testes para taninos, triterpenos e esteroides foram negativos. Tais resultados confirmam atributos diagnósticos distintos em relação a espécies congêneres, como *Maranta pilosissima*, e fundamentam os usos tradicionais da espécie como alimento de fácil digestão e agente terapêutico. Conclui-se que a caracterização farmacobotânica e metabólica de *M. arundinacea* subsidia sua inserção em políticas públicas voltadas às Plantas Alimentícias Não Convencionais, apoia a padronização de sua cadeia produtiva e fortalece seu potencial como recurso funcional estratégico para segurança alimentar, agricultura familiar e fitoterapia.

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Introduction

The Marantaceae family is made up mostly of tropical plants and stands out for its wide morphological, functional, and phylogenetic diversity, with distribution in the main tropical regions of the world, except for Australia. Considered a sister group to the Cannaceae family, it shares important structural traits with it, such as flower symmetry and specific morphophysiological adaptations (Andersson & Chase, 2001; Kress et al., 2001).

This family includes roughly 31 genera and 535 species, with a strong presence in tropical forests of South America, Central America, Africa, and Asia (Prince & Kress, 2006). In Brazil, 13 genera and about 230 species are identified (Flora do Brasil, 2020).

Due to species adaptations, the taxonomic delimitation of Marantaceae species has been revised based on morphological and molecular analyses, since groupings defined by classical criteria have turned out to be paraphyletic or polyphyletic (Andersson & Chase, 2001; Prince & Kress, 2006; Abdullah et al., 2008). This highlights the family's evolutionary complexity and emphasizes the need for integrated approaches to understand its diversity.

Among the standout species of the family is *Maranta arundinacea* L., commonly known as arrowroot, widely used since the pre-Columbian period by indigenous peoples such as the Pataxós, Caiapós, and Guaranis, mainly due to the high digestibility of its starch (Handler, 1971; Posey, 1985; Coelho et al., 2005). The starch extracted from its rhizomes has excellent technological properties, such as a high concentration of amylopectin, good transparency, low retrogradation, and resistance to syneresis, making it valuable for the food and pharmaceutical industries (Blennow et al., 2002; Leonel & Cereda, 2002; Charles et al., 2016).

Currently, there is growing interest in using *M. arundinacea* starch for the production of biomaterials, cosmetics, and pharmaceutical excipients, due to its biocompatibility and thermal stability. In addition, rhizomes and leaves are still used in traditional medicine and food (Piriyaprasarth et al., 2010; Gordillo et al., 2014). From a nutritional point of view, this species stands out for having low calorie content, good levels of proteins, and minerals like iron, calcium, phosphorus, and zinc, making it suitable for groups such as children, the elderly, and people recovering from illness (Jaison et al., 2024). There are also reports of bioactive compounds like flavonoids, tannins, alkaloids, and terpenoids, which have antioxidant, anti-inflammatory, and antimicrobial properties (Kumalasari et al., 2012; Nishaa et al., 2013).

For these reasons, *M. arundinacea* is classified as a Non-Conventional Food Plant (PANC), representing a strategic alternative for food diversification, agrobiodiversity conservation, and strengthening family farming. In this way, valuing it can help reduce the consumption of ultra-processed foods and fight food insecurity (Kinupp & Lorenzi, 2014).

However, despite its potential, the species still lacks greater technical and scientific recognition. The scarcity of studies and specific protocols hinders its inclusion in public policies aimed at PANC and the confirmation of its medicinal use (Brito et al., 2021). Additionally, the species has morphological characteristics similar to other species in the genus, highlighting the

need for pharmacobotanical studies to establish diagnostic markers for the species *M. arundinacea*.

In light of this, to expand its use in production systems and help ensure the safety of its food and medicinal applications, it is necessary to carry out studies that diagnose external morphological, anatomical, and histochemical diagnostic markers. It is worth noting that analyzing external morphology as well as anatomy allows for precise species identification, while histochemistry helps to map bioactive compounds. Therefore, the aim of this study is to characterize external morphological, anatomical, and histochemical diagnostic markers of *M. arundinacea*, commonly known as common arrowroot.

Materials and Methods

Collection and identification of plant material

16 specimens were collected at the agroecological fair in the municipality of Rio Formoso, located in the coastal region of southern Pernambuco. For collecting the botanical material, the guidelines of Albuquerque et al. (2010) were followed, which recommend collecting flowering and/or fruiting plant samples, without mechanical damage or damage caused by insects and fungi. The plant sample was sent to the herbarium of the Agronomic Institute of Pernambuco (Instituto Agrônômico de Pernambuco - IPA) for herbarium preparation and identification, under accession number 95060.

Description of the external morphology

The external morphological characterization was carried out based on the following leaf attributes: Phyllotaxy, leaf blade shape, type of indument, and presence of petiole. The terminology used for describing leaf shapes followed the recommendations proposed by Hickey (1973). For the description of floral structures, the nomenclature followed the systems of Weberling (1992) and Judd et al. (2002). The morphological analysis of the stem was based on the descriptive criteria established by Gonçalves and Lorenzi (2007) and Almeida and Almeida (2014).

