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Chave interativa digital para identificação de *Miconia* s.s. (Melastomataceae) do Pará, Brazil

Florianópolis - SC
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Rennan Lopes Chagas

Digital interactive key for identification of *Miconia* s.s. (Melastomataceae) from Pará, northern Brazil

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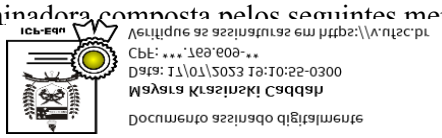

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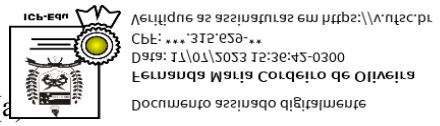

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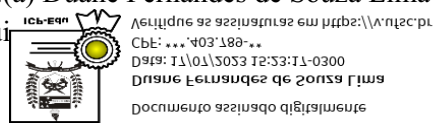

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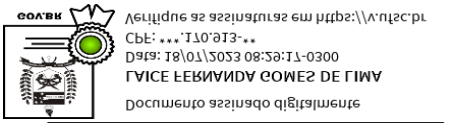

Coordenação do Programa de Pós-Graduação

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Profa. Dra. Mayara Krasinski Caddah
Orientadora

Florianópolis, 2023

[Dedico esse trabalho à Mônica Lopes e
todas as demais mães-solo latino-americanas].

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SUMÁRIO

RESUMO

Miconia é o maior gênero na família Melastomataceae e um dos maiores gêneros da flora do Brasil. A maior lacuna de conhecimento do gênero no país está localizada na região amazônica, onde se estimam ocorrer cerca de 180 espécies. O estado do Pará é o segundo maior estado da região norte do Brasil, e abriga 84 espécies e uma variedade de *Miconia s.s.* Chaves de identificação digitais apresentam várias vantagens em relação às chaves dicotômicas tradicionais, como escolha não-mandatória dos caracteres a serem utilizados, permitem correções e atualizações das informações e, principalmente, podem ser utilizadas como base para construção de chaves mais abrangentes, que incluam mais espécies e/ou caracteres, sem a necessidade de reconfiguração completa. Para contribuir com a taxonomia do gênero *Miconia* no domínio amazônico, neste trabalho desenvolvemos uma chave de identificação digital interativa para as espécies do gênero no estado do Pará, a primeira chave desta natureza para o gênero. A chave foi construída utilizando caracteres morfológicos obtidos de literatura e de análise de materiais físicos e digitais. Para criar a chave, foram utilizados 36 caracteres, com dois a nove estados cada, totalizando 114 estados de caráter, no ambiente virtual da plataforma gratuita Xper³. Desenhos originais e fotos de exsicatas foram incluídos na chave para facilitar a avaliação de estados de caráter pelos usuários, além da descrição dos caracteres e dos respectivos estados. Além da produção da chave, o levantamento dos dados para a construção da chave evidenciou as características morfológicas mais comuns entre as *Miconia* do Pará, e também atualizações necessárias no registro de nove espécies na Flora do Brasil. Acredita-se que essa chave se tornará uma importante ferramenta para auxiliar na identificação de espécies de *Miconia* da região amazônica, e servirá de base para a construção de chaves mais abrangentes para esta região.

Palavras-chave: Amazônia; Miconieae; Taxonomia

ABSTRACT

Miconia s.s. is the largest genus in the Melastomataceae family and one of the largest genera in the flora of Brazil. The biggest gap in knowledge of the genus in the country is the Amazon region, where around 180 species are estimated to occur. The state of Pará is the second largest state in the northern region of Brazil, and is home to 84 species of *Miconia* s.s. Digital identification keys have several advantages compared to traditional dichotomic keys, such as the non-mandatory choice of characters to be used, they allow corrections and updates of information and, mainly, they can be used as a basis for building more comprehensive keys, which include more species and/or characters, without the need for complete reconfiguration. To contribute to the taxonomy of the genus *Miconia* in the Amazonian domain, in this work we developed an interactive digital identification key for the species of the genus in the state of Pará, the first key of this nature for the genus. The key was built using morphological characters obtained from literature and analysis of physical and digital materials. To create the key, 36 characters were used, with two to nine states each, totaling 114 character states, in the virtual, free environment of the Xper³ platform. Original drawings and photos of herbarium sheets were included in the key to facilitate the evaluation of character states by users, in addition to the description of the characters and their respective states. In addition to the production of the key, the data collection for the construction of the key showed the most common morphological characteristics among the *Miconia* of Pará, and also the necessary record updates of nine species in the Flora of Brazil. We believe that this key will become an important tool to assist in the identification of *Miconia* species in the Amazon region, and will serve as a basis for the construction of more comprehensive keys for this region.

Keywords: Amazon; Miconieae; Taxonomy

INTRODUÇÃO GERAL

O domínio fitogeográfico da Amazônia possui cerca de 6 mi km² ao norte na América do Sul. Sua constituição é heterogênea e é composta por uma matriz de diferentes tipos de vegetação (Pires & Prance 1985). A biodiversidade e ocorrência de espécies amazônicas é altamente subestimada (Gómez-Pompa et al. 2010, Koleff et al. 2008, Sosa & Dávila 1994, Villaseñor et al. 2005), o que preocupa taxonomistas devido às ameaças à sua conservação (Viana et al. 2016, BFG 2015). No Brasil, o país com maior extensão do domínio, é sabido que o conhecimento possui lacunas longe de serem preenchidas, considerando sua extensão, falta de especialistas e as vastas coleções ainda a serem estudadas. Essa falta de conhecimento agrava a já crítica crise de perda de biodiversidade.

Com mais de 5,8 mil espécies e distribuição Pantropical, Melastomataceae Juss. está entre as 10 maiores famílias de espermatófitas do planeta (Ulloa et al. 2022). São mais conhecidas por terem folhas simples, não estipuladas e opostas, com venação curvinérvea (Souza & Lorenzi 2019). Melastomataceae constitui uma grande fração da biodiversidade no Brasil, o país mais rico do mundo, com quase 1,5 mil espécies conhecidas (Goldenberg et al. 2012). Com isso, uma das perguntas mais importantes a serem respondidas na taxonomia de Melastomataceae brasileira é a real diversidade da família na Amazônia (Goldenberg et al 2012).

Muitos gêneros da tribo Miconieae foram sinonimizados em *Miconia* Ruiz & Pav., tornando-o o maior gênero dentro de Melastomataceae, que agora compreende cerca de 1900 espécies distribuídas na região Neotropical (Ulloa et al. 2022). Nessa nova circunscrição *Miconia* é o maior gênero do país com cerca de 560 espécies, e dessas, 283 registradas na Amazônia até o momento (FBO - Goldenberg et al. 2020). Entretanto, considerando a grande mudança necessária para adaptar o banco de dados e taxonomia de *Miconia* para refletir essa nova e mais ampla circunscrição (*Miconia s.l.*), a taxonomia de *Miconia* no Brasil ainda está sendo tratada em seu sentido mais estrito (*Miconia* s.s.), como na Flora e Funga do Brasil (https://floradobrasil.jbrj.gov.br/). Os estudos de espécies amazônicas de Melastomataceae são recentes no Brasil, país que retém a maior extensão do território da floresta (e.g, Cangani 2012, Corrêa et al. 2017, Oliveira 2018, Rocha et al. 2017).

Com isso, a real diversidade de *Miconia* da Amazônia é ainda desconhecida (Meirelles et al. 2021). Isso corrobora as novas e contínuas novas descobertas para a flora amazônica brasileira de Melastomataceae (e.g, Goldenberg et al. 2012, Meirelles &

Goldenberg 2014, Meirelles et al 2015, Almeda et al. 2016; Michelangeli & Goldenberg 2016, Meirelles & Bacci 2017, Goldenberg & Hinoshita 2017, Meirelles et al. 2021).

Estudos de padrões de diversidade em diferentes escalas de tempo-espaço podem ser analisados por meio de inventários baseados em táxons delimitados e bem identificados, aplicando um sistema que permita comparação entre eles (Gotelli 2004). A taxonomia integrativa utiliza várias fontes de evidências, como morfologia, estudos moleculares, ecologia e padrões biogeográficos para elucidar outros elementos dentro da análise de decisões nomenclaturais (Rajpoot et al. 2016, Sheth & Thaker 2017) e requer ferramentas focadas em caracteres morfológicos. Estudos para identificação automatizada foram desenvolvidos conforme a necessidade de novos métodos de estudo taxonômico. Chaves de identificação são ferramentas supervisionadas que podem ser classificadas em duas categorias distintas: a) chaves monotéticas seguem passos predefinidos a fim de identificar um táxon; e b) chaves politéticas são mais generalistas, permitindo o usuário a escolher entre múltiplos estados de caráter conforme o espécime é observado sem ordem definida (Murguia-Romero & Villaseñor 2021).

Chaves tradicionais são monotéticas e frequentemente dicotômicas, onde de um primeiro ponto, o usuário segue passos predeterminados em uma ordem de caracteres a serem avaliados. Com essa natureza das chaves convencionais, quanto mais passos necessários na identificação, mais fácil é do usuário errar a identificação correta (Goharimanesh et al 2021). Essas limitações apresentadas, além dos erros humanos e espécies com informações incompletas, são obstáculos que podem ser superados por chaves digitais de múltiplo acesso (Walter & Winterton 2007). O programa limita os possíveis resultados eliminando táxons conforme os estados de caráter são escolhidos, excluindo todo resultado que não se aplica à descrição (Dallwitz et al. 2007), permitindo seleção de caracteres e de espécies, sem ordem definida. Nesse tipo de chave, alguma falta de dados e/ou redundância não afeta tanto o processo de identificação como em chaves dicotômicas tradicionais.

O avanço do acesso amplo da tecnologia trouxe alternativas às chaves dicotômicas e muitos pesquisadores começaram a criar chaves digitais interativas. Algumas destas chaves são gratuitas, como a de acesso aberto Xper³, atualmente na versão 1.6.2, e graças à sua interface acessível ao usuário, tem sido acolhida por novos estudos (Vignes-Lebbe et al. 2017, Pinel et al 2017, Kerner et al, 2021). Até onde sabemos, essas ferramentas de identificação interativas ainda não foram produzidas para espécies brasileiras de *Miconia*.

Considerando a riqueza de espécies e urgência para catalogar a flora Amazônica, métodos práticos para identificação se tornaram fundamentais. Com isso, o objetivo deste trabalho é produzir uma ferramenta alternativa às chaves dicotômicas tradicionais, facilitando a identificação de espécies amazônicas de *Miconia*, além de servir de modelo para a produção e sofisticação colaborativa de novas chaves como a apresentada aqui.

OBJETIVOS

Objetivo geral

Contribuir para a taxonomia de *Miconia* s.s. no Domínio Amazônico por meio da produção de uma chave digital e interativa de múltiplas entradas para o gênero no estado do Pará, região Norte do Brasil.

Objetivos específicos

- Produzir desenhos para ilustrar estados de caráter de características úteis para identificação de espécies de *Miconia* s.s.;
- Identificar os principais caracteres morfológicos para a identificação do gênero no estado do Pará;
- Criar a primeira ferramenta de identificação de múltiplas entradas para *Miconia* s.s. como alternativa para as chaves tradicionais dicotômicas;
- Destacar lacunas de informações sobre as espécies delimitadas;
- Discutir a importância de ferramentas práticas e tecnológicas na produção científica.

Capítulo 1: Artigo a ser submetido à revista *Rodriguésia*

Digital interactive key for identification of *Miconia* s.s. (Melastomataceae) from Pará, northern Brazil

Rennan Lopes, Alexandre Amilton de Oliveira, Julia Meirelles, Mayara Krasinski Caddah

Amazon's phytogeographic domain holds about 6 mi km^2 at the northern portion of South America. Its heterogeneous vegetation is composed by a matrix of different kinds of forests, but also presents open vegetation embedded within it, as savannah, campinarana and rocky outcrop (Pires & Prance 1985). The biodiversity of the Amazon is greatly underestimated, and species occurrence and distribution range is widely neglected (Gómez-Pompa et al., 2010; Koleff et al., 2008; Sosa & Dávila, 1994; Villaseñor et al., 2005), which has worried plant taxonomists because of recent threats to its conservation (Viana et al. 2016; BFG 2015). In Brazil, the country with the largest portion of the Amazon domain, it is widely acknowledged that the knowledge of its flora has information gaps far from being filled, taking into account its vast territory, the lack of specialists and the sizable collections yet to be studied. This lack of knowledge aggravates the already critical biodiversity crisis where many species are becoming extinct without one's notice, as their natural habitats keep on getting smaller.

