

Anatomical and morphological characterization and other aspects of the plant biology of *Diplopterys pubipetala*: a review

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Veronica, Pedro e Vanessa

<https://orcid.org/0000-0002-5956-1457>

Pedro Henrique Fonseca Veloso

Orcid Profile 0000-0003-2802-1244

Vanessa de Andrade Royo

0000-0002-4842-3569

ABSTRACT: This review aims to compile and synthesize existing research related to the liana *Diplopterys pubipetala* (Malpighiaceae), covering anatomical and morphological characterization, as well as general aspects of floral biology. The goal is to provide a comprehensive and updated overview of this species, offering a theoretical basis for future studies and highlighting the importance of species preservation and the conscious exploitation of its benefits, commonly related to ethnobotanical aspects. Extensive searches were conducted in widely recognized databases such as Google Scholar, SciELO (Scientific Electronic Library Online), and the CAPES Periodicals Portal. The species *D. pubipetala*, formerly known as *Banisteriopsis pubipetala*, is widely distributed throughout Brazil, often found in forests and savannas of the Espinhaço Range and Central Plateau. The leaves of this species are sessile and lack trichomes; the trunk has a twisted rope shape with several lobes and exhibits vascular dimorphism; the petals are yellow, with one of them important for visual adjustment and orientation for pollinators due to its wine-colored streaks; the seeds remain small and dark yellow throughout development, and the fruits are winged and have low density, facilitating dispersal. This review compiles knowledge related to the anatomical, morphological, and floral biology

aspects of *D. pubipetala*, noting common and distinctive characteristics of its botanical family, thus providing a theoretical basis for future studies.

KEYWORDS: *Diplopterys pubipetala*, *Banisteriopsis pubipetala*, anatomy, morphology, floral biology

INTRODUCTION

By understanding the functional traits (morphological, physiological) of plants, it is possible to predict their ecological strategies in response to environmental factors and how they intervene in ecosystem properties. Additionally, knowledge about plants aids in the better utilization of biodiversity and promotes interactions between humans, plants, and the atmosphere that are less environmentally impactful (Perez-Harguindeguy et al., 2016).

Diplopterys pubipetala, belonging to the Malpighiaceae, is widely distributed throughout Brazil, often found in the cerrado region of the Espinhaço Range and Central Plateau. In the northern state of Minas Gerais, it is known colloquially as “marvaquero,” and also referred to as “cipó-preto,” “cipó-de-rego,” or “crista-de-galo” (Gates, 1982), while in the northern region of Brazil, it is called “tucunacá” (Oliveira et al., 2023).

Characterized by its climbing aspect, reaching up to one and a half meters in height, with flowers and fruits commonly developing during the spring (Carvalho et al., 2010; Mamede, 2004; Nagamine-Pinheiro et al., 2021).

It is one of over 1315 species belonging to the Malpighiaceae (Christenhusz and Byng, 2016), consisting of around 40 genera predominantly found in tropical regions of the Americas (Almeida and Mamede, 2014; Davis and Anderson, 2010). Among the most studied genera are *Byrsonima*, *Banisteriopsis*, and *Heteropterys*, notable for the variety of secondary metabolites that prompt searches for bioactive compounds for phytotherapeutic use in conjunction with ethnobotanical knowledge (Abbas et al., 2022; Frias et al., 2012). It's worth mentioning the difficulty in distinguishing between species, for which anatomical characteristics of vegetative organs, as well as morphological and taxonomic aspects, are considered (Almeida et al., 2016; Araújo et al., 2010).

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Diplopterys and *Banisteriopsis* are sister genera, given the similarity of floral structure (Gates, 1982), along with molecular data analysis (Anderson and Davis, 2006). For this review, it's important to note that some studies still used the denomination *Banisteriopsis pubipetala*.

In conducting this review, the aim was to compile and synthesize existing research related to *D. pubipetala*, covering anatomical characterization, morphological features and general aspects of floral biology. We also intended to provide a comprehensive and updated overview of this species, offering a theoretical basis for future studies and highlighting the importance of preserving the species and consciously exploiting its benefits, often linked to ethnobotanical aspects.

METHODOLOGY

To investigate the biology of *Diplopterys pubipetala*, searches were conducted using the databases Google Scholar, SciELO (Scientific Electronic Library Online), and CAPES Periodicals Portal, ensuring comprehensive coverage and relevance of the consulted journals. The review included original articles, reviews, bulletins, and technical reports, focusing on the anatomy, morphology of leaves, seeds, and flowers, and reproductive aspects of the species. Taxonomic studies were excluded. The search terms and combinations used were: "*Diplopterys pubipetala*," "*Banisteriopsis pubipetala*," "anatomy," "morphology," "leaf," "stem," "seed," "flower," "floral biology," "reproduction," "glands," "pollen," "reproductive aspects," "Malpighiaceae," and "botany." Relevant data were extracted, organized, and synthesized to provide a comprehensive overview of *D. pubipetala*, highlighting its similarities and differences with other species in the Malpighiaceae family.