Anatomical characterization

For the anatomical characterization of the plant material, FAA50 (formaldehyde, acetic acid, and 50% ethyl alcohol, 1:1:18 v/v) (Johansen, 1940) was used to fix the samples. Freehand cross sections of the root, petiole, and leaf blades were made using steel blades (regular razor blades) with the embaúba pith used as support (*Cecropia* sp.). For the leaf blade, paradermal sections were also made on the adaxial and abaxial surfaces.

Later, for clarification, the sections were treated with a 50% sodium hypochlorite solution (Kraus & Arduin, 1997) and rinsed in distilled water. The cross sections were stained with safrablau (safranin and Astra blue) (Bukatsch, 1972), and the paradermal sections were stained

with 1% methylene blue (Krauter, 1985). After that, semi-permanent slides containing the histological cuts were prepared, following common procedures in plant anatomy (Johansen, 1940; Sass, 1951). For slide analysis, a light and polarization microscope (Leica DM750M) coupled with a digital camera (Leica ICC50W) was used, where the images were processed using software (LAS EZ).

Histochemical characterization

Histochemical tests were carried out on cross sections of fresh leaf blades, obtained by hand (Johansen, 1940). Then specific reagents (Table 1) were used to locate primary and secondary metabolites in the leaf blade.

Table 1.
Methodology used for histochemical analysis.

METABOLITES	REAGENT	INDICATIVE COLORING	REFERENCE
Alkaloids	Dragendorff	Orange	Sass, 1951
Starch	Lugol	Dark blue / Dark brown	Johansen, 1940
Phenolic compounds	Potassium dichromate (10%)	Reddish-brown	Johansen, 1940
Lipophilic compounds	Sudan III	Reddish-orange	Mace & Howell, 1974
Calcium oxalate or calcium carbonate crystals	Hydrochloric acid 10%	Dissolving the crystals	Jensen, 1962
Lignin	Fluoroglucinol	Red	Johansen, 1940
Protein	Ponceau Xylidine	Red	Vidal, 1970
Mucilages	Tannic Acid 5% / Ferric chloride 3%	Black	Pizzolato & Lillie, 1973
Pectins	Ruthenium red 0.1%	Pink	Johansen, 1940
Tannins	Hydrochloric vanillin	Red	Yoder & Mahlberg, 1976
Triterpenes and steroids	Antimony trichloride	Reddish-orange	Mace et al., 1974

Source: The authors (2025).

Simultaneous controls were carried out alongside the histochemical tests, and semi-permanent slides with cross sections were prepared (Johansen, 1940; Sass, 1951). The slides were analyzed using images captured by a digital camera (Leica ICC50 W) attached to a light optical microscope (Leica DM750M) and processed with software (LAS EZ).

Results and Discussion

Description of external morphology

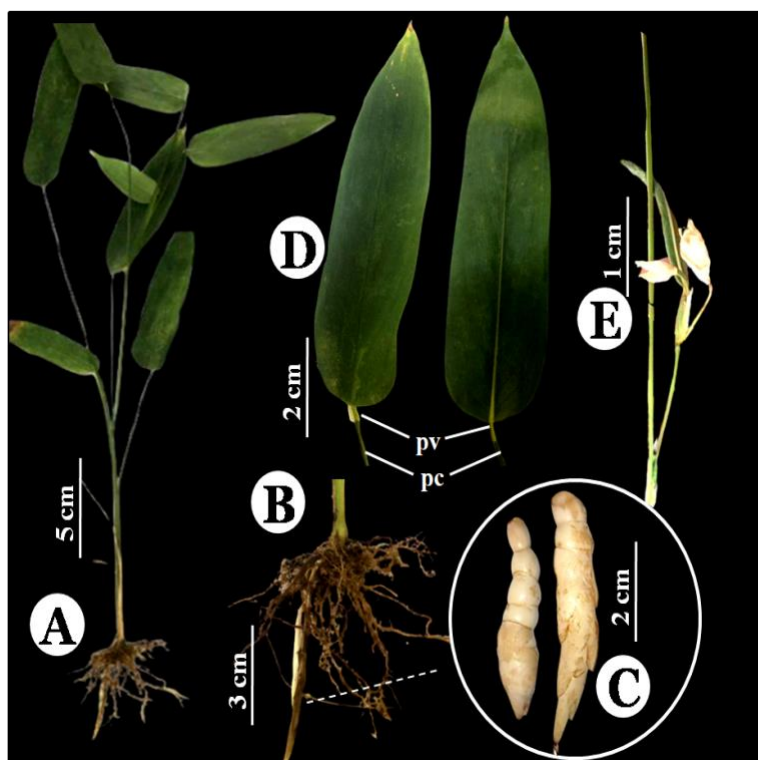
M. arundinacea is a perennial herb, rosette-shaped, unbranched, and rhizomatous (Figure 1A). It has a fasciculate root system, with whitish-yellow to cream roots, 10-30 cm long, fusiform to cylindrical, slightly fibrous, and branched (Figure 1B). The rhizomes are fusiform, white, very fibrous, with short internodes and thin, detachable scales (Figure 1C). The leaves are

alternate, distichous, petiolate, with long sheaths, an oval-lanceolate to lanceolate blade, acuminate, measuring $10-20 \times 5-8$ cm, with parallel venation and a prominent basal pulvinus, which allows nyctinastic movements (Figure 1D). The inflorescences are paniculate, terminal, with small, white flowers, either solitary or grouped, protected by enveloping bracts and with zygomorphic symmetry (Figure 1E).