With more than 5,8 thousand species and a Pantropical distribution, Melastomataceae Juss. is one of the 10 largest flowering plant families of the world (Ulloa et al. 2022). Their main diagnostic features are the simple leaves, curved secondary veins (Fig.1), exstipulate and opposite phyllotaxis (Souza; Lorenzi 2019). Considering the size of the family, Melastomataceae species constitute a big portion of Brazil's biodiversity, the richest country on the planet, with almost 1,5 thousand known species (Goldenberg et al. 2012). With the large gap in knowledge of the Brazilian Amazon flora, one of the more important questions to be answered about Brazilian Melastomataceae taxonomy is the real diversity of the family in that domain (Goldenberg et al 2012).

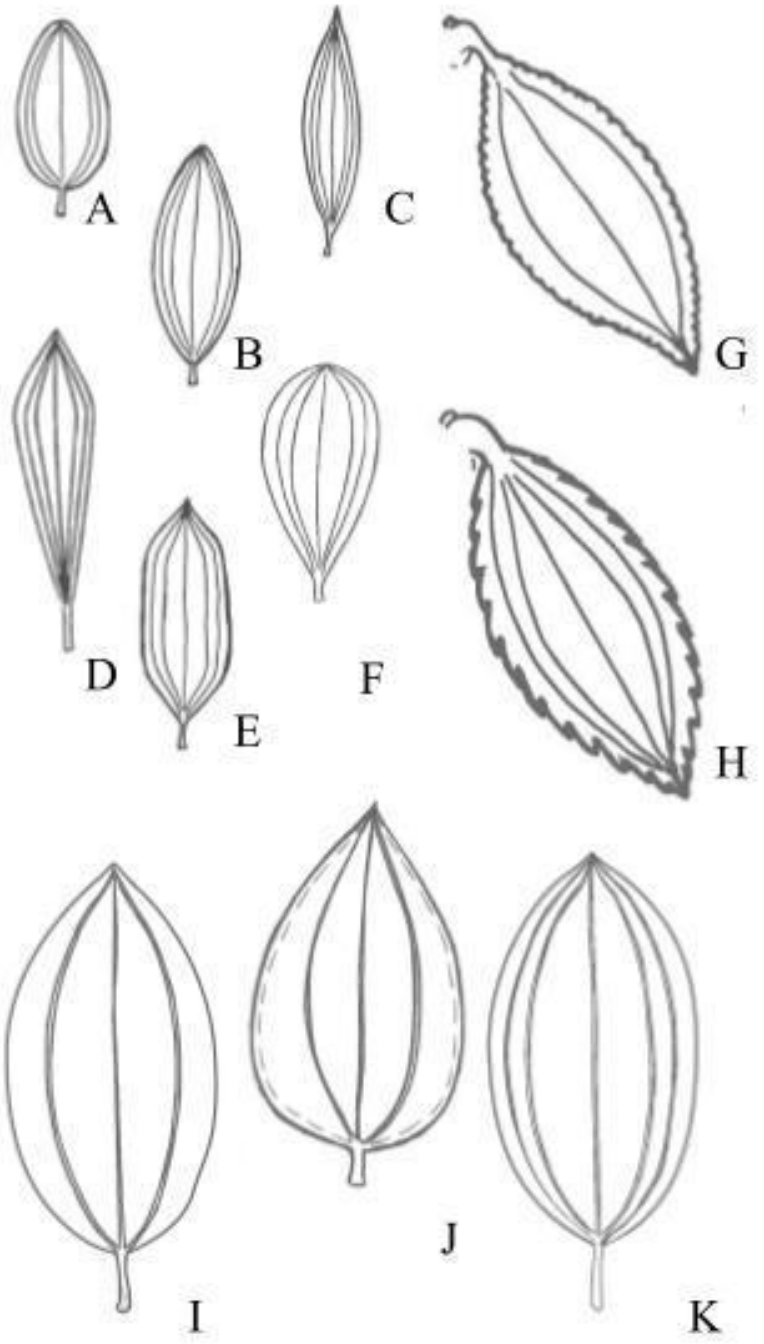


Figure 1. Leaf character states as seen in the digital interactive key for *Miconia* s.s. species from Pará state, northern Brazil – A-F. Blade shape, A. ovate, B. elliptic, C.lanceolate, D. oblanceolate, E. oblong, F. obovate; G-H. Blade margin, G. crenate margin, H. serrulated margin; I-K. Main veins (primary plus acrodrome secondaries), I. 3-nerved, J. 3-nerved plus two acrodromes, K. 5-nerved plus two acrodromes.

Several genera of the Miconieae tribe had been synonymized under *Miconia* Ruiz & Pav., making it the biggest genus of Melastomataceae, which now comprises about 1900 species distributed across the Neotropical region (Ulloa et al. 2022). Considering this new circumscription, *Miconia* s.s. is Brazil's biggest plant genus, with about 560 species in the whole country, and 283 reported in the Amazon region, up to now (Goldenberg et al., 2020). However, considering the large changes necessary to adapt all the database and taxonomy of *Miconia* to reflect this new, wider circumscription (*Miconia* s.l.), the taxonomy of *Miconia* in Brazil has still been treated in its strict, narrow, sense (*Miconia* s.s. = *Miconia* sensu Cogniaux 1891, see Michelangeli *et al.* 2022), as in the Flora e Funga of Brazil (https://floradobrasil.jbrj.gov.br/). After a great focus on Eastern brazilian diversity, only in the recent years taxonomic studies of Amazonic species of Melastomataceae have been carried out in Brazil (e.g, Cangani 2012, Corrêa et al. 2017, Oliveira 2018, Rocha et al. 2017). Considering the small number of studies carried out in the region, the real diversity of *Miconia* from the Amazon is still unknown (Meirelles et al. 2021). This can be corroborated by the many new and continuous discoveries for the Brazilian Amazon Melastomataceae flora (e.g, Goldenberg et al. 2012, Meirelles & Goldenberg 2014, Meirelles et al 2015, Almeda et al. 2016; Goldenberg & Michelangeli 2016, Meirelles & Bacci 2017, Goldenberg & Hinoshita 2017, Meirelles et al. 2021).

Biodiversity patterns in different space-time approaches can only be studied with inventories based on taxa delimited and accurately identified, applying a system that allows comparisons between them (Gotelli 2004). Integrative taxonomy uses various sources of evidence, such as morphological structures, molecular studies, ecological aspects, biogeographical patterns to elucidate other elements into the analysis of nomenclatural decisions (Rajpoot et al. 2016, Sheth & Thaker 2017), and requires identification tools focused on morphological characters. As the need for more trustworthy methods of taxonomic study rises, strategies for streamlined identification have been conceptualized. Digital identification keys are supervised taxonomic tools and can be categorized in two sorts: a) monothetic keys are those in which the user follow a certain predefined sequence of steps in order to identify a taxon; and b) polythetic keys, more generalists, are those in which the user can select a number of character states as the specimen is being observed, in no particular order (Murguía-Romero & Villaseñor 2021).

The standard, monothetic keys, are often dichotomous, which from a single entry point the user follows a predetermined set of steps in an order of characters to be evaluated. But with the "pathway" nature of the conventional keys, the more steps needed to identify a taxon, the easier it is for the user to get off track from the correct identification (Goharimanesh et al 2021). These keys present limitations, especially when it comes to human error and incomplete specimens, obstacles that can be surpassed by digital multiple access computer keys (Walter & Winterton 2007). In this case, the program narrows down the possible results eliminating taxa as the character states are being chosen, excluding every result that does not apply to the set of descriptions given by the user (Dallwitz et al. 2018), allowing the selection of a broad variety of characters and species, with no mandatory order. Also, some lack of information and redundancy does not affect the process as much as it does in dichotomous keys. Another advantage of digital, multiple access keys is that it allows the increment of characters, character states and even taxa after the key is completely set, making easier to correct it or update it, if necessary, or to develop wider, more comprehensive identification tools.

As an alternative for the conventional dichotomous keys and with the advancements of wide technology access, many researches started to create and utilize interactive digital keys, such as the collaborative Royal Botanic Garden, Kew Neotropikey project (Milliken et al. 2009) using LUCID® software (www.lucidcentral.org). Free softwares made for interactive identification have also been developed, like the open-access Xper³, currently in the version 1.6.2 (http://www.xper3.fr/). Thanks to its easy to learn and user-friendly design, many new studies are starting to adopt this tool (Vignes-Lebbe et al. 2017, Pinel et al. 2017, Kerner et al. 2022). Digital interactive keys have not yet been produced for Brazilian *Miconia*. Considering the richness in species and the urgency to catalog the Amazon flora, practical methods for identification are critical. Thus, the goal of this study is to produce an alternative tool for the traditional dichotomous keys, which can facilitate the identification of Amazonian species of *Miconia*, and serve as a model to kickstart the production and collaboration of these keys.

Material and Methods

Study area

Besides a smaller portion of Cerrado in the southeast (INPE 2023), the state of Pará is completely inserted in the amazonic phytogeographic domain, and it is covered by a diverse mosaic of phytoecological regions, such as savannas, floodplain forests, palm tree forests, mangroves and dryland forests (Pires & Prance 1985). The soil in these areas can be composed with clay and quartz sand beaches in rivers and ponds (Vieira et al. 1971).

Taxa

A preliminary list of taxa was made based on the synopsis of *Miconia* of Pará, by Oliveira (2018), and specimens listed on online repositories (SpeciesLink, http://splink.cria.org.br/; Flora do Brasil 2020, http://reflora.jbrj.gov.br).The names were checked and updated considering Goldenberg et al. (2021). Species extinction threat level was compiled from Flora e Funga do Brasil database (2023) for a slightly richer discussion in this paper.

Software platform

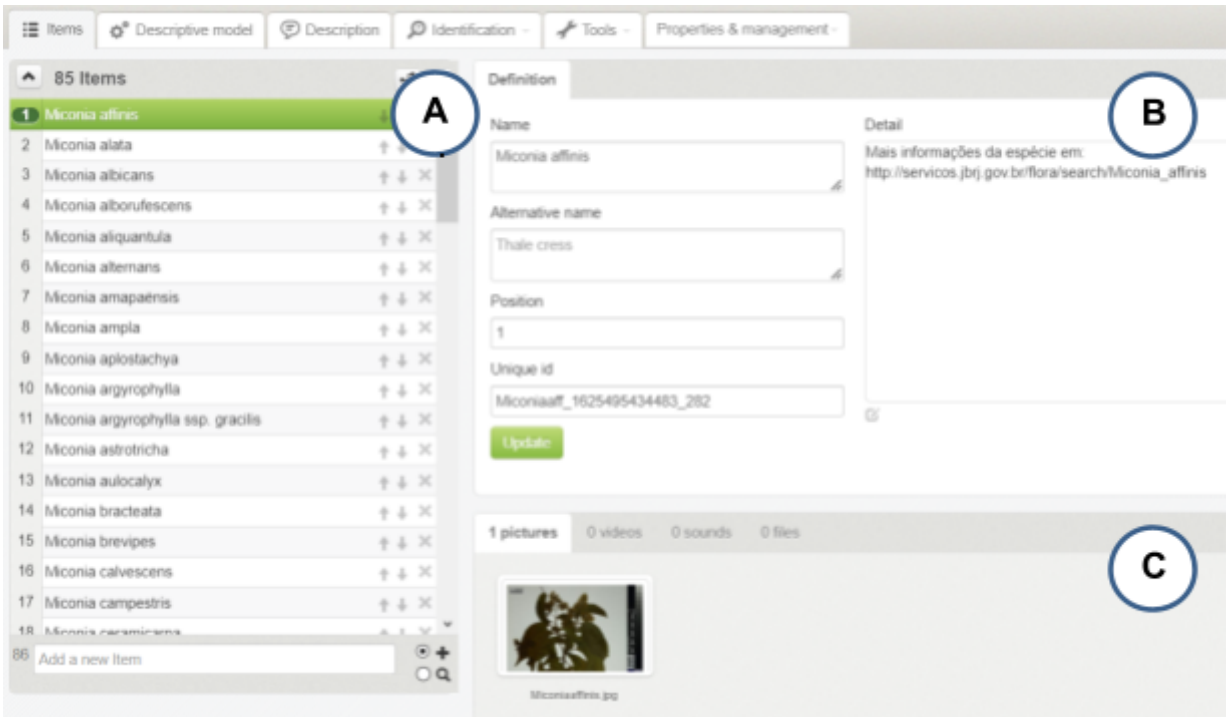
As a free access platform, Xper³ was the software chosen for the confection of the present key. Xper³ is a program with no requirements of external data storage. This platform was chosen because it is compatible with all the major operating systems including mobile (i.e. Windows, MacOS, Linux, Android, iOS) and the interface is currently available in French and English, with the entries in the keys available in whatever language the authors write them in (http://www.xper3.fr/). Every tool and functionality required for the construction of a multi-entry interactive key are included within the platform, remote access is allowed via the internet and it has both web-based and mobile interfaces. Every database created within the platform is easily shareable and multiple contributors are allowed to access and edit the keys via invitation. The Xper³ website can be accessed at http://www.xper3.fr/ and an in-depth user documentation can be read http://wiki.xper3.fr/lib/exe/fetch.pfp?media=wiki:xper3documentation.pdf. The entries in this study's key were written in Portuguese, considering its main public.