LEAF ANATOMY

Among the anatomical characteristics of *D. pubipetala* leaves, it is observed that the epidermis is single-layered on both sides, with characteristic dorsiventral and a peciolar vascular system organized into four accessory bundles. There is an absence of trichomes, and a pair of glands are present on the sessile leaves, with a camptodromous-brochidodromous venation pattern (Araújo et al., 2010; Possobom

et al., 2010; Vilarinho et al., 2023). The arrangement of secretory epidermal cells resembles the palisade layer, with a thicker periclinal wall and thinner anticlinal walls. The cuticle consists of two layers, with the outer layer being thin and homogeneous, and the inner layer thicker and reticulated (Possobom et al., 2010).

The study conducted by Câmara et al. (2020) identified the brochidodromous venation pattern in *Camarea* species (Malpighiaceae). Concerning the leaf cuticle, it was observed to be thin, and the epidermal cells may be either bi-layered (continuously or discontinuously) or uni-layered.

In *D. pubipetala*, when leaf glands are in pre-secretory stages, the development of gaps in the subcuticular space is noted, where secretion accumulates. The degradation of this cuticle reflects in the secretion of the nectaries, which can be granulocrine or eccrine. This secretion predominantly occurs in young leaves during the peak of flowering and early fruiting between the months of August and September (Possobom et al., 2010).

In other Malpighiaceae belonging to the Cerrado in the Southeast region of Brazil, such as *Heteropteris acutifolia* Juss., *Heteropteris byrsonimifolia* Juss., *Banisteriopsis stellaris* Juss., *Banisteriopsis campestris* Juss., and *Peixotoa reticulata* Juss., nectar is stored in the subcuticular space before release. Such nectaries are discoid, with a raised morphotype, sessile or with a short peduncle, located on the petiole and on the abaxial surface of the leaf, as observed through scanning electron microscopy. These observations are complemented by the possibility of nectar release through pores identified in the cuticle (Machado et al., 2008) and ants were the main visitors to extrafloral nectaries of the investigated plants.

The larger and more vascularized leaf glands in *D. pubipetala*, located at the apex and base of the blade, secrete more abundantly than the tiny glands belonging to the blade margin, which can be as effective and morphologically complex as the large glands. It is precisely in these glands that the highest ant activity is found (Possobom et al., 2010).

ANATOMY OF THE STEM/WOOD

D. pubipetala possesses stems that coil around a host, resembling a twisted rope, with many lobes exhibiting a braided appearance. The inner bark has a dark yellow color (Oliveira et al., 2023). The stem features distinct marginal lines marking well-defined growth rings, highlighted by fibers of latewood with flattened and robust walls and non-lignified marginal bands. The presence of paired prismatic crystals in cells is directly related to the anatomical aspects of Malpighiaceae, characterized by the abundant presence of crystals in the axial parenchyma, which are associated

with defense mechanisms against herbivory (Oliveira et al., 2023; Nagamine-Pinheiro et al., 2021; Silva et al., 2021).

In a study related to three species of *Stigmaphyllon* (Malpighiaceae), gelatinous fibers were found grouped in the xylem of *S. auriculatum*, sparsely in *S. ciliatum*, and scarcely in *S. paralias*, while extraxylary fibers were reported only for *S. auriculatum* and *S. ciliatum*. Druses were found in the phloem and cortex, and rarely were crystals observed in the axial and radial regions of the xylem of these mentioned species (Guimarães et al., 2016).

Other qualitative and quantitative anatomical characteristics of this species, in conjunction with the Malpighiaceae family, include: simple perforation plates, narrow vessels in a radial pattern, bordered pits, septate fibers, high heterocellular mixed rays and perforated ray cells, alternate, circular, and ornamented vessel pits; the pits between ray and vessel are similar in shape and size to the pits between vessels; few tyloses (Nagamine-Pinheiro et al., 2021; Oliveira et al., 2023), many of these characteristics were also described by Amorin et al. (2017) for the *Heteropterys serrata* and *H. nitida*.

This facilitates the understanding of evolutionary adaptations and diversity patterns, revealing specific environmental adaptations such as herbivory defense strategies, and identifying evolutionary patterns that indicate phylogenetic relationships between species.

Common *Banisteriopsis*, the climbing growth habit of *D. pubipetala* confers a lianescent vascular syndrome, which attributes few fibers (mostly gelatinous) to the liana, benefiting in the conduction and flexibility of the vines for climbing. The soft and rigid tissues (vascular dimorphism) ensure the plant's water security and act in wound regeneration, as the non-lignified parenchyma is prone to division and redifferentiation in cambial variants (Nagamine-Pinheiro et al., 2021; Quintanar-Castillo and Pace, 2022).