Among the species of the genus *Maranta*, *Maranta pilosa* (F. Fraga, L. J. T. Cardoso & J. M. A. Braga) shows morphological similarities that can make identification difficult at certain stages of development. However, according to Fraga et al. (2022), this species is distinguished from *M. arundinacea* showing erect to occasionally prostrate growth, with a densely branched aerial stem; filiform root system, without storage accumulation; simple, horizontal, and unbranched rhizomes. The leaves are densely hairy all over, with smaller blades ($3-17 \times 1.6-6$ cm) and a papery texture. The inflorescences, which are axillary and complex, have several levels of branching, larger flowers (15-18 mm), long and hairy bracts, as well as an elaborate floral structure with silky sepals, varied staminodes, and differentiated appendages. These features show clear differences in the species' external morphology.

Figure 1.

External morphology of *Maranta arundinacea* L.



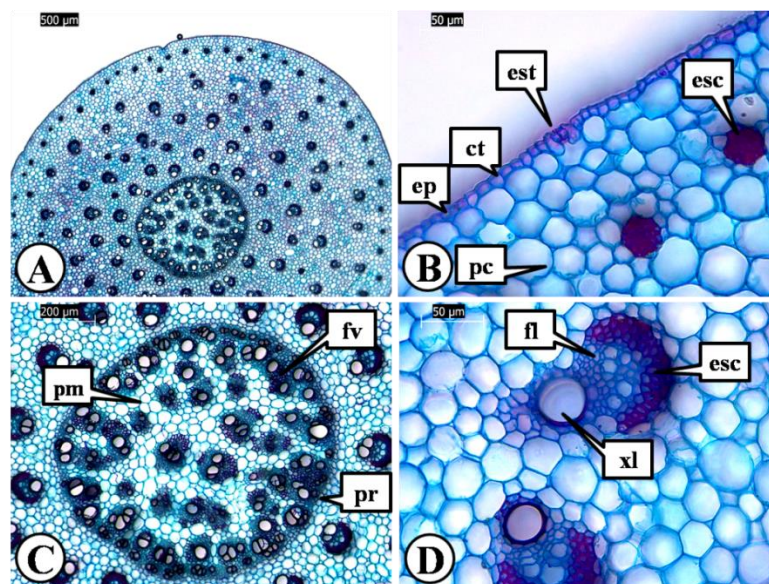
A: general appearance of the species; B: detail of the root; C: detail of the rhizome; D: detail of the leaf; E: details of the inflorescence. pc: petiole; pv: pulvinus. Source: From the authors (2025).

Anatomical characterization

In cross-section, the rhizome of *M. arundinacea* has a cylindrical shape (Figure 2A). A thin cuticle covers the uniseriate epidermis (Figure 2B). After the epidermis, the cortex is observed, made up of cortical parenchyma (Figure 2B). Stomata are seen at the level of the epidermis (Figure 2B). In the cortical region, sclerenchymatic caps surround the entire rhizome near the epidermis (Figure 2B), and sclerenchyma is also observed near the phloem (Figures 2B, 2D). In the central region, the pericycle (Figure 2C) and medullary parenchyma (Figure 2C) are evident. The vascular bundle is classified as collateral, and two forms of distribution are observed: one in the central region after the pericycle (Figure 2C) and another randomly in the cortical region of the rhizome (Figure 2D).

Figure 2.

Cross sections of the rhizome of *Maranta arundinacea* L.



A: General aspect of the rhizome; B-E: Details of the rhizome; ct: cuticle; ep: epidermis; esc: sclerenchyma; est: stomata; fl: phloem; fv: vascular bundle; pc: cortical parenchyma; pm: medullary parenchyma; pr: pericycle; xl: xylem. Source: The authors (2025).