Data collection

Diagnostic characters and character states were mainly derived from literature (Meirelles 2015, Oliveira 2018), but herbarium specimens were also examined (FLOR, INPA, MG and UPCB). Vegetative and reproductive characters that can be seen with naked eyes were primarily chosen, but a stereoscopic microscope or a hand magnifying glass may be required for smaller floral and trichome characters analysis, such as stamen size and branched trichome type. Character states were delineated considering a wide margin of interpretations. Multiple similar states were gathered in single options, as seen in leaf bases.

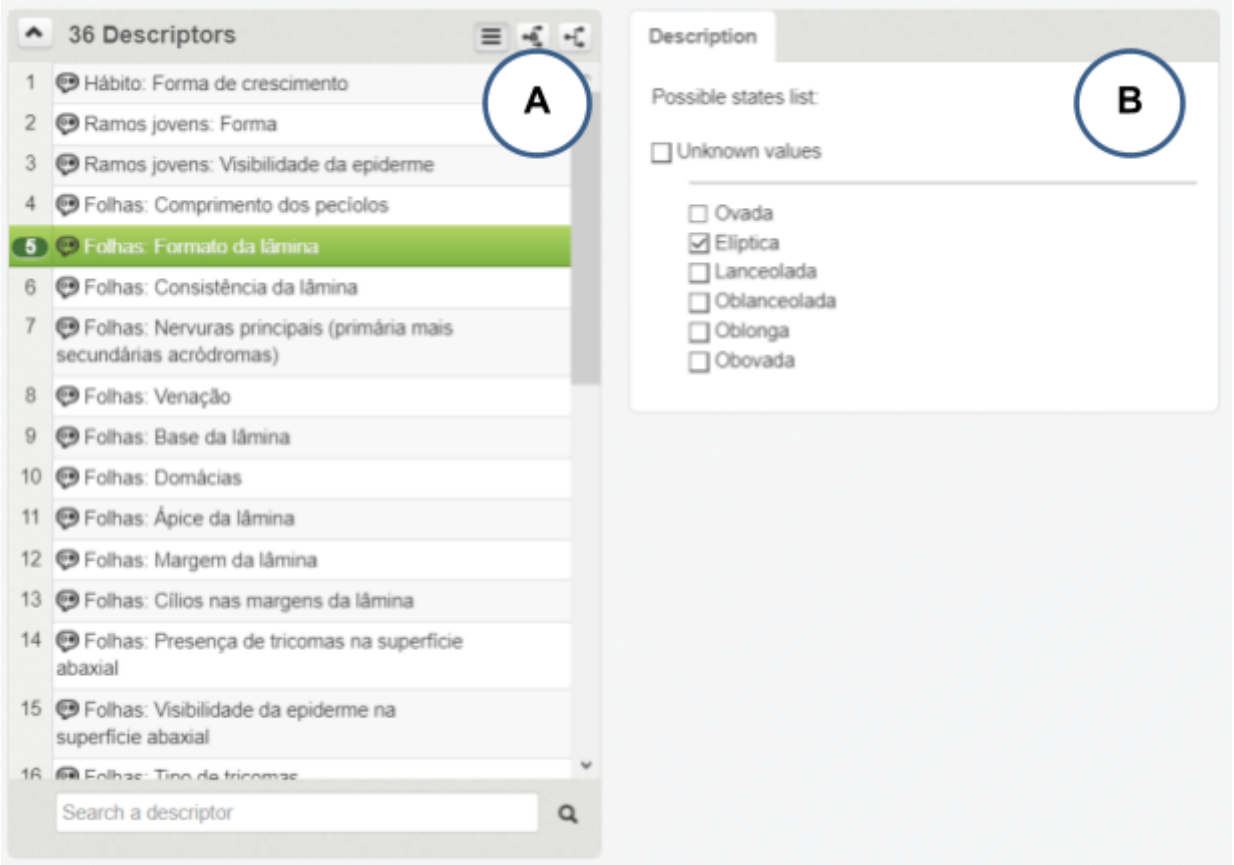
Interactive key descriptors were characters in which each species was classified. The character states in the program represent the form in which each character are presented. All the species were written on the Xper³ platform under the tab "itens" (Figure 2). The characters were written down on the "descriptive model" tab, with each state possible on the "states" tab of each descriptor. Each character and character state were manually coded for every species under the "description" tab (Figure 2).

Figure 2. Screenshot of the "items" tab on the Xper³ platform of the digital interactive key of *Miconia* s.s. of the state of Pará, which compiles the taxa studied, herbarium sheet photos of the species and a reference to the species page in Flora do Brasil (Flora e Funga do Brasil 2023, http://reflora.jbrj.gov.br): A. taxa list present in the current database; B. reference of the species page in the Flora e Funga do Brasil platform; C. media upload tab with the herbarium sheet picture of *Miconia alata.*



The characters and terminology used in the key were organized numerically according to their discriminating potential, from vegetative to reproductive descriptors, and include habit, young branches, leaves, inflorescences, flowers, stamens, and pistil characters (Figure 3).

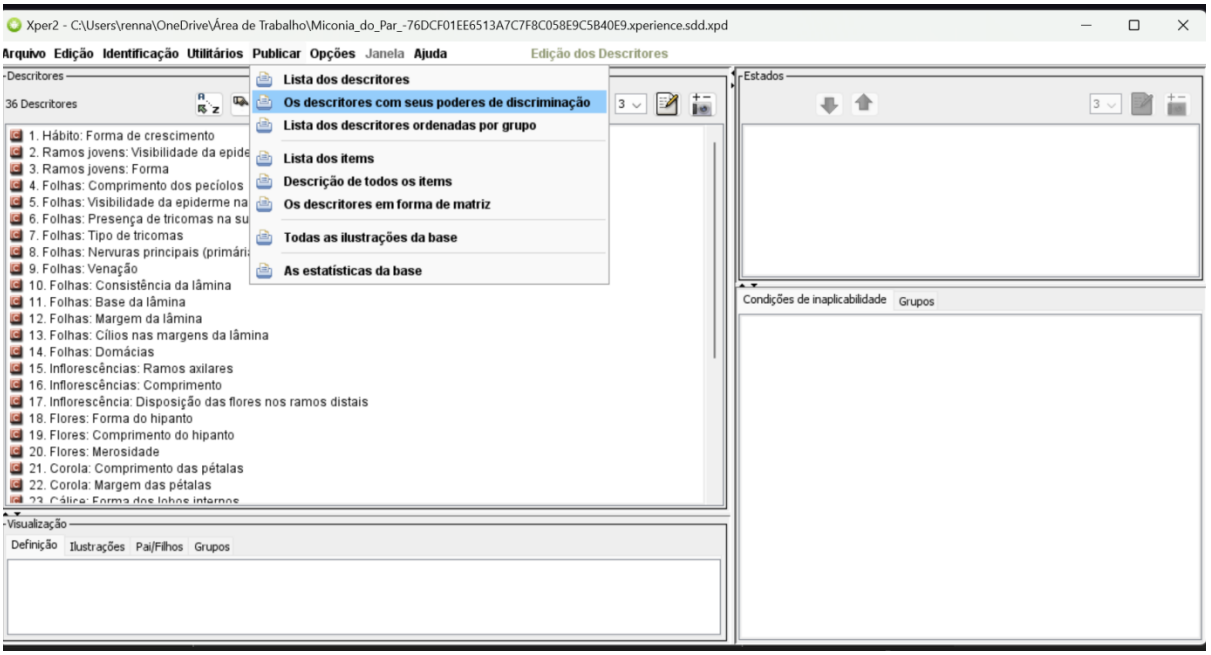
Figure 3. Screenshot of the description page of the xper3 platform of the *Miconia* ss. from the state of Pará, where the descriptors and states coded in the "description model" are assigned to each taxon individually: A. descriptors tab with every character in the respective category; B. possible known character states of the study's taxa.



The discriminatory value was calculated by analyzing three indexes via the Xper² software: Xper index, Jaccard index (1901) (*SJaccard = c/(a+b-c)*) (*SJaccard = /(a+b−c)*) and Sokal & Michener index (1958) (*SSM = (a+d)/(a+b+c+d)*), where *a*= present descriptor states, whether or not they are present in both taxa; *b*= present descriptor states present only in the first taxon; *c*= present descriptor states only in the second taxon and *d*= descriptor states not applicable in none of the taxa analyzed.). The discriminatory value of each descriptor for each one of the three indexes is calculated by the sum of the dissimilarity between each and all possible pairs of taxa. The Xper index is determined by the differences

between descriptors. Thus, the index evaluates the potential of a descriptor to differentiate two distinct taxa, giving a higher value to the descriptors the more exclusive to each taxon (if $a = 0$ then Xper = 1) (Vignes-Lebbe 2017). The Jaccard (1901) index is based on the similarity, meaning two taxa are similar when they share common descriptors, while Sokal & Michener (1958) index is based on the shared similarities both in the occurrence and lack of characters and states, meaning two taxa are alike when they share the presence and absence of characters and states in this index. As well as the Xper, these indexes goes from 0 to 1 but depend on the number of character states in common (Vignes-Lebbe 2017). By analyzing these indexes, it is possible to evaluate the most efficient characters and what characters could be reformulated or deleted (tab. 4).

Figure 4. Screenshot of the *Miconia* ss. of the state of Pará Xper2 database. In blue highlight on the window tab ("*janela*" in portuguese) is the discrimination index calculating tool of the Xper2 software.



Morphological concepts were set according to Gonçalves & Lorenzi (2007). Mistakes related to species without filled-in characters, wrongly placed characters and discernibility among species were verified using the Xper3 "checkbase" tool.

Images

All the character states were hand drawn based on herbarium sheets or digitized images using ink pen on paper, then scanned in high-fidelity, either in the web-based interface

or mobile. Few drawings were edited after scanning using Photoshop, Microsoft Paint and CorelDraw® for upscaling. Besides character states drawings, each species were represented by a digital picture taken from SpeciesLink. The species type was prioritized when the collection took place in the state of Pará.

Results and discussion

This study produced an interactive key for *Miconia* s.s. (Melastomataceae) from the state of Pará, Brazil (Figure 5). As long as the authors know, it is the first interactive key of *Miconia* s.s. in general, and the first interactive key for the Melastomataceae family in the state of Pará, Brazil. The interactive key is available as an Xper³ online app (https://www.xper3.fr/xper3GeneratedFiles/publish/identification/-8015989149121494953/mkey.html) .

Figure 5. Screenshot of the interactive identification of *Miconia* s.s. of the state of Pará: A. illustrated descriptors with a brief definition and all the possible states underneath. The green indicators stand for the corresponding taxa represented by each state; B. the list containing the remaining and excluded taxa (black and grey font respectively) for the identification in-progress.