Such vascular dimorphism, presence of gelatinous fibers, and abundance of large prismatic crystals in the axial parenchyma are also described for *Heteropterys* in the research by Amorin et al. (2017).

FLORAL BIOLOGY

The flowers of *D. pubipetala* are hermaphroditic with dehiscent anthers that release white pollen grains. They exhibit bilateral symmetry and have a longevity of two days, emitting a sweet fragrance and displaying a yellow color. The glands on the fringed edges are more numerous and developed on the posterior petal, especially at the basal portion of the limb, compared to the lateral petals. Sepals are

opposite the posterior petal commonly lack glands (Carvalho et al., 2010; Possobom et al., 2015).

The floral longevity in *Malpighia emarginata* DC. (Malpighiaceae) is approximately 32 hours. The bright pink flowers persist until fading to white, progressing to non-receptivity of the stigmas and subsequent loss of fruit-forming ability (Oliveira et al., 2015). Even shorter is the 24-hour period corresponding to the darkening and shedding of anthers and petals, and the drying of the oil glands in the flowers of *Byrsonima crassifolia* (Pereira and Freitas, 2002).

Although in Malpighiaceae, such as *Banisteriopsis campestris*, *Banisteriopsis malifolia*, and *Peixotoa tomentosa*, oils are the primary floral resources, which may consist of substances that support larval survival or have repellent properties for hive construction, pollen is also a significant reward for visiting bees as it is rich in proteins and nutrients (Barônio et al., 2017).

The visit of bees follows a precise orientation adjustment as they use the posterior petal with vinous streaks as a visual guide, enabling exact landing (Carvalho et al., 2010; Possobom et al., 2015).

MORPHOANATOMY OF THE SEEDS

During the development phase, the seed has specific characteristics, being subcampylotropous, with a broad chalaza and indistinct raphe from the beginning. The chalaza expands to form the region known as the pachychalaza, which can encompass half of the seed. Throughout all development stages, *D. pubipetala* seeds maintain a small size and dark yellow color. The increase in volume at the beginning of development is attributed to the cell divisions of the nucellus in various planes and also to cell vacuolization. The integuments, which are the outer layers of the seed, do not change in number; the seed accommodates growth as scattered anticlinal divisions occur, associated with the increase in cell volume due to vacuolization. The fusion of the integuments allows for the formation of unitegmic seeds (Souto and Oliveira, 2008).

The characteristics observed for *D. pubipetala* seeds also occur in other Malpighiaceae: *Janusia mediterranea*, *Janusia occhionii*, *Mascagnia cordifolia*, and *Tetrapterys chamaecerasifolia*, with the difference that only one integument is present in species of the *Janusia* (Souto and Oliveira, 2014). The study also found that *M. cordifolia* and *T. chamaecerasifolia* have an indistinct internal epidermis from the mesophyll. In *D. pubipetala*, the cells composing the mesophyll are longitudinal, vacuolated, with prominent nuclei and thin walls (Souto and Oliveira, 2008).

Throughout all development stages, *D. pubipetala* seeds are small and dark yellow with pachychalaza. The mature, exalbuminous seed has an embryo that fills the entire seed cavity. The embryonic axis is straight and short, with two large, fleshy, planar-convex, and approximately symmetrical cotyledons, which are well-developed (Coutinho and Silva, 2016; Souto and Oliveira, 2008). The seeds are rounded and enclosed in thick fruits, either samaroid or nut-like, highly lignified, with a vinous red color, ranging from silky to glabrous with dorsal wings (Carvalho et al., 2010; Souto and Oliveira, 2008). During maturation, the samaroids remain united; eventually, they are dispersed by wind, but many remain on the ground near the parent plant (Coutinho and Silva, 2016). The anemochorous dispersal and other seed development characteristics of *D. pubipetala* resemble those of *B. campestris* (Adr. Jussieu) E.L. Little, *Banisteriopsis oxyclada* (Adr. Jussieu) B. Gates, and *Banisteriopsis stellaris* (Grisebach.) B. Gates (Souto and Oliveira, 2008).

MORPHOLOGY OF THE LEAVES

The leaves of *D. pubipetala* are characterized as simple, opposite, petiolate with marginal attachment, and glandular. The cross-section of the petiole has a concavo-convex aspect, and the leaf blade is large, elliptical, and symmetrical, with an entire margin, flat or slightly revolute, and pinnate venation (Carvalho et al., 2010; Nagamine-Pinheiro et al., 2021; Possobom et al., 2010; Vilarinho et al., 2023).