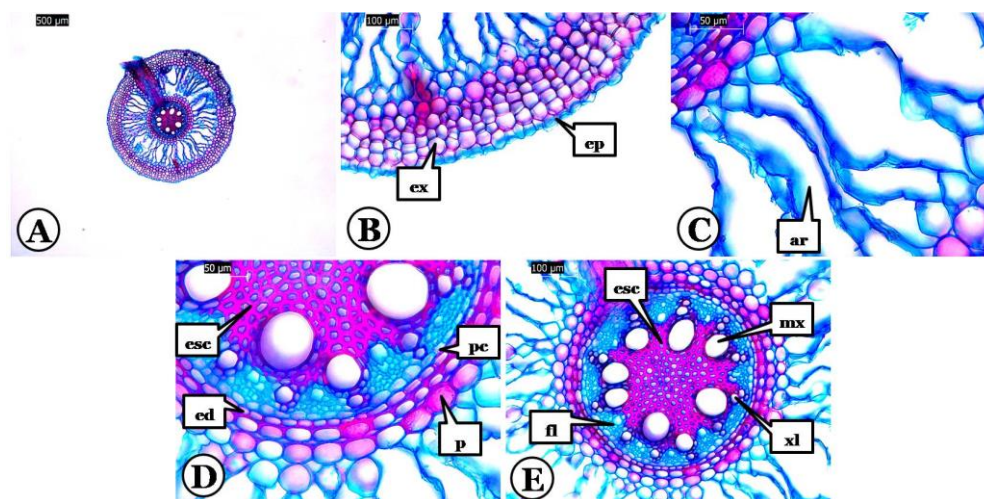
In a cross-section of the root, during secondary growth (Figure 3A), a single-layered epidermis is observed, followed by exodermis with 4-5 layers of suberized cells (Figure 3B). After the exodermis, the cortex is seen, composed of aerenchyma, tangentially delimited by vertical spaces formed by a single layer of cells (Figure 3C), and by inner parenchyma layers with regular cells with U-shaped wall thickenings, similar to endodermis (Figure 3D). The endodermis shows U-shaped cells, followed by the pericycle (Figure 3D). The root is polyarch (Figure 3E) with a collateral-type vascular bundle showing sclerenchyma in the central region (Figures 3D, 3E).

In line with the results obtained in this study, Tomlinson (1961), when describing the anatomy of species in the Marantaceae family, reported recurring features, such as the presence of aerenchyma with a distribution similar to that observed in the present analysis. He also

highlighted the occurrence of inner layers of parenchyma, vascular systems with a polyarch pattern, and, in some cases, metaxylem elements. However, he did not mention the presence of sclerenchyma in the central region of the root.

Figure 3.

Cross sections of the root of *Maranta arundinacea* L.



A: General aspect of the root; B-E: Root details; ar: aerenchyma; ed: endodermis; ep: epidermis; esc: sclerenchyma; ex: exodermis; fl: phloem; mx: metaxylem; p: parenchyma; pc: pericycle; xl: xylem. Source: The authors (2025).

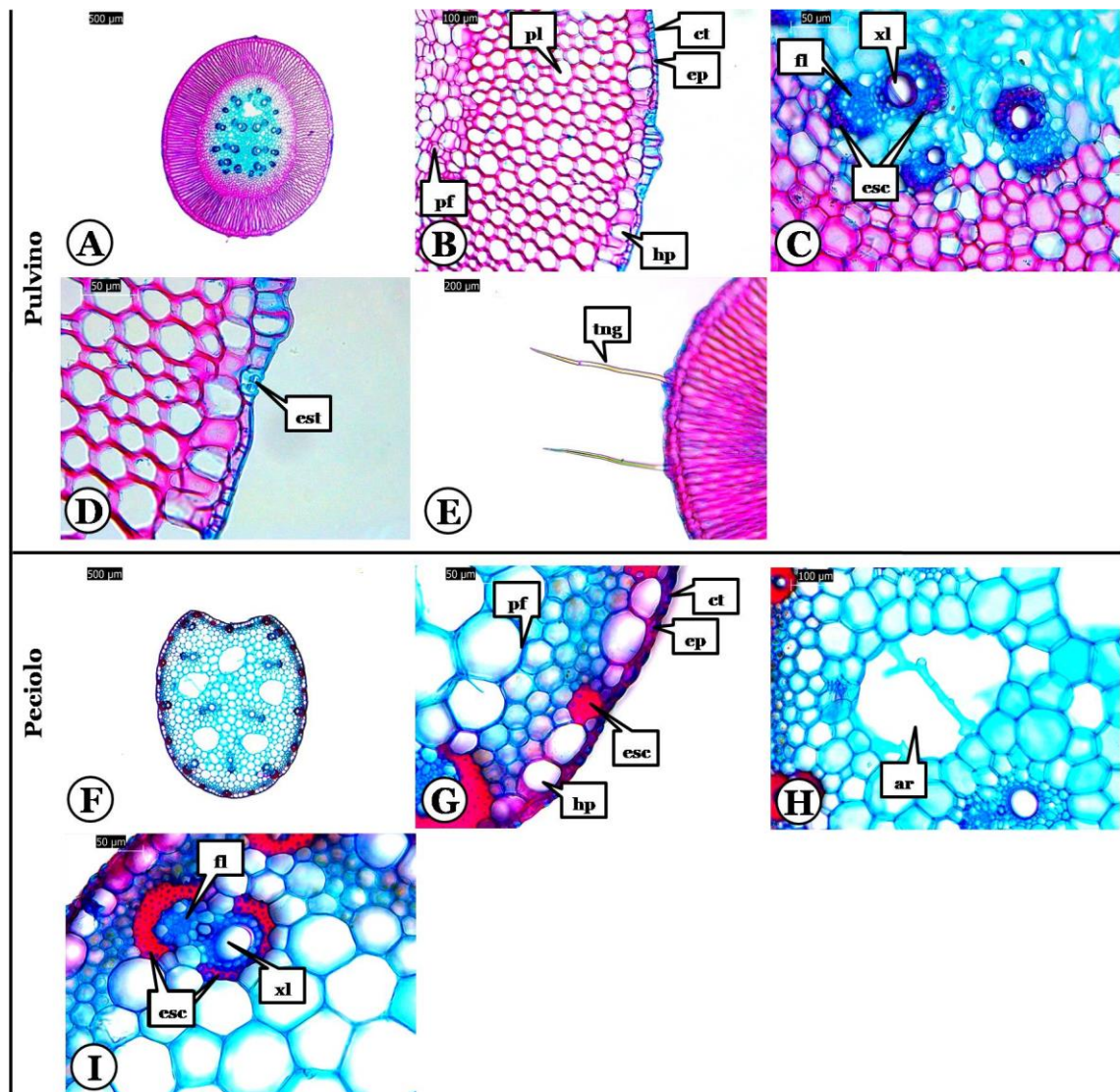
In cross-section, the pulvinus has a cylindrical shape (Figure 4A) and the petiole has a concave-convex shape (Figure 4F). In both leaf structures, a slightly thick cuticle can be seen covering the single-layered epidermis (Figures 4B, 4G). Adjacent to the epidermis, a layer of hypodermis with irregularly sized cells is observed (Figures 4B, 4G).