1. The key database

In total, 85 taxa (84 species and one subspecies; Table 1) were included in the interactive key and all of them can be completely discernible, with no conflicting descriptions. This study

diverged from the earlier treatment for *Miconia* from the state of Pará (Oliveira 2018) only by the inclusion of *Miconia waimiri-atroari* Meirelles & Caddah (Meirelles et al. 2021). Nine species included here were absent from the FBO occurency database at the time of the key production, while other nine species were present in FBO but their identification needs reevaluation or update (see bellow in suggestions for FBO inclusions and removals).

Table 1. Taxa included in the interactive key of *Miconia* s.s. (Melastomataceae) from the state of Pará, Brazil, with their respective IUCN Red List threat level as well as the voucher used to illustrate each species:

Species	**Threat level**	**Voucher**
Miconia affinis	LC	UPCB 91978
Miconia alata	NE	NY 1039157
Miconia albicans	LC	UPCB 68184
Miconia alborufescens	LC	UPCB 30623
Miconia aliquantula	LC	NY 987393
Miconia alternans	LC	UPCB 90768
Miconia amapaënsis	NE	NY 3754439
Miconia ampla	LC	NY 3697016
Miconia aplostachya	LC	NY 1539165
Miconia argyrophylla	LC	NY 3697068
Miconia argyrophylla ssp. *gracilis*	NE	UPCB 79297
Miconia astrotricha	NE	INPA 84671
Miconia aulocalyx	NE	NY 1189124
Miconia bracteata	NE	NY 1421522
Miconia brevipes	LC	NY 1598948
Miconia calvescens	LC	HUEFS 145658
Miconia campestris	NE	NY 1164811
Miconia ceramicarpa	LC	NY 1599175
Miconia chrysophylla	LC	NY 3908152
Miconia ciliata	LC	NY 1599064
Miconia cowanii	NE	IAN 127512
Miconia cuspidata	NE	NY 229119
Miconia diaphanea	NE	NY 987390
Miconia dichrophylla	NE	NY 1539049
Miconia dispar	LC	MBM 238474
Miconia dolichorrhyncha	LC	MBM 38466
Miconia egensis	LC	UPCB 90793
Miconia elata	LC	NY 1722472

Miconia elegans	LC	NY 916775
Miconia eriodonta	LC	FLOR 64680
Miconia fallax	NE	HUEFS 164978
Miconia ferruginata	NE	UPCB 83740
Miconia gratissima	LC	NY 1176804
Miconia heliotropoides	NE	UEC 172998
Miconia holosericea	LC	NY 925407
Miconia hypoleuca	LC	MBML 31759
Miconia ibaguensis	NE	NY 1652870
Miconia lanata	LC	MBM 413667
Miconia lappacea	NE	NY 987622
Miconia lasseri	NE	NY 1855441
Miconia lateriflora	LC	NY 987629
Miconia lepidota	LC	UPCB 42885
Miconia longifolia	LC	NY 1652945
Miconia longispicata	LC	NY 1653140
Miconia macrothyrsa	NE	UPCB 45852
Miconia manauara	LC	NY 1365178
Miconia matthaei	LC	NY 3908150
Miconia mattogrossensis	NE	UPCB 84433
Miconia melinonis	NE	NY 1098169
Miconia minutiflora	LC	EAC 31502
Miconia mirabilis	LC	UPCB 68361
Miconia myriantha	LC	NY 1855439
Miconia navioensis	NE	NY 229270
Miconia nervosa	LC	NY 2714376
Miconia phaeophylla	LC	NY 1653672
Miconia platypoda	NE	NY 229308
Miconia poeppigii	LC	NY 925198
Miconia prasina	LC	SP 4826
Miconia pubipetala	LC	UPCB 82023
Miconia pyrifolia	LC	FLOR 64670
Miconia radulifolia	NE	INPA 249770
Miconia regelii	LC	P 579021
Miconia renatogoldenbergii	NE	NY 1100184
Miconia rhytidophylla	NE	UEC 50390
Miconia rimachii	NE	NY 38514
Miconia rubiginosa	LC	UPCB 83802
Miconia rufescens	LC	NY 1467406
Miconia ruficalyx	LC	HUEFS 234000

Miconia sagotiana	NE	P 107981
Miconia santaremensis	NE	HUFU 79578
Miconia secundiflora	NE	U 1395226
Miconia serialis	LC	NY 2479084
Miconia serrulata	LC	MBM 235445
Miconia splendens	LC	UPCB 84224
Miconia staminea	NE	HUCP 13984
Miconia stelligera	LC	NY 1738531
Miconia stenostachya	LC	NY 748818
Miconia tetraspermoides	NE	F 66114
Miconia tomentosa	LC	CEN 83860
Miconia traillii	LC	FLOR 64682
Miconia trinervia	LC	NY 1738648
Miconia truncata	LC	F V0181332F
Miconia tschudyoides	NE	F V0181331F
Miconia wagneri	NE	NY 1075588

To allow the discrimination of species, 36 descriptors were chosen as characters, with 114 character states associated to them. The full character table is presented below (Table 2). A conventional key automatically produced by Xper3 is provided in Appendix 1. The characters have two to nine states associated, but the majority of them have only two (47%), three (19%) or four states (22%). Among the descriptors, 16 were vegetative and 20 were reproductive: *habit* (1 character), *young branches* (2), *leaves* (13), *inflorescences* (4), *flowers* (3), *calyx* (2), *corolla* (2), *androecium* (5) and *gynoecium* (5). All the characters had information gathered for at least 77 taxa (90.59%), except for the ovary position, with only 58 taxa (68.24%) with this character assessed. Twenty-nine characters were polymorphic for at least one taxon, that is, taxa could present two or more states. Across the 114 character states, 13 can be considered rare (occurrence up to 5% of the species) among *Miconia* from Pará: (1) obovate blades; (2) leaves with only three main veins (without a marginal pair); (3) attenuated leaf base; (4) auriculate leaf base; (5) cuneate leaf base; (6) leaf domatia; (7) rounded leaf apex; (8) obtuse leaf apex; (9) glandular trichomes on leaf surface; (10) absence of trichomes on leaf surface; (11) inflorescences shorter than 1.8 cm; (12) umbelliform placement of flowers; (13) capitate to discoid stigma. Anther dehyscence and domatia were the most homogenous characters among the studied species, with over 90% of the taxa with one of the character states (poricide: 90.58%; absent domatia: 98.82%). The three most

efficient (with greater discriminatory value) characters were (1) leaf trichome types (X=0.7; MS=0.22; J=0.78); (2) flower organization in distal branches (X=0.64; MS=0.36; J=0.68); and (3) blade consistency (X=0.61; MS=0.35; J=0.67).

Table 2: Full character list of the *Miconia* s.s. from Pará, northern Brazil, including the respective morphologic information coverage and distribution of states across the taxa surveyed.

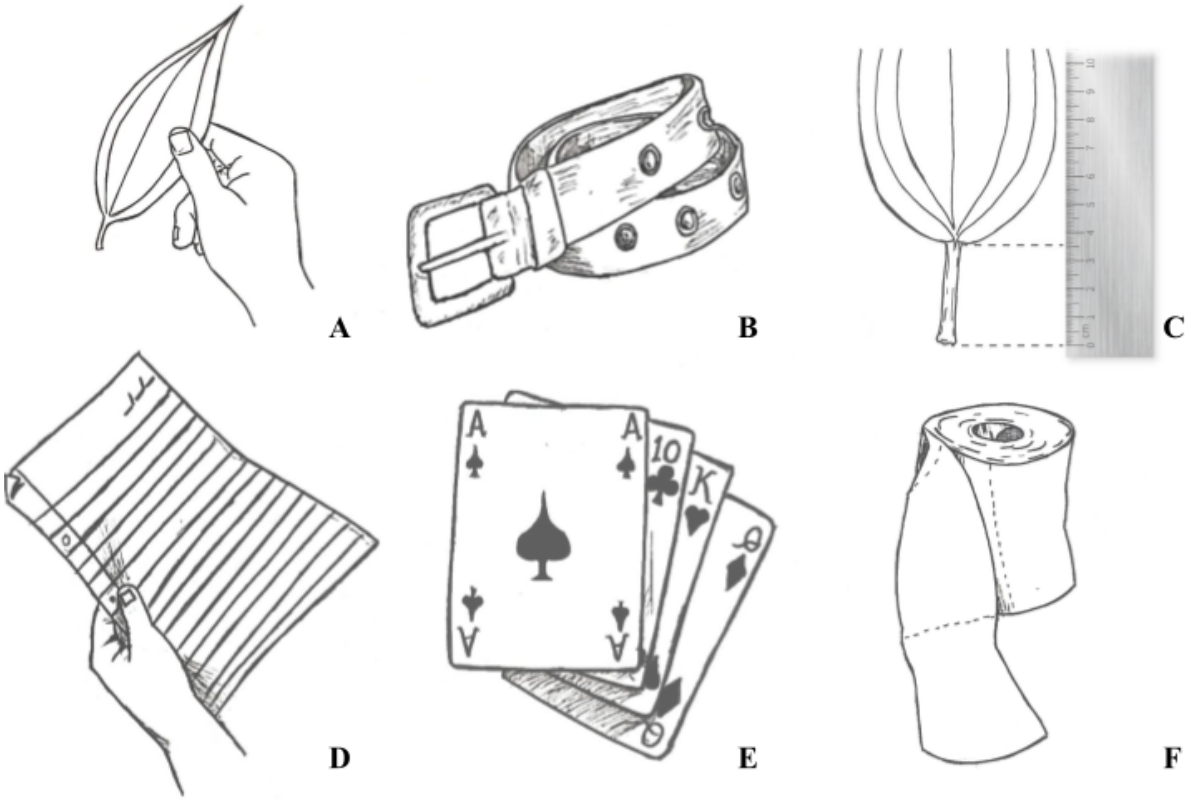
Categories	Characters	States	Coverage	States distribution								
				1	2	3	4	5	6	7	8	9
Habit	Growth pattern	1- Tree; 2- Schrub	100%	66% (56)	84% (71)							
Young branches	Shape	1- Cylindrical; 2- Quadrangular	100%	41% (35)	60% (51)							
	Epidermis visibility	1- Invisible to the naked eye; 2- Visible to the naked eye	99%	64% (54)	61% (52)							
Leaves	Petiole length	1-≤4.5mm; 2- between 4.5mm and 14mm; 3- between 15mm and 37mm;4- ≥38mm	100%	33% (28)	69% (59)	61% (52)	16% (14)					
	Blade shape	1- Ovate; 2- Elliptic; 3- Lanceolate; 4- Oblanceolate; 5- Oblong; 6- Obovate	100%	51% (43)	78% (66)	46% (39)	8% (7)	18% (15)	5% (4)			
	Blade consistency	1-Papyraceous; 2- Membranaceous; 3- Cartaceous; 4 - Coriaceous	100%	6% (5)	35% (30)	48% (41)	19% (16)					
	Main veins*	1- Three; 2- Three plus two faint veins; 3- Five plus two faint veins	100%	2% (2)	80% (68)	19% (16)						
	Venation	1- Basal; 2- Suprabasal	100%	73% (62)	32% (27)							
	Blade base	1- Acute; 2- Rounded; 3- Atenuated; 4- Auriculated; 5- Cordate or cordulate; 6- Cuneate; 7- Decurrent; 8- Obtuse; 9- Truncate	100%	51% (43)	34% (29)	5% (4)	1% (1)	28% (24)	2% (2)	15% (13)	47% (40)	6% (5)
	Domatia	1- Absent; 2- Present.	100%	99% (84)	1% (1)							
	Blade apex	1- Rounded; 2- Acute; 3- Acuminated; 4- Atenuated; 5- Obtuse	99%	4% (3)	27% (23)	66% (56)	41% (35)	5% (4)				
	Blade margin	1- Entire; 2- Crenulate; 3- Serrate to dentate; 4- Ondulate	99%	72% (61)	11% (9)	35% (30)	26% (22)					
	Leaf margin cilia	1- Absent; 2- Present	100%	79% (67)	21% (18)							