The apex lacks color, and the central vein is prominent on both sides at acute and obtuse angles, with an acuminate and drip-tipped shape. The leaf base is convex to rounded with acute and obtuse angles. The glands are positioned with abaxial marginal attachment. The indumentum (adaxial and abaxial) is glabrous (Carvalho et al., 2010; Nagamine-Pinheiro et al., 2021; Vilarinho et al., 2023). They can be distinguished from other *Banisteriopsis* leaves by the thickness between the adaxial and abaxial walls, cuticle layers, and the adaxial epidermis with straight anticlinal walls (Nagamine-Pinheiro et al., 2021).

Corroborating investigations related to the foliar characterization of Malpighiaceae, it has been found that species of *Camarea* St. Hill analyzed by Câmara et al. (2020) possess pedicellate glands with a concave surface on the leaf blade (*C. axillaris*, *C. affinis*, *C. ericoides*, *C. hirsuta*, *C. sericea*). The petiole contour is planar-convex in just *C. elongata*. In these species, the petiole region also has a thin cuticle and unistratified epidermis with elevated cells.

The petiole contour of Malpighiaceae species holds significance concerning taxonomic units. Previously, only the planar-convex and concavo-convex contours were known (Araújo et al., 2010). In recent research, Araújo et al. (2020), when verifying the taxonomic relevance of leaf anatomy in *Banisteriopsis* and other

Malpighiaceae genera, characterized the petiole contour of *Stigmaphyllon cavernulosum* as concave-convex and found a planar-convex contour for *D. lutea*, *D. valvata*, and *P. tomentosa*. Additionally, in this same study of 42 *Banisteriopsis* species, a third unexpected contour type was observed: circular, only in *B. acerosa* and *B. scutellata*.

Young leaves of *D. pubipetalata* are reddish except for the apical region, which can be greenish or yellowish, and have non-secretory trichomes on the adaxial and abaxial surfaces. The size of adult leaves can reach up to 10.2 cm in length and 5.8 cm in width, with a characteristic dark green or black color, glabrous, chartaceous, and with dry aspect. These leaves, as well as those aging, predominate during the period of mature fruit dispersal and the beginning of the rainy season (Possobom et al., 2010; Vilarinho et al., 2023).

LEAF GLANDS

The quantity and size of leaf glands vary depending on their location (apex, base, or margin). Those located at the apex and base are oval to circular, larger, and densely vascularized; whereas the glands distributed along the margins appear as small spots, compensated by their abundance (Nagamine-Pinheiro et al., 2021; Possobom et al., 2010). Scanning electron microscopy revealed that the cuticle is smooth, without pores, and the basal region of each gland is surrounded by T-shaped Malpighian trichomes (Possobom et al., 2010). For *C. sericea* and *C. hirsuta*, the morphology of the trichomes was also described as Malpighiaceae, but in T and V shapes (Câmara et al., 2020).

In the study by Araújo and Meira (2016), the foliar glands of *Banisteriopsis* were quite compatible with the species in this review. Most analyzed species have a thin cuticle adhered to the uniseriate palisade epidermis that covers the secretory glands, which have a smooth surface without invaginations. The vascular supply is provided by the presence of phloem and xylem through accessory bundles or secondary lateral veins.

FLORAL GLANDS

The glandular tissue of the calyx is characterized by lipophilic droplets present in the elaiophores, while the glandular tissue of the corolla complements this lipophilic nature with substances responsible for chemical attraction found in the osmophores. The glandular tissue of the androecium contains cells involved in the production and release of pollen grains. For this tissue, the proposed functions are: pollen mimicry (visual attraction), presence of osmophores (chemical attraction),

and secretion of mucilage, which possibly ensures moisture and adhesion of pollen grains to the pollinator (Possobom et al., 2015).

POLLEN MORPHOLOGY

Based on the analysis of photomicrographs, the pollen grains of *D. pubipetala* are apolar and of medium size, circular with 7 pores having short colpi without asperities. The diameter is considered intermediate when compared to *Banisteriopsis*, *Byrsonima* and other genera. Near the colpi, the exine is rugulate with psilate areas. The nexine is thicker than the sexine. Psilate areas on the pollen grains are present in the exine ornamentation near the apertures and small granules within the colpi (Belonise Gasparino, 2015).

PERICARP MORPHOLOGY

D. pubipetala exhibits disparities in the structure and development of the pericarp compared to *B. campestris*, *B. oxyclada*, and *B. stellaris* (with schizocarpic fruits). Specifically, it has a thinner and more aerenchymatous internal endocarp, possessing six ventral bundles that merge into three apical ones at the base of the ovary. Another distinguishing feature is the peculiar vascularization of the carpels. The intense proliferation of the endocarp leads to collapse in the mature pericarp and is of great importance in seed development. The winged fruits of *D. pubipetala* have low density because the tissue contains intercellular spaces filled with air, which does not add significant weight.