Unlike the pulvinus, the petiole has sclerenchyma caps that alternate with the hypodermis in a symmetrical way (Figure 4G). After the hypodermis, layers of parenchyma with lignified cells with slightly thickened walls and fundamental parenchyma in the central region of the pulvinus become evident (Figures 4B, 4C). Fundamental parenchyma with smaller cylindrical cells near the hypodermis and larger ones in the central region fills the entire petiole (Figure 4G). Aerenchyma is observed in the petiole (Figure 4H). The vascular bundles, both in the pulvinus and the petiole, are classified as collateral, showing sclerenchyma at the ends near the phloem and xylem (Figures 4C, 4I). In the pulvinus, stomata are observed at the level of the epidermis (Figure 4D), along with non-glandular trichomes (Figure 4E).

Fraga et al. (2022) reported, in *M. pilosissima*, characteristics similar to those observed in this study regarding the epidermis, hypodermis, and vascular bundle. However, the authors identified the presence of trichomes in both the pulvinus and the petiole, as well as a layer of obliquely elongated cells with slight wall thickening in the pulvinus, which differs from the findings presented here. These particularities are important for the anatomical identification and distinction of *M. arundinacea*, constituting a diagnostic feature of the species.

Figure 4.

Cross sections of the pulvinus and petiole of *Maranta arundinacea* L.



A: Overall view of the petiole; B: detail of the petiole tissues; C: detail of the vascular bundle; D-E: detail of the druse-type crystal under light microscopy and polarized light. Abbreviations: co: collenchyma; ct: cuticle; dr: druse; ep: epidermis; fv: vascular bundle; pf: ground parenchyma. Source: The authors (2025). Pulvinus, Petiole [Pulvino. Peciolo]

In paradermal sections, the leaf blade shows epidermal cells with a wavy outline on the adaxial side (Figure 5A) and a straight outline on the abaxial side (Figure 5B). The blade is classified as amphistomatic, with tetracytic stomata on the adaxial side (Figure 5A) and paracytic and anisocytic stomata on the abaxial side (Figure 5B).