	Abaxial trichome	1- Present on the entire blade; 2- Entirely absent or only on the veins	100%	73% (62)	28% (24)							
	Abaxial epidermis	1- Invisible to the naked eye; 2- Visible to the naked eye	100%	39% (33)	61% (52)							
	Trichome type	1- Absent; 2- Aracnoid; 3- Dendritic; 4- Scaly; 5- Stellate; 6- Glandular; 7- Lepidote; 8- Simple	100%	2% (2)	16% (14)	24% (20)	7% (6)	46% (39)	1% (1)	12% (10)	13% (11)	
Inflorescences	Axillary branches	1- Absent; 2- Present	99%	81% (69)	20% (17)							
	Total length	1-≤1.8cm; 2- between 1.8cm and 15.3cm; 3- between 15.3cm and 22.5cm;4- ≥ 22,5cm	100%	1% (1)	85% (72)	38% (32)	16% (14)					
	Flowers in distal branches	1- Dichasial; 2- Scorpioid to subscorpioid; 3- Glomerular to subglomerular; 4- Umbeliform.	100%	41% (35)	64% (54)	64% (54)	4% (3)					
	Branch epidermis	1- Invisible to the naked eye; 2- Visible to the naked eye	99%	64% (54)	40% (34)							
Flowers	Hipanthium shape	1- Campanulate to semi-elliptic; 2- Tubular; 3- Urceolate to suburceolate	100%	64% (54)	27% (23)	40% (34)						
	Hipanthium length	1- ≤1.8mm; 2- between 1.9mm and 2.5mm; 3- between 2.6mm and 3.5mm; 4- ≥3.6mm	98%	49% (42)	42% (36)	28% (24)	15% (13)					
	Merosity	1- Tetramerous; 2- Pentamerous; 3- Hexamerous or more	100%	6% (5)	92% (78)	9% (8)						
Calyx	Internal lobe shape	1- Rounded or obtuse; 2- Triangular or deltoid; 3- Truncate or repand	98%	14% (12)	59% (50)	25% (21)						
	Fruit sepals	1- Persistent; 2- Deciduous	99%	60% (51)	39% (330							
Corola	Petal length	1-≤1.8mm; 2- between 1.9mm and 2.5mm; 3- between 2.6mm and 3.5mm; 4- ≥3.6mm	99%	24% (20)	42% (36)	51% (43)	33% (28)					
	Petal margin	1- Eciliated; 2- Glandular-ciliated	99%	89% (76)	11% (9)							
Androecium	Stamen symmetry	1- Isomorphic; 2-Dimorphic	96%	7% (6)	91% (77)							

	Anther dehiscence	1- Poricide; 2- Longitudinal	98%	91% (77)	7% (6)							
	Connective extension	1- Absent; 2- Present	98%	29% (25)	69% (58)							
	Connective appendices	1- Absent; 2- Dorsal projection; 3- Two ventral projections; 4- Skirt-like	98%	14% (12)	61% (52)	71% (60)	6% (5)					
	Connective glands	1- Absent; 2- Present	91%	79% (67)	12% (10)							
Gynoecium	Style shape	1- Curved; 2- Straight; 3- Sigmoid to subsigmoid.	99%	39% (33)	47% (40)	31% (26)						
	Stigma shape	1- Truncate; 2- Punctiform; 3- Capitate to discoid	99%	46% (39)	4% (3)	52% (44)						
	Ovary position	1- Inferior or partially inferior; 2- Superior	68%	54% (46)	14% (12)							
	Indument on ovary apex	1- Absent; 2- Present.	99%	39% (33)	61% (52)							

Some characters traditionally used in identification keys of Melastomataceae could have ambiguous interpretation, since it requires a degree of subjectivity on the part of the analyzer, such as trichome density and epidermis visibility. Simple trichomes, even with high density, won't make the epidermis invisible. These characters may seem obvious to specialists but may be misidentified by people not used to botany vocabulary, in general, or to Melastomataceae morphology, specifically. To overcome this difficulty, each character and character state are presented along with a brief description and an illustration. The characters and states were illustrated with 140 original images (66 vegetative, 63 reproductive, 11 measurements) and an herbarium sheet digital photo was included representing all 85 species. In some cases, a ludic approach to the drawings was taken to illustrate tactile feeling states or size measurements (Fig.6)

Figure 6. Tactile and size characters illustrated by ludic drawings, exemplifying harder to illustrate *Miconia* s.s. characters and states; A. hand feeling the leaf consistency, B. leather representing a leaf coriaceous consistency, C. ruler measuring the petiole length, D. paper sheet illustrating a leaf membranaceous consistency, E. deck of cards representing a leaf cartaceous consistency, F. toilet paper to represent a leaf papyraceous consistency.



2. The *Miconia* genus in the state of Pará.

The compilation of the database information allowed us to draw an archetypic *Miconia* s.s. from the studied area, considering the most common (occurrence in at least 50% of the taxa) character states. Therefore, *Miconia s.s.* in Pará are, in general, as follows: Shrubs (84%) or trees (66%) with quadrangular young branches (60%), with or without epidermis visible through the indument (64% and 61% respectively). Petiole 4.5-37mm long (69% 4.5-14 mm long, 61% 15-37 mm long). Leaves without domatia (99%), cartaceous or membranaceous (48% and 35% respectively). Elliptic blades (78%) with acute to obtuse base (51% and 47% respectively) and acuminated apex (66%). Basal-3-nerved with two faint marginal veins (73% and 80% respectively). Blade margin eciliated (79%) and entire (72%). Stellate (46%) and dendritic trichomes (24%) present in the entire abaxial surface of the leaves (73%) with visible epidermis (61%). Inflorescences 1.8-15.3cm long (85%) and axillary branches absent (81%). Distal branch flowers scorpioid (64%) or glomerular (64%) and inflorescence epidermis not visible through indument (64%). Pentamerous flowers (92%), hypanthium 0.1-2.5mm long (49% ≤1.8mm; 42% 1.9-2.5mm), campanulate (64%). Calyx with triangular internal lobes (59%), and persistent sepals in fruit (60%). Eciliated petals (89%), 2.6-3.5mm long (51%). Dimorphic stamens (91%) with poricide anthers (91%). Connectives prolonged (69%), with two ventral projections (71%) and without connective glands (79%). Straight or curved styles (47% and 39% respectively) with capitate or discoid stigma (52%) and inferior ovaries (54%) with apical indument (61%).

Regarding the Red List threat level, the Pará *Miconia* had most taxa categorized as “least concerning” (52) threat level, and several species were “not evaluated” yet (33). This can highlight the information gap on the yet understudied conservation of the genus. Studies like this can alert the urgency of investigating the species distribution and conservation status since the few and far between biodiversity analyses might not be enough to cover the already endangered and not yet evaluated.

3. Suggestions for FBO inclusions and removals

The species list included in this work is based on the survey presented by Oliveira (2020). It includes 85 species of Miconia for the state of Pará, this list has a few disagreements in relation to the Flora of Brazil (FBO-Goldenberg et al. 2020), the most complete catalog of plant species for that country. FBO monograph of *Miconia* was largely

based on species records available in online databases (Caddah, pers. comm.), and herbarium collections not registered in those virtual platforms, as MG from Belém, Pará, which holds an important collection of plants from Pará, remained uncovered by that monograph. Therefore, eight species treated here are new records for Pará, while we were not able to confirm the occurrence of nine species cited in FBO and, therefore, we recommend that those records should be reviewed.

3.1. New records of *Miconia* species for the state of Pará

Miconia aulocalyx

This species was analyzed by Oliveira (2020) through two sheets collected in the state of Pará: one new collection (Oliveira 4655) and one reidentification (Ribeiro 2359), formerly identified as *Miconia pubipetala.* However, the distribution is not yet updated in Flora do Brasil (2023).

Miconia bracteata

This species was identified by Oliveira (2020) through two sheets (Rocha 31, Rocha 41) collected in the state of Pará. However, the distribution is not yet updated in Flora do Brasil (2023)

Miconia campestris

This species was reidentified by Oliveira (2020) through one plant sheet (Mexia 5964 - a) collected in the region that was formerly registered as *Mouriri nigra.* However, the distribution is not yet updated in Flora do Brasil (2023).

Miconia cowanii

The species is not yet updated on Flora do Brasil, some earlier *Miconia punctata* sheets (Silva & Nascimento 3991, Cid et al 1356, C. A. Cid Ferreira 1948, C. A. Cid Ferreira 9613, Oliveira, E 3061, Prance et al 24843, Menandro 52, Menandro 56) as well as *Leandra micropetala* and *Miconia argyrophylla* (Freitas 39, Bastos 2233, Santos 508, Fróes 19912) were reidentified by Oliveira (2020).

Miconia rhytidophylla

The only record of the species is deposited in MG (Ducke 10628) and not yet available in the online databases. Thus, still to be included in Flora do Brasil.

Miconia stelligera

Probably not included in Flora do Brasil due to missed oversight (Ducke 15186).

Miconia traillii

Some sheets were not included online, such as (Ducke 17207 and Oliveira 4617) probably deposited in MG. Other ones determined on the web databases as *Miconia santaremensis* and *Miconia dispar* (Oliveira 4638, Goldenberg et al 2252) are now reviewed as *Miconia traillii*.

Miconia tschudyoides

Collection registered in 2021 (Oliveira 70), after the publication of Flora do Brasil in 2020.

Miconia waimiri-atroari Meirelles & Caddah

New species described by Meirelles et al. 2021, after the publication of Flora do Brasil in 2020.

3.2. **Dubious registers in Flora & Funga do Brasil in need of confirmation:**

Miconia biglandulosa

This species is listed in Flora & Funga do Brasil (2023) as occurrent in the state of Pará. However, the only two sheets identified as *M. biglandulosa* in specieslink (Sobral 10564, Silva et al 1015) were reidentified by Oliveira (2019) as *M. tomentosa*. No other records of the species' occurrence in the state were found, therefore, it is suggested that a revaluation of the species distribution in the Flora & Funga do Brasil platform.

Miconia crassinervia

This species is listed in Flora & Funga do Brasil (2023) as occurrent in the state of Pará. However, the only sheet identified as *M. crassinervia* (Silva, 345) was not analyzed in this study or in the synopsis by Oliveira (2019). Thus, the occurrence in the state needs to be confirmed for eventual update of the identification key. No plant sheets of this species were

analyzed meaning that it might occur in the area, but confirmation is still pending for the two sheets collected in the state (Huber 2121, Silva 345)

Miconia dodecandra

This species is listed in Flora & Funga do Brasil (2023) as occurrent in the state of Pará. However, the only sheet identified as *M.* dodecantra (Silva 1269) was not analyzed in this or in the synopsis by Oliveira (2019). Thus, the occurrence in the state needs to be confirmed for eventual update of the identificaion key. Only one collection of this species took place in Pará (Silva1269), may still need confirmation of its occurrence.

Miconia lourteigiana

This species is listed in Flora & Funga do Brasil (2023) as occurrent in the state of Pará. However, the two sheets identified as *M. lourteigiana* in specieslink (Ribeiro & Pinheiro 1302, MR dos Santos 566) were reidentified by Oliveira (2019) as *M. navioensis.* No other record suggest the occurrence in the state, thus, it is suggested a revaluation of the species distribution in the Flora & Funga do Brail platform.

Miconia punctata

Many sheets of this species were reviewed as *Miconia cowanii* (Cid 1356, Cid 1948, Cid 9613, Ferreira 9613, Menandro 52, Menandro 56, Oliveira 3061, Prance et al 24843, Silva 3963), one was reviewed as *Miconia renatogoldenbergii* (Amaral et al 874) and a few are still needing analysis (Amaral 1042, Bringel 331, Junqueira 1105, Silva 73, Silva 190 and Silva 1436) for a better judgment of the occurrence of *Miconia punctata* in Pará.

Miconia racemosa

This species is morphologically similar to *Miconia ciliata*, which occurs in Pará, but *Miconia racemosa* is yet to be confirmed in the state. One collection of *Miconia racemosa* with a few duplicates (Sobel 4934) was collected in Pará, but the identification is in need of revision.

Miconia stellulata

This species is listed in Flora & Funga do Brasil (2023) as occurrent in the state of Pará. However, the couple of sheets identified as *M. stellulata* in specieslink (Sobral 9708, Sobral

9928) were reidentified by Oliveira (2019) as *M rimachii*. No other records were found suggesting this species occurrence in the state, thus, it is advised to correct the distribution of this species in the Flora & Funga do Brasil platform.