REPRODUCTIVE SYSTEM

In the study on pollen viability conducted by Possobom et al. (2016) involving 12 individuals of *D. pubipetala*, it was observed that the peak of flowering occurred at the end of the dry season (August and September), with the dispersal of mature fruits at the beginning of the rainy season (November). The average percentage of viable pollen grains per flower to be $93.5 \pm 6.8\%$, with dehiscent anthers observed in all individuals. However, in the study by Sigrist and Sáizima (2004), pollen viability was much lower (22%), and the anthers were indehiscent, a possible characteristic related to agamospermy, a fact that occurred in only one individual in the aforementioned investigation.

Pollen viabilities exceeding 90% were found in *Byrsonima sericea* and *Banisteriopsis caapi* (Teixeira and Machado, 2000). In another study, the average percentage of pollen viability for cultivated specimens of *B. caapi* was 97.60%, and

approximately 85.25% for native individuals, both considered high values (Carvalho et al., 2023).

Furthermore, in the study by Carvalho et al. (2023), the variation in values was attributed to seasonal and water-related factors, as well as anthropogenic action, since uncultivated individuals, like specimens of *D. pubipetala*, are found in disturbed areas such as forest fragment edges and roadside verges, which facilitate the occupation of these environments and enable the dissemination of locally adapted genotypes through agamospermy, while also allowing genetic recombination through sexual reproduction.

Possobom, Machado, and Guimarães (2016) found that *D. pubipetala* had the highest fruiting rate with cross-pollination, with flowers visited by bees of the *Monoeca* species showing a fruit quantity increase up to five times compared to the control, indicating high efficiency. Siqueira et al. (2011), using a variety of acerola trees (*M. emarginata*), cited allogamy as the most significant form to promote an increase in the fruiting rate of that species. For muricis (*Byrsonima crassifolia*), cross-pollination maximizes the productive potential, causing increases in yield of up to 157% (Pereira and Freitas, 2002).

PRESERVATION AND ETHNOBOTANICAL KNOWLEDGE

Recognizing that the Malpighiaceae is widely distributed in the Cerrado biome, which exhibits varied extension, structural complexity, and biodiversity, it is necessary to promote the understanding and identification of the species present there (Conceição et al., 2011). This is due to the significant economic potential of native Cerrado species, which can serve as sources of food, medicine, timber, ornamental plants, and artisanal products, offering viable alternatives for local use and income generation. Additionally, these species present considerable environmental and social ethnobotanical benefits (Santos et al., 2020; Weichert et al., 2024).

In this context, where the Cerrado biome stands out for its richness in natural resources, focusing on plant species with therapeutic potential (Barbosa et al., 2023), *D. pubipetala* stands out in terms of its ethnobotanical potential. Studies related to its chemical composition have revealed relevant classes of bioactive compounds (Sacramento et al., 2020), with emphasis on the presence of β -carbonyl alkaloids (Santos et al., 2020), which are components of Ayahuasca tea. This hallucinogenic beverage was originally elaborated and consumed by indigenous peoples of the Amazon region in shamanic rituals (McKenna, 2004), but has gained popularity in recent decades. The consumption of the beverage is associated with mystical experiences and spiritual encounters, promoting healing properties used to treat spiritual, physical, and psychological diseases (Ruffell et al., 2020).

Currently, there is growing scientific interest in the potential of this tea, which has been investigated for the treatment of neurodegenerative diseases, depression, anxiety, post-traumatic stress disorders, eating disorders, and addiction disorders, leading to significant improvements in mental health conditions and personality traits (McKenna, 2004; Perkins et al., 2023; Sheth et al., 2024).

It is well established that the Cerrado biome, home to *D. pubipetala*—a species analogous to *B. caapi*, from which leaves and stems are harvested for the preparation of Ayahuasca tea—stands as one of the most endangered Brazilian biomes due to extensive anthropogenic impacts. According to Klink and Machado (2005), approximately 50% of its native area has been lost due to agricultural expansion or pasture areas. Therefore, studies related to the encouragement of proper use and management are necessary to help valorize resources, combat predatory harvesting, and ensure the protection and preservation of valuable species in this biome (Weichert et al., 2024). Additionally, investment in research and sustainable development of this and other species will provide benefits to the environment and local communities, promoting sustainable and integrated development.

FINAL CONSIDERATIONS

The research addressed in this review encompasses botanical, morphoanatomical, and reproductive aspects of *Diplopterys pubipetala*, covering various parts of the plant such as leaves, stems, flowers, and seeds. This study is notable for its novel synthesis of existing knowledge, providing a comprehensive overview that facilitates the identification of new starting points for future investigations focused on anatomy, morphology, reproductive biology, and, particularly, the conservation and biodiversity of the species. Furthermore, the review highlights the importance of exploring potential attributes related to secondary metabolism, as observed in other species within the Malpighiaceae family, offering a solid foundation for studies aimed at ethnobotanical applications and conservation strategies. Thus, this work significantly contributes to advancing the understanding of *D. pubipetala*, while underscoring the need for conscious and sustainable exploration of its resources.