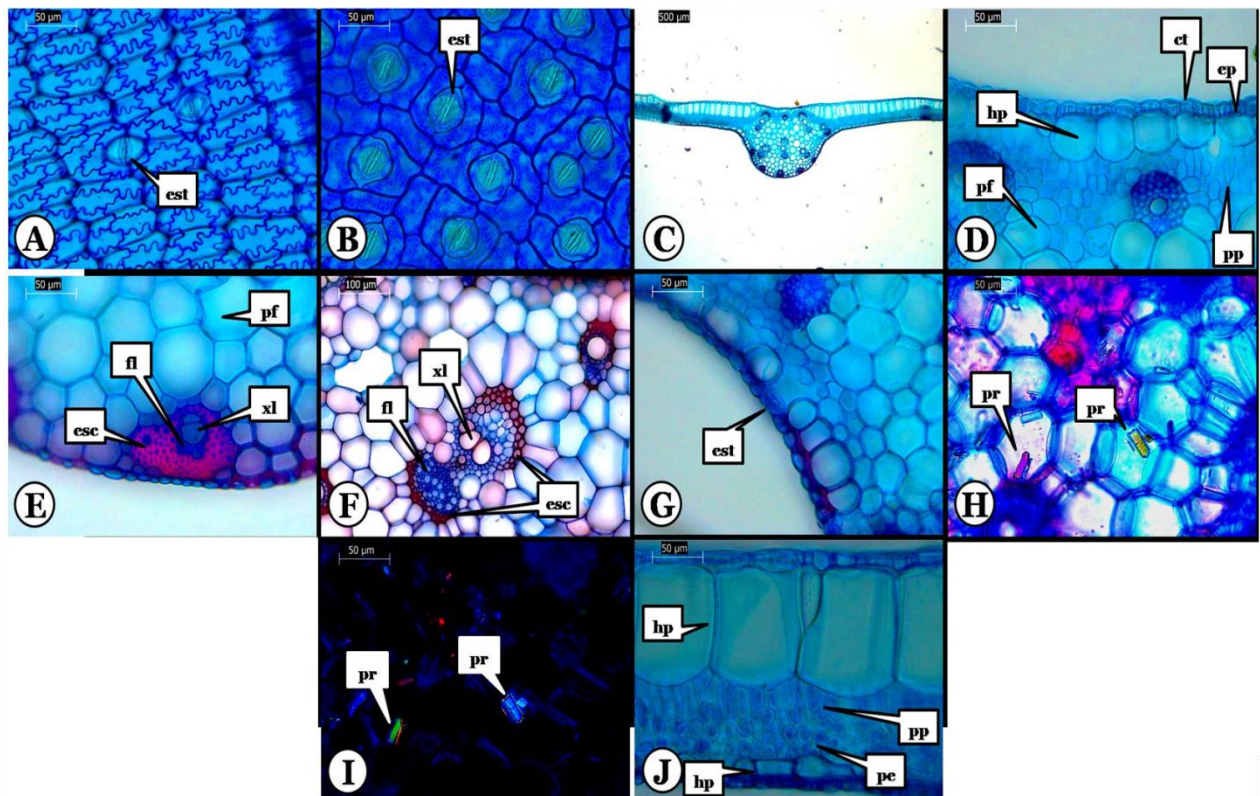
As described by Tomlinson (1961), in the Marantaceae family, stomata are generally absent or infrequent on the adaxial leaf surface, predominating on the abaxial surface, which differs from the pattern observed in the present study. The occurrence of amphistomatic stomata is an unusual feature in the family, possibly linked to physiological adaptations and serving as an important diagnostic trait, as well as highlighting the anatomical variability present in Marantaceae.

In a cross-section of the leaf blade, the central vein shows a flat-convex contour (Figure 5B). A slightly thickened cuticle covering the single-layered epidermis is observed (Figure 5D). Adjacent to the epidermis, a hypodermis with a single layer of cells is seen, followed by palisade parenchyma on the adaxial side (Figure 5D). Ground parenchyma fills the entire central vein (Figures 5D, 5E). The vascular bundle is classified as collateral, with two distribution patterns: One close to the epidermis (Figure 5E) and another randomly in the central region of the vein (Figure 5F). Sclerenchyma is observed at the ends of the vascular bundle (Figures 5E, 5F). Stomata appear at the same height as the epidermis in a cross-section of the leaf blade (Figure 5G). Prismatic crystals are evident in the central vein (Figures 5H, 5I).

The mesophyll is of the dorsiventral type, composed of palisade parenchyma, 1-2 layers of cells, and spongy parenchyma (Figure 5J). In the mesophyll region, the hypodermis is evident on both sides (Figure 5J).

Figure 5.

Cross sections of the leaf blade of *Maranta arundinacea* L.



A: Adaxial side; B: Abaxial side; C: General aspect; B-G: central vein details; H: mesophyll detail. ct: cuticle; dr: druse; ep: epidermis; esc: sclerenchyma; est: stomata; hp: hypodermis; fl: phloem; pe: spongy parenchyma; pf: ground parenchyma; pp: palisade parenchyma; pr: prism; xl: xylem. Source: The authors (2025).

The characteristics of *M. arundinacea* are in line with the general descriptions attributed to the Marantaceae family (Tomlinson, 1961). On the other hand, Fraga et al. (2022), when analyzing *M. pilosissima*, noted distinct traits, such as leaf blades with a concave-convex shape, the presence of unicellular trichomes, collenchyma layers, absence of crystals, and mesophyll