Miconia stephananthera

This species is listed in Flora & Funga do Brasil (2023) as occurrent in the state of Pará. However, two of three sheets identified as *M. stephananthera* (Black 18619, Black 18620) were too damaged for analysis and accurate identification, while the third sheet (Spruce 1850) was not analyzed in this study or in the synopsis by Oliveira (2019) and is marked as c.f. (*conferatum*). Thus, the occurrence confirmation of this species is still pending for eventual update of the identification key.

Miconia tetrasperma

This species is listed in Flora & Funga do Brasil (2023) as occurrent in the state of Pará. However, the only record identified as *M. tetrasperma* on specieslink (Prance 25822) was reidentified by Oliveira (2019) as *M. tetraspermoides.* Thus, the occurrence confirmation of this species is still pending for eventual update of the identification key.

Conclusions

The Amazon domain represents one of the most challenging portions of the world when it comes to biodiversity knowledge because of the large not sampled areas and its high degree of richness (Hopkins 2007; Cardoso et al. 2017). Like other vegetations in similar situation, any taxonomic treatment of its flora is frequently considered outdated in a matter of a few years because of the constant new discoveries (Bittrich et al. 2012). Interactive keys in Brazil are still on the early days of wider use and could represent an alternative tool to speed up biodiversity knowledge.

We produced an interactive, multiple-access, digital key to the identification of species of *Miconia* s.s. (= *Miconia* sensu Cogniaux 1891, see Michelangeli *et al.* 2022) of the state of Pará, northern Brazil. It encompasses a large portion of the diversity of the genus in the Amazon domain and, apart of species identification, it can be also used as template for producing new *Miconia* keys, or simply be updated to contemplate more inclusive and/or natural regions. Like any other multiple access identification key, this key had the initial

disadvantage of requiring a higher effort for gathering of all character states of every taxa (or most of them) for every added character. If used as a template for other areas, it's important that the character states of this key get reassessed to contemplate a possible morphological variation. Also, as the species identifiable in the key have many characters specific to the genus, it has limited usefulness as a template for other taxa. However, as an online tool, the key can also be enhanced by adding new character states when species polymorphism is observed, or by filling missing information, the ones we fail to find in the vouchers examined or in the consulted literature. The more complete the key, the more trustworthy the identification will be. Since the tool produced in this study is open-access, it also contributes to the reassessment of data, furthermore, building a cohesive collaborative effort in taxonomy studies.

This study shows that well-made digital interactive keys are viable and can be accurate identification tools for species in phytogeographic regions with information gaps. Fields researchers may benefit with the reduction in equipment weight by utilizing the updatable data compiled in these keys. We are now aware of some difficulties not only regarding the successful identification of the biggest genus of Melastomataceae, but also possible means of solving the challenges in interactive key confection.

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APÊNDICE 1: Chave elaborada automaticamente pelo Xper3 para Miconia s.s. do Pará, norte do Brasil, a partir do banco de dados elaborado neste trabalho.

1 Folhas: Tipo de tricomas:

- Ausente *2*
- Aracnóide *3*
- Dendrítico *4*
- Escamiforme *5*
- Estrelado *6*
- Glandulares ..... *Miconia amapaënsis*
- Lepidoto *7*
- Simples *8*

2 Gineceu: Posição do ovário:

- Ínfero ou parcialmente ínfero ..... *Miconia poeppigii*
- Súpero ..... *Miconia lasseri*

3 Gineceu: Forma do estilete:

- Curvo *9*
- Reto *10*
- Subsigmoide a sigmoide *11*

4 Folhas: Consistência da lâmina:

- Papirácea *12*
- Membranácea *13*
- Cartácea *14*
- Coriácea *15*

5 Folhas: Base da lâmina:

- Aguda... ..... *16*
- Arredondada *17*
- Cordada ou cordulada *18*
- Obtusa *19*
- Truncada ..... *Miconia myriantha*

6 Folhas: Consistência da lâmina:

- Papirácea *20*
- Membranácea *21*
- Cartácea *22*
- Coriácea *23*

7 Cálice: Forma dos lobos internos:

Arredondada ou obtusa *24*
Triangular ou deltoide *25*
Truncada ou repanda *26*

8 Cálice: Forma dos lobos internos:
Arredondada ou obtusa ..... *Miconia bracteata*
Triangular ou deltoide *27*
Truncada ou repanda *28*

9 Folhas: Consistência da lâmina:
Papirácea ..... *Miconia secundiflora*
Membranácea ..... *Miconia argyrophylla ssp. gracilis*
Cartácea ..... *Miconia argyrophylla*
Coriácea *29*

10 Folhas: Consistência da lâmina:
Papirácea ..... *Miconia serialis*
Cartácea *30*
Coriácea *31*

11 Inflorescências: Comprimento:
Entre 1,8 e 15,3 cm *32*
Entre 15,3 e 22,5 cm ..... *Miconia gratissima*
22,5 cm ou maior ..... *Miconia ampla*

12 Gineceu: Forma do estigma:
Truncado ..... *Miconia traillii*
Capitado a discoide ..... *Miconia tomentosa*

13 Inflorescência: Disposição das flores nos ramos distais:
Dicasiais ..... *Miconia rimachii*
Escorpióides a subescorpioides *33*
Glomeruladas a subglomeruladas *34*

14 Folhas: Base da lâmina:
Aguda *35*
Arredondada ..... *Miconia mirabilis*
Cordada ou cordulada *36*
Cuneada ..... *Miconia platypoda*
Obtusa *37*

15 Flores: Comprimento do hipanto:
Hipanto até 1,8 mm *38*

Hipanto entre 1,9 e 2,5 mm ..... *Miconia rhytidophylla*
Hipanto entre 2,6 e 3,5 mm ..... *Miconia campestris*

16 Gineceu: Forma do estigma:
Truncado ..... *Miconia tetraspermoides*
Capitado a discoide ..... *Miconia pyrifolia*

17 Folhas: Formato da lâmina:
Ovada ..... *Miconia pyrifolia*
Elíptica ..... *Miconia pyrifolia*
Lanceolada ..... *Miconia myriantha*
Oblonga ..... *Miconia manauara*

18 Ramos jovens: Visibilidade da epiderme:
Epiderme não visível a olho nu: completamente cobertos por indumento .....
..... *Miconia manauara*
Epiderme vísível a olho nu: não cobertos por indumento ou cobertos apenas parcialmente ..... *Miconia mattogrossensis*

19 Gineceu: Indumento no ápice do ovário:
Indumento ausente ..... *Miconia minutiflora*
Indumento presente ..... *Miconia tetraspermoides*

20 Ramos jovens: Forma:
Cilíndricos ..... *Miconia waimiri-atroari*
Quadrangulares *39*

21 Gineceu: Forma do estilete:
Curvo *40*
Reto *41*
Subsigmoide a sigmoide *42*

22 Cálice: Forma dos lobos internos:
Arredondada ou obtusa *43*
Triangular ou deltoide *44*
Truncada ou repanda *45*

23 Inflorescência: Disposição das flores nos ramos distais:
Dicasiais *46*
Escorpióides a subescorpioides *47*
Glomeruladas a subglomeruladas *48*

24 Gineceu: Forma do estilete:

Curvo ..... *Miconia chrysophylla*
Reto ..... *Miconia elata*
Subsigmoide a sigmoide ..... *Miconia pubipetala*

25 Gineceu: Indumento no ápice do ovário:
Indumento ausente *49*
Indumento presente *50*

26 Gineceu: Forma do estigma:
Truncado ..... *Miconia renatogoldenbergii*
Capitado a discoide ..... *Miconia dichrophylla*

27 Flores: Comprimento do hipanto:
Hipanto até 1,8 mm ..... *Miconia ciliata*
Hipanto entre 1,9 e 2,5 mm *51*
Hipanto entre 2,6 e 3,5 mm ..... *Miconia radulifolia*
Hipanto com 3,6 mm ou maior *52*

28 Gineceu: Forma do estilete:
Curvo *53*
Reto *54*

29 Gineceu: Forma do estigma:
Truncado ..... *Miconia stenostachya*
Punctiforme ..... *Miconia fallax*

30 Ramos jovens: Forma:
Cilíndricos ..... *Miconia navioensis*
Quadrangulares ..... *Miconia hypoleuca*

31 Gineceu: Forma do estigma:
Truncado ..... *Miconia alborufescens*
Capitado a discoide ..... *Miconia albicans*

32 Gineceu: Posição do ovário:
Ínfero ou parcialmente ínfero ..... *Miconia truncata*
Súpero ..... *Miconia holosericea*

33 Gineceu: Indumento no ápice do ovário:
Indumento ausente ..... *Miconia wagneri*
Indumento presente ..... *Miconia dispar*

34 Gineceu: Forma do estigma:

Truncado *55*
Capitado a discoide *56*

35 Cálice: Forma dos lobos internos:
Arredondada ou obtusa ..... *Miconia egensis*
Triangular ou deltoide ..... *Miconia dispar*
Truncada ou repanda ..... *Miconia mirabilis*

36 Gineceu: Forma do estilete:
Reto ..... *Miconia aliquantula*
Subsigmoide a sigmoide ..... *Miconia serrulata*

37 Gineceu: Indumento no ápice do ovário:
Indumento ausente ..... *Miconia sagotiana*
Indumento presente *57*

38 Cálice: Sépalas na frutificação:
Persistente ..... *Miconia ferruginata*
Caduco ..... *Miconia rubiginosa*

39 Gineceu: Forma do estigma:
Truncado ..... *Miconia traillii*
Capitado a discoide ..... *Miconia tomentosa*

40 Corola: Comprimento das pétalas:
Pétalas com até 1,8 mm *58*
Pétalas entre 1,9 e 2,5 mm *59*
Pétalas entre 2,6 e 3,6 mm *60*
Maiores que 3,6 mm *61*

41 Inflorescências: Ramos axilares:
Ausentes *62*
Presentes *63*

42 Corola: Margem das pétalas:
Eciliadas ..... *Miconia melinonis*
Glandular-cilioladas ..... *Miconia pubipetala*

43 Inflorescência: Disposição das flores nos ramos distais:
Dicasiais ..... *Miconia egensis*
Glomeruladas a subglomeruladas ..... *Miconia calvescens*
Umbeliformes ..... *Miconia pubipetala*

44 Folhas: Base da lâmina:

Aguda *64*
Arredondada ..... *Miconia pyrifolia*
Atenuada ..... *Miconia alata*
Cordada ou cordulada *65*
Cuneada ..... *Miconia platypoda*
Decurrente *66*
Obtusa *67*

45 Inflorescência: Disposição das flores nos ramos distais:

Dicasiais ..... *Miconia staminea*
Escorpióides a subescorpioides *68*
Glomeruladas a subglomeruladas ..... *Miconia longispicata*

46 Gineceu: Forma do estigma:

Truncado ..... *Miconia phaeophylla*
Capitado a discoide ..... *Miconia brevipes*

47 Gineceu: Forma do estigma:

Truncado ..... *Miconia macrothyrsa*
Capitado a discoide ..... *Miconia ferruginata*

48 Cálice: Forma dos lobos internos:

Triangular ou deltoide ..... *Miconia rufescens*
Truncada ou repanda ..... *Miconia aplostachya*

49 Gineceu: Forma do estigma:

Truncado ..... *Miconia cowanii*
Capitado a discoide ..... *Miconia lepidota*

50 Inflorescência: Disposição das flores nos ramos distais:

Dicasiais ..... *Miconia splendens*
Escorpióides a subescorpioides ..... *Miconia trinervia*
Glomeruladas a subglomeruladas ..... *Miconia aulocalyx*

51 Gineceu: Indumento no ápice do ovário:

Indumento ausente ..... *Miconia matthaei*
Indumento presente *69*

52 Androceu: Apêndices no conectivo:

Apêndices completamente ausentes ..... *Miconia radulifolia*
Uma projeção dorsal (em ao menos um dos ciclos de estames) .....
..... *Miconia lappacea*

53 Flores: Merosidade:

5 (flores pentâmeras) ..... *Miconia nervosa*

6 (flores hexâmeras) ou mais ..... *Miconia santaremensis*

54 Gineceu: Forma do estigma:

Truncado ..... *Miconia amapaënsis*

Capitado a discoide ..... *Miconia ceramicarpa*

55 Gineceu: Forma do estilete:

Curvo ..... *Miconia stelligera*

Reto ..... *Miconia astrotricha*

56 Androceu: Apêndices no conectivo:

Uma projeção dorsal (em ao menos um dos ciclos de estames) .... *Miconia diaphanea*

Duas projeções ventrais (em ao menos um dos ciclos de estames) .... *Miconia lanata*

57 Gineceu: Forma do estigma:

Truncado ..... *Miconia dolichorrhyncha*

Capitado a discoide ..... *Miconia dispar*

58 Androceu: Prolongamento do conectivo:

Prolongamento ausente ..... *Miconia lateriflora*

Prolongamento presente ..... *Miconia tetraspermoides*

59 Gineceu: Forma do estigma:

Truncado ..... *Miconia longifolia*

Capitado a discoide ..... *Miconia dispar*

60 Inflorescência: Disposição das flores nos ramos distais:

Dicasiais ..... *Miconia longifolia*

Escorpióides a subescorpioides ..... *Miconia dispar*

Glomeruladas a subglomeruladas ..... *Miconia matthaei*

Umbeliformes ..... *Miconia longifolia*

61 Androceu: Glândulas no conectivo:

Glândulas Ausentes ..... *Miconia cuspidata*

Glândulas Presentes ..... *Miconia rimachii*

62 Ramos jovens: Visibilidade da epiderme:

Epiderme não visível a olho nu: completamente cobertos por indumento .....