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REFERENCES

- Abbas, H. A., Tadros, S. H., El-Toumy, S. A., Salama, A. M., & El Gedaily, R. A. ://doi.org/10.21608/ejchem.2022.119510.5372.
- Almeida, R. F., Francener, A., & Amorim, A. M. (2016). A generic synopsis of Malpighiaceae in the Atlantic Forest. *Nordic Journal of Botany*, 34, 285–301. <https://doi.org/10.1111/njb.01016>.
- Almeida, R. F., & Mamede, M. C. H. (2014). Checklist, conservation status, and sampling effort analysis of Malpighiaceae in Espírito Santo State, Brazil. *Brazilian Journal of Botany*, 37, 329–337. <https://doi.org/10.1007/s40415-014-0078-x>.
- Amorim, A. M., Marinho, L. C., Pessoa, C., & Pace, M. R. (2017). A new Heteropterys (Malpighiaceae) from semideciduous forest, with notes on wood anatomy. *Plant Systematics and Evolution*, 303, 177–185. <https://doi.org/10.1007/s00606-016-1360-0>.
- Anderson, W. R., & Davis, C. C. (2006). Expansion of Diplopterys at the expense of Banisteriopsis (Malpighiaceae). *Harvard Papers in Botany*, 11, 1-16. [https://doi.org/10.3100/1043-4534\(2006\)95](https://doi.org/10.3100/1043-4534(2006)95).
- Araújo, J. S., Azevedo, A. A., Silva, L. C., & Meira, R. M. S. A. (2010). Anatomia foliar como ferramenta adicional de taxonomia para 16 espécies de Malpighiaceae encontradas na região do Cerrado (Brasil). *Plant Systematics and Evolution*, 286, 117–131. <https://doi.org/10.1007/s00606-010-0268-3>.
- Araújo, J. S., & Meira, R. M. S. A. (2016). Comparative anatomy of calyx and foliar glands of Banisteriopsis C. B. Rob. (Malpighiaceae). *Acta Botanica Brasilica*, 30, 112-123. <https://doi.org/10.1590/0102-33062015abb0248>.
- Barônio, G. J., Haleem, M. A., Marsaioli, A. J., & Torezan-Silingardi, H. M. (2017). Characterization of Malpighiaceae flower-visitor interactions in a Brazilian savannah: How do floral resources and visitor abundance change over time. *Flora*, 234, 126-134. <https://doi.org/10.1016/j.flora.2017.07.015>.
- Belonsi, T. K., & Gasparino, E. C. (2015). Pollen morphology of Malpighiaceae from Brazilian forest fragments. *Brazilian Journal of Botany*, 38, 379–393. <https://doi.org/10.1007/s40415-015-0134-1>.
- Câmara, A. R. M., Vilarinho, M. P., & Araújo, J. S. (2020). Leaf anatomy as a subsidy to the taxonomy of the genus *Camarea* St.-Hil (Malpighiaceae). *Research, Society and Development*, 9, e1739108525. <https://doi.org/10.33448/rsd-v9i10.8525>.

Carvalho, A. B., Silva, C. J., Zortéa, K. É. M., Fernandes, J. M., Alves, A. O., Corrêa, M. A., & Rossi, A. A. (2023). Morfologia floral e política e aspectos reprodutivos de *Banisteriopsis caapi* (Spruce ex Griseb.) CV Morton nativos e cultivados no Município de Alta Floresta, Mato Grosso. *Delos: Desarrollo Local Sostenível*, 16, 1632-1655. <https://doi.org/10.55905/rdelosv16.n45-010>.

Carvalho, P. D., Rapini, A., & Conceição, A. A. (2010). Flora da Bahia: Malpighiaceae - *Banisteriopsis*, *Bronwenia* e *Diplopterys*. *Sitentibus Série Ciências Biológicas*, 10, 159-191. <https://doi.org/10.13102/scb7958>.

Christenhusz, M. J. M., & Byng, J. W. (2016). The number of known plant species in the world and its annual increase. *Phytotaxa*, 261, 201. <https://doi.org/10.11646/phytotaxa.261.3.1>.

Conceição, G. M., Ruggieri, A. C., & Rodrigues, M. S. (2011). Malpighiaceae do cerrado do Parque Estadual do Mirador, Maranhão, Brasil. *Scientia Plena*, 7, 1-7. Disponível em: www.scientiaplena.org.br.

Coutinho, D. J. G., & Silva, S. I. (2016). Morphology of fruits, seeds and seedlings, and germination of two species of Malpighiaceae occurring in caatinga Buíque (PE-Brazil). *Natureza Online*, 15, 78-87.