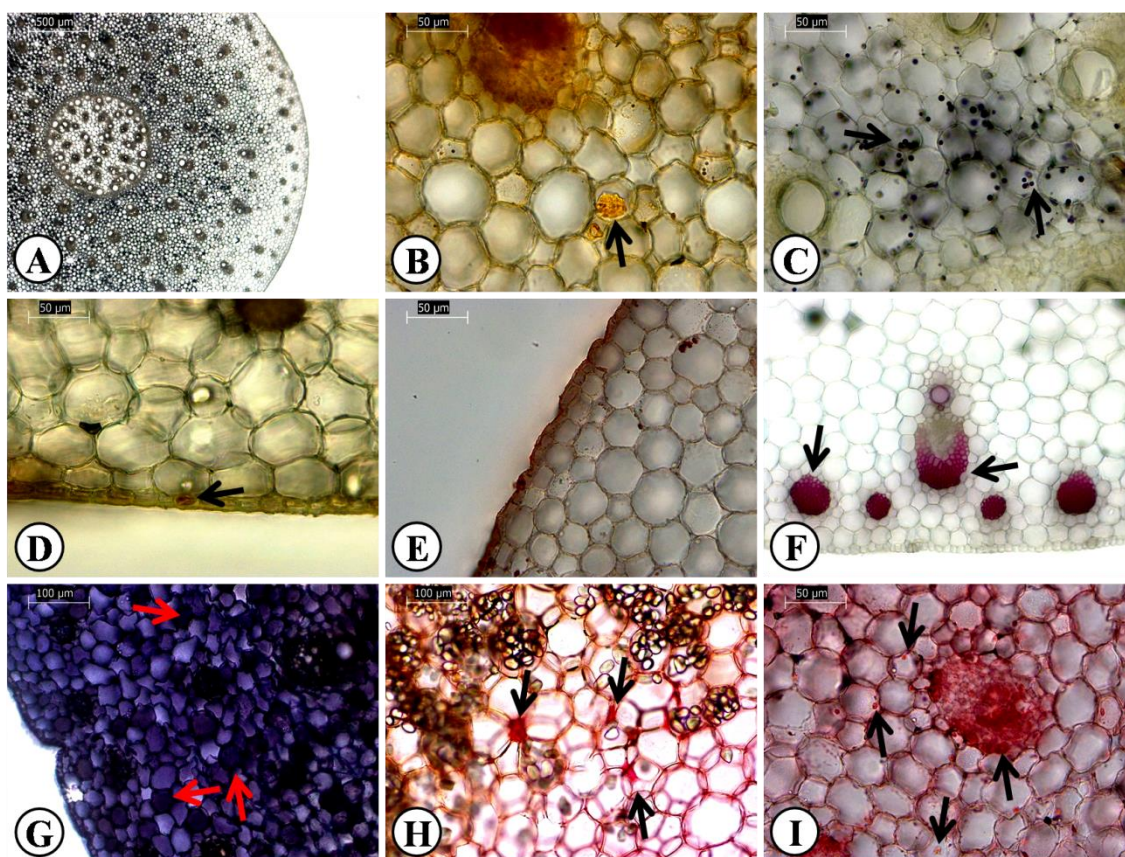
made up of a single layer of short palisade parenchyma, differentiating it from the species investigated in the present study.

Histochemical characterization

Figure 6 shows the results of the histochemical tests, displaying a cross-section of the rhizome without any reagents in Figure 6A. Alkaloids (Figure 6B) and starch (Figure 6C) were observed in the cortical parenchyma cells. Phenolic compounds were localized in the epidermis (Figure 6D). Lipophilic compounds were evident in the cuticle (Figure 6E). Lignin was observed in the xylem (Figure 6F). Mucilages (Figure 6G) and pectins (Figure 6H) were seen in the parenchyma of the cortical region. Proteins were observed in both the vascular bundle region and the cortical parenchyma (Figure 6I). Tests for tannins, triterpenes, and steroids were negative.

Figure 6.

Histochemistry of the rhizome of *Maranta arundinacea* L.



A: Control; B: Dragendorff; C: Lugol; D: Potassium dichromate 10%; E: Sudan III; F: Phloroglucinol; G: Tannic acid 5% / Ferric chloride 3%; H: Ruthenium red; I: Xylidine Ponceau. Source: The authors (2025).

Phytochemical studies with the rhizome of *M. arundinacea* have shown flavonoids, tannins, alkaloids, and terpenoids, which contribute to antioxidant, anti-inflammatory, and antimicrobial properties (Kumalasari et al., 2012; Nishaa et al., 2013). Jayakumar and Suganthi

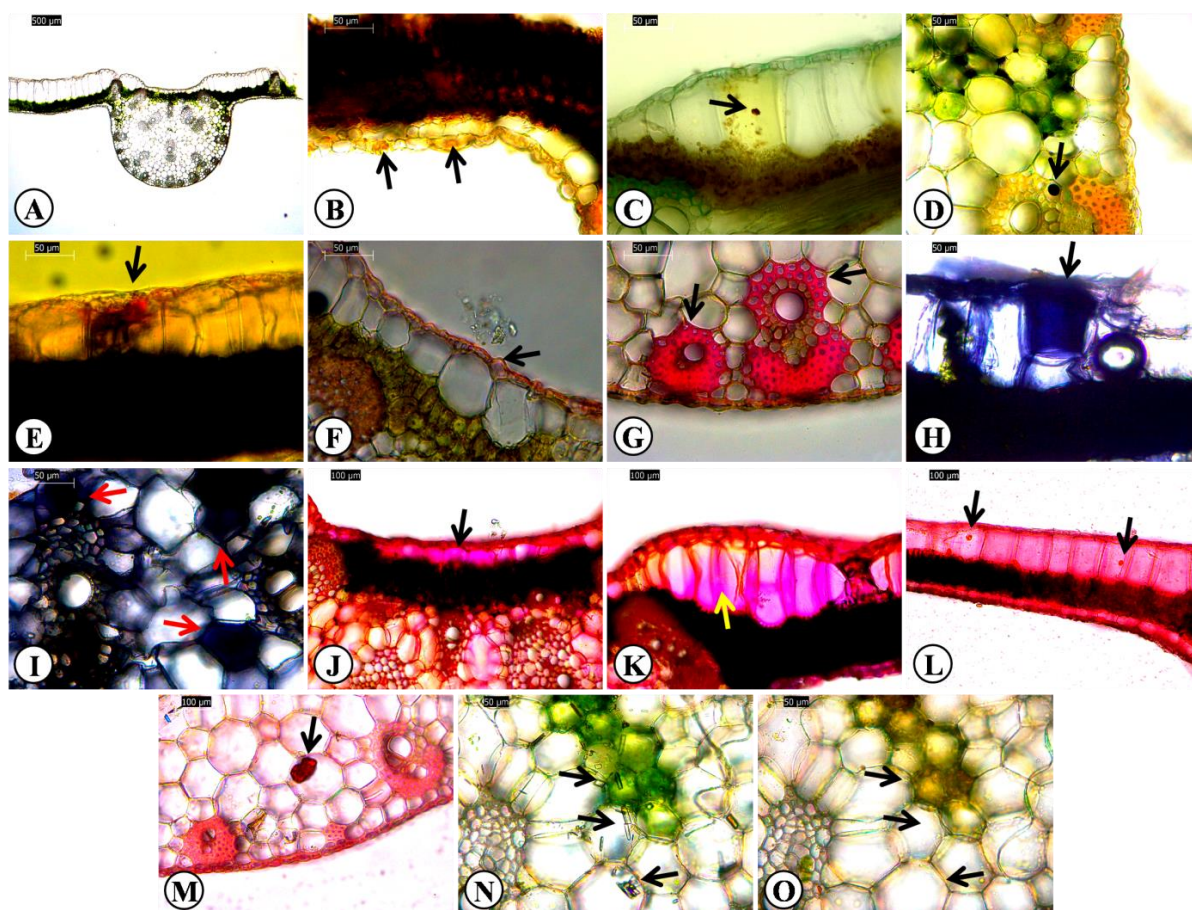
(2017), in a phytochemical analysis of the rhizome, found the presence of alkaloids, glycosides, flavonoids, terpenoids, saponins, and tannins.