..... *Miconia manauara*

Epiderme vísível a olho nu: não cobertos por indumento ou cobertos apenas parcialmente ..... *Miconia myriantha*

63 Folhas: Base da lâmina:

Cordada ou cordulada ..... *Miconia mattogrossensis*

Obtusa ..... *Miconia minutiflora*

64 Gineceu: Indumento no ápice do ovário:

Indumento ausente *70*

Indumento presente *71*

65 Gineceu: Indumento no ápice do ovário:

Indumento ausente ..... *Miconia alternans*

Indumento presente ..... *Miconia serrulata*

66 Folhas: Ápice da lâmina:

Agudo *72*

Acuminado *73*

Atenuado ..... *Miconia elegans*

67 Gineceu: Indumento no ápice do ovário:

Indumento ausente *74*

Indumento presente *75*

68 Androceu: Glândulas no conectivo:

Glândulas Ausentes *76*

Glândulas Presentes ..... *Miconia heliotropoides*

69 Gineceu: Posição do ovário:

Ínfero ou parcialmente ínfero ..... *Miconia ibaguensis*

Súpero ..... *Miconia tschudyoides*

70 Gineceu: Forma do estigma:

Truncado ..... *Miconia affinis*

Capitado a discoide ..... *Miconia prasina*

71 Gineceu: Forma do estilete:

Curvo *77*

Reto ..... *Miconia pyrifolia*

72 Gineceu: Indumento no ápice do ovário:

Indumento ausente ..... *Miconia prasina*

Indumento presente ..... *Miconia alata*

73 Cálice: Sépalas na frutificação:

Persistente ..... *Miconia alternans*

Caduco ..... *Miconia prasina*

74 Gineceu: Forma do estigma:

Truncado ..... *Miconia affinis*

Capitado a discoide ..... *Miconia alternans*

75 Gineceu: Forma do estigma:

Truncado ..... *Miconia dolichorrhyncha*

Capitado a discoide ..... *Miconia dispar*

76 Flores: Comprimento do hipanto:

Hipanto até 1,8 mm ..... *Miconia eriodonta*

Hipanto entre 1,9 e 2,5 mm ..... *Miconia ruficalyx*

77 Ramos jovens: Forma:

Cilíndricos ..... *Miconia regelii*

Quadrangulares ..... *Miconia díspar*

Apêndice 2: Tabela de caracteres presentes em *Miconia* s.s. do estado do Pará com seus respectivos potenciais discriminatórios medidos nos índices XPER, Sokal & Michener e Jaccard por meio do software Xper2:

		XPER	Sokal & Michener	Jaccard
[1. Ramos jovens]	1. Hábito: Forma de crescimento	406/3570 (0.11)	1309/3570 (0.37)	1309/3570 (0.37)
[1. Ramos jovens]	2. Ramos jovens: Visibilidade da epiderme	1500/3570 (0.42)	1700/3570 (0.48)	1700/3570 (0.48)
[2. Folhas]	3. Ramos jovens: Forma	1700/3570 (0.48)	1742/3570 (0.49)	1742/3570 (0.49)
[2. Folhas]	4. Folhas: Comprimento dos pecíolos	959/3570 (0.27)	1460/3570 (0.41)	2073/3570 (0.58)
[2. Folhas]	5. Folhas: Visibilidade da epiderme na superfície abaxial	1716/3570 (0.48)	1716/3570 (0.48)	1716/3570 (0.48)
[2. Folhas]	6. Folhas: Presença de tricomas na superfície abaxial	1403/3570 (0.39)	1445/3570 (0.4)	1445/3570 (0.4)

[2. Folhas]	7. Folhas: Tipo de tricomas	2483/3570 (0.7)	797/3570 (0.22)	2790/3570 (0.78)
[2. Folhas]	8. Folhas: Nervuras principais (primária mais secundárias acródromas)	1171/3570 (0.33)	809/3570 (0.23)	1179/3570 (0.33)
[2. Folhas]	9. Folhas: Venação	1334/3570 (0.37)	1496/3570 (0.42)	1496/3570 (0.42)
[2. Folhas]	10. Folhas: Consistência da lâmina	2194/3570 (0.61)	1239/3570 (0.35)	2392/3570 (0.67)
[2. Folhas]	11. Folhas: Base da lâmina	1967/3570 (0.55)	880/3570 (0.25)	2743/3570 (0.77)
[2. Folhas]	12. Folhas: Margem da lâmina	1124/3570 (0.31)	1319/3570 (0.37)	2023/3570 (0.57)
[2. Folhas]	13. Folhas: Cílios nas margens da lâmina	1206/3570 (0.34)	1206/3570 (0.34)	1206/3570 (0.34)
[2. Folhas]	14. Folhas: Domácias	84/3570 (0.02)	84/3570 (0.02)	84/3570 (0.02)
[3. Inflorescência]	15. Inflorescências: Ramos axilares	1005/3570 (0.28)	1128/3570 (0.32)	1128/3570 (0.32)
[3. Inflorescência]	16. Inflorescências: Comprimento	780/3570 (0.22)	927/3570 (0.26)	1561/3570 (0.44)
[3. Inflorescência]	17. Inflorescência: Disposição das flores nos ramos distais	2275/3570 (0.64)	1282/3570 (0.36)	2439/3570 (0.68)
[4. Flores]	18. Flores: Forma do hipanto	1772/3570 (0.5)	1419/3570 (0.4)	2054/3570 (0.58)
[4. Flores]	19. Flores: Comprimento do hipanto	1737/3570 (0.49)	1543/3570 (0.43)	2413/3570 (0.68)
[4. Flores]	20. Flores: Merosidade	539/3570 (0.15)	495/3570 (0.14)	733/3570 (0.21)
[6. Corola]	21. Corola: Comprimento das pétalas	1696/3570 (0.48)	1637/3570 (0.46)	2467/3570 (0.69)
[6. Corola]	22. Corola: Margem das pétalas	600/3570 (0.17)	683/3570 (0.19)	683/3570 (0.19)
[5. Cálice]	23. Cálice: Forma dos lobos internos	1902/3570 (0.53)	1379/3570 (0.39)	2012/3570 (0.56)
[5. Cálice]	24. Cálice: Sépalas na frutificação	1683/3570 (0.47)	1725/3570 (0.48)	1725/3570 (0.48)
[7. Androceu]	25. Androceu: Simetria dos estames	380/3570 (0.11)	542/3570 (0.15)	542/3570 (0.15)
[7. Androceu]	26. Androceu: Deiscência das anteras	462/3570 (0.13)	545/3570 (0.15)	545/3570 (0.15)

[7. Androceu]	27. Androceu: Prolongamento do conectivo	1450/3570 (0.41)	1533/3570 (0.43)	1533/3570 (0.43)
[7. Androceu]	28. Androceu: Apêndices no conectivo	1098/3570 (0.31)	1160/3570 (0.32)	1859/3570 (0.52)
[7. Androceu]	29. Androceu: Glândulas no conectivo	670/3570 (0.19)	978/3570 (0.27)	978/3570 (0.27)
[8. Gineceu]	30. Gineceu: Forma do estigma	1796/3570 (0.5)	1308/3570 (0.37)	1911/3570 (0.54)
[8. Gineceu]	31. Gineceu: Posição do ovário	552/3570 (0.15)	1335/3570 (0.37)	1335/3570 (0.37)
[8. Gineceu]	32. Gineceu: Indumento no ápice do ovário	1632/3570 (0.46)	1715/3570 (0.48)	1715/3570 (0.48)
[2. Folhas]	33. Folhas: Ápice da lâmina	1315/3570 (0.37)	1100/3570 (0.31)	2172/3570 (0.61)
[3. Inflorescência]	34. Inflorescências: Visibilidade da epiderme dos ramos	1500/3570 (0.42)	1700/3570 (0.48)	1700/3570 (0.48)
[2. Folhas]	35. Folhas: Formato da lâmina	810/3570 (0.23)	1110/3570 (0.31)	2188/3570 (0.61)
[8. Gineceu]	36. Gineceu: Forma do estilete	2101/3570 (0.59)	1511/3570 (0.42)	2225/3570 (0.62)