Davis, C. C., & Anderson, W. R. (2010). A complete generic phylogeny of Malpighiaceae inferred from nucleotide sequence data and morphology. *American Journal of Botany*, 97, 2031-2048. <https://doi.org/10.3732/ajb.1000146>.

Frias, U. A., Mendes-Costa, M. C., Takahashi, J. A., & Oki, Y. (2012). *Banisteriopsis* species: A source of bioactive potential medical application. *International Journal of Biotechnology and Wellness Industry*, 1, 163-171.

Gates, B. (1982). *Banisteriopsis*, *Diplopterys* (Malpighiaceae). *Flora Neotropica*, 30, 1-237.

Guimarães, A. L. A., Costa, R. P. C., Cabral, L. M., & Vieira, A. C. M. (2016). Comparative anatomy and chemical analysis of the vegetative organs of three species of *Stigmaphyllon* (Malpighiaceae). *Flora*, 224, 30-41. <https://doi.org/10.1016/j.flora.2016.07.001>.

Klink, C. A., & Machado, R. B. (2005). Conservation of the Brazilian Cerrado. *Conservation Biology*, 19, 707-713. <https://doi.org/10.1111/j.1523-1739.2005.00702.x>.

Machado, S. R., Morellato, L. P., Sajo, M. G., & Oliveira, P. S. (2008). Morphological patterns of extrafloral nectaries in woody plant species of the Brazilian cerrado. *Plant Biology*, 10, 660-673. <https://doi.org/10.1111/j.1438-8677.2008.00068.x>.

Mamede, M. C. H. (2004). Flora de Grão-mogol, Minas Gerais: Malpighiaceae. *Boletim de Botânica Da Universidade de São Paulo*, 22, 291–302. <http://www.jstor.org/stable/42871651>.

McKenna, D. J. (2004). Clinical investigations of the therapeutic potential of ayahuasca: Rationale and regulatory challenges. *Pharmacology & Therapeutics*, 102, 111–129. <https://doi.org/10.1016/j.pharmthera.2004.03.002>.

Nagamine-Pinheiro, N., Fagg, C. W., Gomes, S. M., Oliveira, R. C., & Sonsin-Oliveira, J. (2021). Vegetative anatomy, morphology and histochemistry of three species of Malpighiaceae used in analogues of the Amazonian psychoactive beverage ayahuasca. *Flora*, 275, 151760. <https://doi.org/10.1016/j.flora.2020.151760>.

Oliveira, J. E. M., Nicodemo, D., & Oliveira, F. F. (2015). Contribuição da polinização entomófila para a produção de frutos de aceroleira. *Pesquisa Agropecuária Tropical*, 45, 56–65. <https://doi.org/10.1590/1983-40632015v4529199>.

Oliveira, R. C., Behrens, C. S. B., Nagamine-Pinheiro, N., Fagg, C. W., Silva, M. S., Martins-Silva, T., & Sonsin-Oliveira, J. (2023). Ethnobotany and wood anatomy of *Banisteriopsis caapi* ethnntaxa and *Diplopterys* cf. *pubipetala*, components of ayahuasca in Brazilian rituals. *Economic Botany*, 77, 18–47. <https://doi.org/10.1007/s12231-023-09567-w>.

Pereira, J. O. P., & Freitas, B. M. (2002). Estudo da biologia floral e requerimentos de polinização do muricizeiro (*Byrsonima crassifolia* L.). *Revista Ciência Agronômica*, 33, 5–12.

Pérez-Harguindeguy, N., Díaz, S., Garnier, E., Lavorel, S., Poorter, H., Jaureguiberry, P., & Bret-Harte, M. S. (2016). Corrigendum to: New handbook for standardised measurement of plant functional traits worldwide. *Australian Journal of Botany*, 64, 715–716. https://doi.org/10.1071/BT12225_CO.

Perkins, D., Opaleye, E., Bousso, J. C., Tófoli, L. F., Sarris, J., Schubert, V., Ruffell, S., & Simonova, H. (2023). Insights, life changes and lifestyle changes reported by individuals consuming ayahuasca in naturalistic settings: Nature, frequency and associations with mental health and wellbeing. *Psychoactives*, 2, 256–86. <https://doi.org/10.3390/psychoactives2040017>.

Possobom, C. C. F., Guimarães, E., & Machado, S. R. (2010). Leaf glands act as nectaries in *Diplopterys pubipetala* (Malpighiaceae). *Plant Biology*, 12, 863–870. <https://doi.org/10.1111/j.1438-8677.2009.00304.x>.

Possobom, C. C. F., Guimarães, E., & Machado, S. R. (2015). Structure and secretion mechanisms of floral glands in *Diplopterys pubipetala* (Malpighiaceae), a neotropical species. *Flora - Morphology, Distribution, Functional Ecology of Plants*, 211, 26–39. <https://doi.org/10.1016/j.flora.2015.01.002>.