Figure 7 shows the results of the histochemical tests, displaying a cross-section of the leaf blade without adding any reagent in Figure 7A. Alkaloids were observed in the epidermis and hypodermis (Figures 7B, 7C). Starch was detected in the parenchyma near the vascular bundle (Figure 7D). Phenolic compounds were histolocalized in the epidermis and hypodermis (Figure 7E). Lipophilic compounds were found in the cuticle (Figure 7F). Lignin was detected in the xylem (Figure 7G).

Mucilage was observed in the hypodermis (Figure 7H) and in the parenchyma (Figure 7I). Pectins were histolocalized in the cell walls of the epidermis and hypodermis (Figures 7J, 7K). In the hypodermis (Figure 7L) and in the ground parenchyma, proteins were observed (Figure 7M). The test with hydrochloric acid (10%) showed that the prismatic crystals are calcium oxalate, after their dissolution (Figures 7N, 7O). Tests for tannins, triterpenes, and steroids were negative.

Figure 7.

Histochemistry of the leaf blade of *Maranta arundinacea* L.



A: Control; B: Phloroglucinol; C-D: 10% Hydrochloric Acid; E-F: Sudan III; G-H: Dragendorff; I: 10% Potassium Dichromate; J: Lugol; K-L: Ruthenium Red; M-N: Xylidine Ponceau; O: 5% Tannic Acid / 3% Ferric Chloride. Source: The authors (2025).

Final Considerations

The integrated characterization of *Maranta arundinacea* L. confirms that the species has morphological, anatomical, and histochemical traits that clearly set it apart from its relatives, while also highlighting its traditional functional value. Outwardly, its pinkish stature, robust starch-rich rhizome, smooth leaves with movable pulvini, and panicle-shaped inflorescence of small white flowers form a diagnostic set that stands in sharp contrast to the hairy habit, branched stem, and filamentous root system of *M. pilosissima*. Internally, it stands out with a poliarc root with central sclerenchyma, a rhizome with peripheral sclerenchymatous caps, a pulvinus and petiole without trichomes, and an amphistomatic leaf blade with prismatic crystals, characteristics which, together, provide strong taxonomic support for the safe identification of the raw material.

Histochemical tests revealed a wide distribution of alkaloids, flavonoids (phenolic compounds), starch, mucilages, pectins, and lipids in the plant tissues, while tannins, triterpenes, and steroids were not detected. The presence of bioactive metabolites in the storage tissues (rhizome) and conduction tissues (leaf blade) may be related to the popular use of arrowroot as a digestive, healing, and anti-inflammatory agent, as well as providing a basis for future phytochemical and pharmacological studies. The co-location of starch and mucilage in the rhizome also supports its culinary use for easily digestible diets.

The information generated lays the groundwork to standardize the production chain, support in-depth phytochemical research, and promote the development of innovative natural products, highlighting the strategic role of *M. arundinacea* in food security, herbal medicine, and the appreciation of Non-Conventional Food Plants.

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Conflict of interest statement

The authors declare that they have no financial, commercial, personal, or academic relationships that could be perceived as influencing the results or interpretation of this manuscript.

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Generative artificial intelligence tools were used solely for linguistic editing, reference standardization, and improvement of textual clarity. The tools were not employed to generate ideas, hypotheses, interpretations, analyses, results, or scientific conclusions. The authors

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