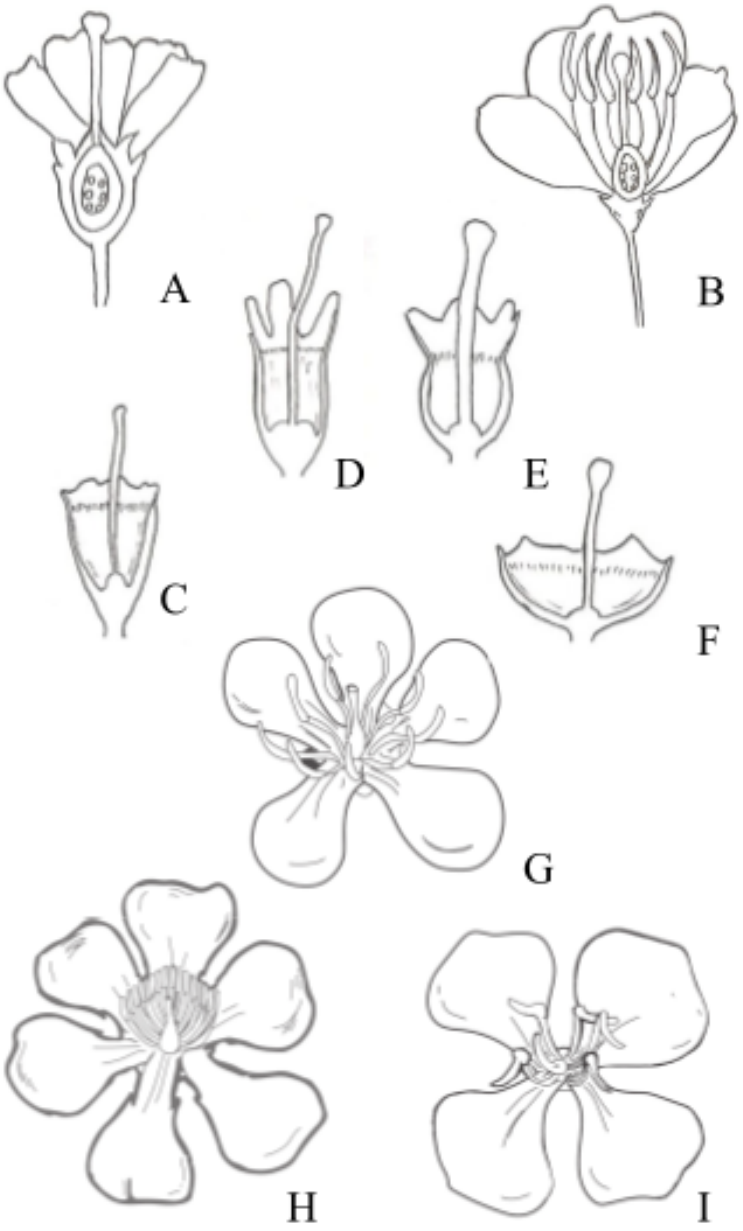
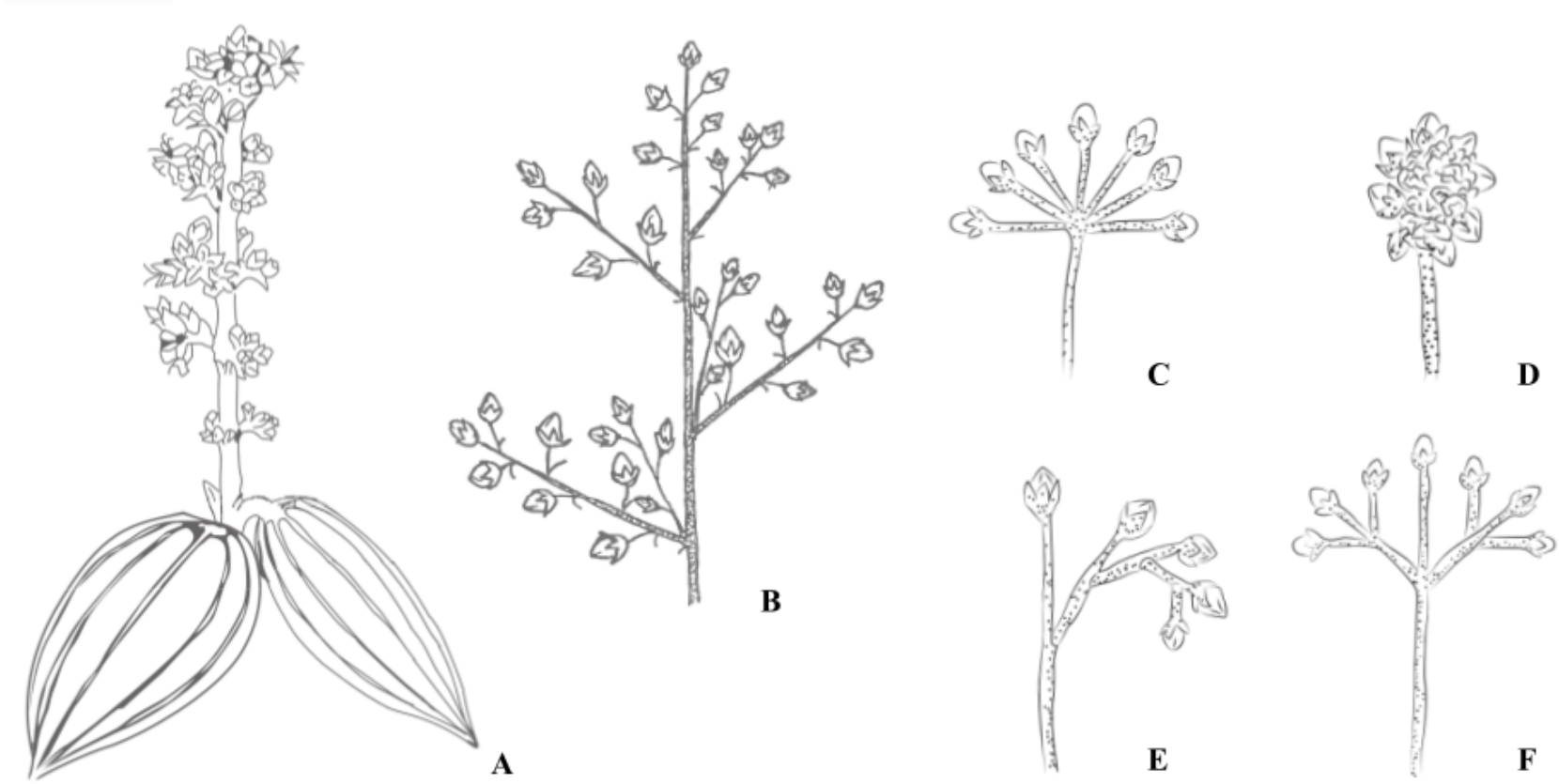


Figure 1. Flower morphologic details present in the species of Pará as seen the key – A-B. Ovary position; A. inferior;,B. superior – C-F. Hipantium shape; C. campanulate, D. tubular, E. urceolate, F. semi-elliptic – H-I. Merosity; H. hexamerous, G. pentamerous, I. tetramerous

.Figure 2. Some



inflorescence characters and states as seen in the key – A. *Miconia* sp. inflorescence, B. inflorescence with axilar branches, C-F. Flower placement in distal branches, C. umbela, D. glomerulus, E. scorpioid, F. dichasium.

Categories	Characters	States	Coverage	States distribution								
				1	2	3	4	5	6	7	8	9
Habit	Growth pattern	1- Tree; 2- Schrub	100%	66% (56)	84% (71)							
Young branches	Shape	1- Cylindrical; 2- Quadrangular	100%	41% (35)	60% (51)							
	Epidermis visibility	1- Invisible to the naked eye; 2- Visible to the naked eye	99%	64% (54)	61% (52)							
Leaves	Petiole length	1-≤4.5mm; 2- between 4.5mm and 14mm; 3- between 15mm and 37mm;4- ≥38mm	100%	33% (28)	69% (59)	61% (52)	16% (14)					
	Blade shape	1- Ovate; 2- Elliptic; 3- Lanceolate; 4- Oblanceolate; 5- Oblong; 6- Obovate	100%	51% (43)	78% (66)	46% (39)	8% (7)	18% (15)	5% (4)			
	Blade consistency	1-Papyraceous; 2- Membranaceous; 3- Cartaceous; 4 - Coriaceous	100%	6% (5)	35% (30)	48% (41)	19% (16)					
	Main veins*	1- Three; 2- Three plus two faint veins; 3- Five plus two faint veins	100%	2% (2)	80% (68)	19% (16)						
	Venation	1- Basal; 2- Suprabasal	100%	73% (62)	32% (27)							
	Blade base	1- Acute; 2- Rounded; 3- Atenuated; 4- Auriculated; 5- Cordate or cordulate; 6- Cuneate; 7- Decurrent; 8- Obtuse; 9- Truncate	100%	51% (43)	34% (29)	5% (4)	1% (1)	28% (24)	2% (2)	15% (13)	47% (40)	6% (5)
	Domatia	1- Absent; 2- Present.	100%	99% (84)	1% (1)							
	Blade apex	1- Rounded; 2- Acute; 3- Acuminated; 4- Atenuated; 5- Obtuse	99%	4% (3)	27% (23)	66% (56)	41% (35)	5% (4)				
	Blade margin	1- Entire; 2- Crenulate; 3- Serrate to dentate; 4- Ondulate	99%	72% (61)	11% (9)	35% (30)	26% (22)					
	Leaf margin cilia	1- Absent; 2- Present	100%	79% (67)	21% (18)							
	Abaxial trichome	1- Present on the entire blade; 2- Entirely absent or only on the veins	100%	73% (62)	28% (24)							

	Abaxial epidermis	1- Invisible to the naked eye; 2- Visible to the naked eye	100%	39% (33)	61% (52)							
	Trichome type	1- Absent; 2- Aracnoid; 3- Dendritic; 4- Scaly; 5- Stellate; 6- Glandular; 7- Lepidote; 8- Simple	100%	2% (2)	16% (14)	24% (20)	7% (6)	46% (39)	1% (1)	12% (10)	13% (11)	
Inflorescences	Axillary branches	1- Absent; 2- Present	99%	81% (69)	20% (17)							
	Total length	1-≤1.8cm; 2- between 1.8cm and 15.3cm; 3- between 15.3cm and 22.5cm;4- ≥ 22,5cm	100%	1% (1)	85% (72)	38% (32)	16% (14)					
	Flowers in distal branches	1- Dichasial; 2- Scorpioid to subscorpioid; 3- Glomerular to subglomerular; 4- Umbeliform.	100%	41% (35)	64% (54)	64% (54)	4% (3)					
	Branch epidermis	1- Invisible to the naked eye; 2- Visible to the naked eye	99%	64% (54)	40% (34)							
Flowers	Hipanthium shape	1- Campanulate to semi-elliptic; 2- Tubular; 3- Urceolate to suburceolate	100%	64% (54)	27% (23)	40% (34)						
	Hipanthium length	1- ≤1.8mm; 2- between 1.9mm and 2.5mm; 3- between 2.6mm and 3.5mm; 4- ≥3.6mm	98%	49% (42)	42% (36)	28% (24)	15% (13)					
	Merosity	1- Tetramerous; 2- Pentamerous; 3- Hexamerous or more	100%	6% (5)	92% (78)	9% (8)						
Calyx	Internal lobe shape	1- Rounded or obtuse; 2- Triangular or deltoid; 3- Truncate or repand	98%	14% (12)	59% (50)	25% (21)						
	Fruit sepals	1- Persistent; 2- Deciduous	99%	60% (51)	39% (330							
Corola	Petal length	1-≤1.8mm; 2- between 1.9mm and 2.5mm; 3- between 2.6mm and 3.5mm; 4- ≥3.6mm	99%	24% (20)	42% (36)	51% (43)	33% (28)					
	Petal margin	1- Eciliated; 2- Glandular-ciliated	99%	89% (76)	11% (9)							
Androecium	Stamen symmetry	1- Isomorphic; 2-Dimorphic	96%	7% (6)	91% (77)							
	Anther dehiscence	1- Poricide; 2- Longitudinal	98%	91% (77)	7% (6)							

	Connective extension	1- Absent; 2- Present	98%	29% (25)	69% (58)							
	Connective appendices	1- Absent; 2- Dorsal projection; 3- Two ventral projections; 4- Skirt-like	98%	14% (12)	61% (52)	71% (60)	6% (5)					
	Connective glands	1- Absent; 2- Present	91%	79% (67)	12% (10)							
Gynoecium	Style shape	1- Curved; 2- Straight; 3- Sigmoid to subsigmoid.	99%	39% (33)	47% (40)	31% (26)						
	Stigma shape	1- Truncate; 2- Punctiform; 3- Capitate to discoid	99%	46% (39)	4% (3)	52% (44)						
	Ovary position	1- Inferior or partially inferior; 2- Superior	68%	54% (46)	14% (12)							
	Indument on ovary apex	1- Absent; 2- Present.	99%	39% (33)	61% (52)							

CONSIDERAÇÕES FINAIS

O já importante gênero *Miconia* tornou-se ainda maior ao englobar toda a tribo Miconieae em sua mais recente circunscrição, estando hoje entre os 10 maiores gêneros de angiospermas nos Neotrópicos (Michelangeli et al. 2022). O presente trabalho produziu uma chave restrita à circunscrição anterior (*Miconia* s.s.) para o estado do Pará, representando um primeiro passo em direção de uma chave interativa para *Miconia* sensu lato. A descrição em detalhes das presentes 85 táxons é a nossa contribuição para esse objetivo.

Apesar da praticidade da ferramenta online e gratuita, a natureza online do software traz consigo algumas desvantagens, como uma dependência de conexão com a rede para acesso, edição e upload de arquivos. É possível fazer o download da chave, para evitar a necessidade de conexão, mas nesse caso, o download se dá na forma de chave tradicional (ver apêndice 1), perdendo a interface interativa da chave em prol de um arquivo pdf offline. Instabilidades do servidor do Xper também causam contratempos, impossibilitando a edição ocasionalmente durante um dia inteiro. Durante a confecção deste trabalho, o servidor não salvou edições em alguns momentos, fazendo com que o progresso a curto prazo fosse perdido. Além disso, algumas funções do Xper2 foram omitidas no Xper3, como o gerador dos índices de confiabilidade. Isso pode gerar a necessidade da utilização da versão antiga para obtenção desses dados por ocasião de atualização ou ampliação da chave, caso haja interesse.

Porém, junto destas dificuldades, esta pesquisa demonstrou que o aperfeiçoamento da técnica do desenvolvimento de ferramentas de identificação interativa é exequível. A facilidade de compartilhamento da base de dados agiliza o processo da construção colaborativa destas tecnologias. Outros táxons podem ser incluídos no banco de dados conforme novos registros forem detectados.

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