Possobom, C. C. F., Machado, S. R., & Guimarães, E. (2016). Reproductive system of *Diplopterys pubipetala* (Malpighiaceae) plants from a savanna ecosystem. *The International Journal of Plant Reproductive Biology*. <https://doi.org/10.14787/ijprb.2016.8.1.1-0>.

Quintanar-Castillo, A., & Pace, M. R. (2022). Cunhas do floema em Malpighiaceae: origem, estrutura, diversificação e relevância sistemática. *EvoDevo*, 13, 1-16. <https://doi.org/10.1186/s13227-022-00196-3>.

Sacramento, V. M., Santos, K. T., Rocha, D. F. O., Cabral, E. C., Eberlin, M. N., Mercadante-Simões, M. O., Fonseca, F., Melo, J. A., Menezes, E., Oliveira, D., & Royo, V. A. (2020). Chemical profile and antioxidant activity in *Diplopterys pubipetala* (Malpighiaceae). *Natural Product Research*, 1–5. <https://doi.org/10.1080/14786419.2020.1855644>.

Santos, B. W. L., Oliveira, R. C. de, Sonsin-Oliveira, J., Fagg, C. W., Barbosa, J. B. F., & Caldas, E. D. (2020). Biodiversity of β -Carboline Profile of *Banisteriopsis caapi* and *Ayahuasca*, a plant and a brew with neuropharmacological potential. *Plants (Basel)*, 9, 1-7. <https://doi.org/10.3390/plants9070870>.

Sheth, R., Parikh, E., Olayeye, K., Pfeifer, K., & Khanna, D. (2024). The effects of ayahuasca on psychological disorders: A systematic literature review. *Cureus*, e55574. <https://doi.org/10.7759/cureus.55574>.

Sigrist, M. R., & Sazima, M. (2004). Pollination and reproductive biology of twelve species of neotropical Malpighiaceae: Stigma morphology and its implications for the breeding system. *Annals of Botany*, 94, 33–41. <https://doi.org/10.1093/aob/mch108>.

Silva, V., Cury, G., Barbosa, L. H. S., Santos, D. L. T., Souza, R. C. S., & Prata, A. P. N. (2021). Underground system of the weed *Stigmaphyllon blanchetii* C. E. Anderson (Malpighiaceae) and its vegetative propagation role. *Flora*, 278. <https://doi.org/10.1016/j.flora.2021.151789>.

Siqueira, K. M. M., Martins, C. F., Kiill, L. H. P., & Silva, L. T. (2011). Estudo comparativo da polinização em variedades de aceroleiras (*Malpighia emarginata* DC, Malpighiaceae). *Revista Caatinga*, 24, 18-25.

Souto, L. S., & Oliveira, D. M. T. (2014). Seed development in Malpighiaceae species with an emphasis on the relationships between nutritive tissues. *C. R. Biol.*, 337, 62-70. <https://doi.org/10.1016/j.crv.2013.11.001>.

Souto, L. S., & Oliveira, D. M. T. (2008). Morfoanatomia e ontogênese das sementes de espécies de *Banisteriopsis* C. B. Robinson e *Diplopterys* A. Juss. (Malpighiaceae). *Acta Botanica Brasilica*, 22, 733–740. <https://doi.org/10.1590/S0102-33062008000300011>.

Souto, L. S., & Oliveira, D. M. T. (2012). Estrutura do pericarpo de *Banisteriopsis* C. B. Rob. e *Diplopterys* A. Juss. (Malpighiaceae): novos dados suportando a segregação genérica. *Acta Botanica Brasilica*, 26, 527-536. <https://doi.org/10.1590/S0102-33062012000300003>.

Teixeira, L. A. G., & Machado, I. C. (2000). Sistema de polinização e reprodução de *Byrsonima sericea* DC (Malpighiaceae). *Acta Botanica Brasilica*, 14, 347-357. <https://doi.org/10.1590/S0102-33062000000300011>.

Vilarinho, M. P., Silva, A. K., Lima, C. S., Ferreira, N. S. C., Santos, J. V. C., & Araújo, J. S. (2023). New contributions of comparative leaf anatomy to the phylogeny of *Stigmaphylloids* (Malpighiaceae Juss.). *Flora*, 298, 152194. <https://doi.org/10.1016/j.flora.2022.152194>.

Weichert, R. F., Nunes, B. V., Mazzinghy, A. C. do C., Costa, B. A., Lopes, L. F., Garcia, L. S., Reis, M. C., & Melo, J. O. F. (2024). Cerrado in focus: The vital role of the Cerrado in the planet's biodiversity. *Contribuciones a Las Ciencias Sociales*, 17, e5378. <https://doi.org/10.55905>.