

UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL  
DEPARTAMENTO DE BOTÂNICA  
PROGRAMA DE PÓS-GRADUAÇÃO EM BOTÂNICA

**TRADITIONAL USES, POLLINATION, AND REPRODUCTIVE BIOLOGY FOR  
NEOTROPICAL ARECACEAE SPECIES**

OSCAR ADOLFO PERDOMO BÁEZ

Orientador: Dr. Rodrigo Bustos Singer (UFRGS)

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Tese apresentada ao Programa de Pós-graduação  
em Botânica da Universidade Federal do Rio  
Grande do Sul, como requisito parcial para a  
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## RESUMEN

Areacaceae es de gran importancia para las comunidades indígenas y campesinas que las han usado como fuente de alimento, madera, hojas para techos, lugares de caza, materiales para artesanías entre otros. Los nombres comunes y usos de las palmas reflejan la historia de esta relación. Pero parte de esas informaciones se encuentran asociadas con los nombres sinonimizados, los cuales pueden ser ignorados en revisiones etnobotánicas, cuyas informaciones son de gran interés para alcanzar el uso sustentable y la conservación de las especies. Otra información relevante en este campo es la biología reproductiva y la identificación de los visitantes florales y polinizadores, las cuales revelan la interacción de las plantas con la fauna local. En este estudio buscamos responder si la inclusión de los nombres científicos válidos y los que se encuentran sinonimizados, pero que fueron citados anteriormente en otros trabajos, puede incrementar la cantidad de información etnobotánica recuperada. Para esto realizamos una revisión de los usos y nombres comunes de las especies del género *Euterpe* Mart., distribuidas desde el sur de Brasil hasta el norte de Colombia, comúnmente llamadas Asaí, usando diferentes bases de datos para determinar la cantidad de información recuperada con cada uno. También determinamos el sistema sexual, identificamos los polinizadores y las perspectivas de uso sustentable y conservación de las palmas neotropicales *Butia lallemantii* y *Bactris setosa* nativas de los biomas Pampa y Mata Atlántica, respectivamente. Para esto realizamos experimentos de polinización para evaluar alogamia, autopolinización, autogamia, geitonogamia, apomixia, y polinización natural. La inclusión de los sinónimos de las especies incrementó la recuperación de usos en 11.1% e de nombres comunes en 17.8%. Así, la exclusión de los sinónimos de las especies implica la pérdida de información etnobotánica relevante. Identificamos que *B. lallemantii* y *B. setosa* son autocompatibles y polinizadas principalmente por Coleópteros, Himenópteros y Dípteros, a pesar de que la antesis sucede en el día en el primer caso, y en el día y la noche para el segundo, indicando la relevancia de esta información para la reproducción y conservación de esas especies. Ambas especies tienen un gran potencial para su inclusión en sistemas agroforestales y en la diversificación de agroecosistemas, lo cual incrementa sus posibilidades de uso sustentable y conservación.

**Palabras clave:** autoincompatibilidad, etnobotánica, nombres comunes, polinizadores, sinonimización, sistema sexual, visitantes florales, usos.

## RESUMO

A família Arecaceae é de grande importância para as comunidades indígenas e camponesas, que as têm utilizado como fonte de alimento, madeira, folhas para coberturas, locais de caça, materiais para artesanato, entre outros. Os nomes comuns e usos das palmeiras refletem a história dessa relação. No entanto, parte dessas informações está associada aos nomes sinonimizados, que podem ser ignorados em revisões etnobotânicas, cujas informações são de grande interesse para alcançar o uso sustentável e a conservação das espécies. Outra informação relevante nesse campo é a biologia reprodutiva e a identificação dos visitantes florais e polinizadores, que revelam a interação das plantas com a fauna local. Neste estudo, buscamos responder se a inclusão dos nomes científicos válidos e dos sinonimizados, mas que foram citados anteriormente em outros trabalhos, pode aumentar a quantidade de informação etnobotânica recuperada. Para isso, realizamos uma revisão dos usos e nomes comuns das espécies do gênero *Euterpe* Mart., distribuídas do sul do Brasil ao norte da Colômbia, comumente chamadas de Açaí, usando diferentes bases de dados para determinar a quantidade de informação recuperada com cada uma. Também determinamos o sistema sexual, identificamos os polinizadores e as perspectivas de uso sustentável e conservação das palmeiras neotropicais *Butia lallemantii* e *Bactris setosa*, nativas dos biomas Pampa e Mata Atlântica, respectivamente. Para isso, realizamos experimentos de polinização para avaliar a alogamia, autopolinização, autogamia, geitonogamia, apomixia e polinização natural. A inclusão dos sinônimos das espécies aumentou a recuperação de usos em 11,1% e de nomes comuns em 17,8%. Portanto, a exclusão dos sinônimos das espécies implica na perda de informações etnobotânicas relevantes. Identificamos que *B. lallemantii* e *B. setosa* são autocompatíveis e polinizadas principalmente por Coleópteros, Himenópteros e Dípteros, apesar de que a antese ocorre durante o dia no primeiro caso e durante o dia e a noite no segundo, indicando a relevância dessas informações para a reprodução e conservação dessas espécies. Ambas as espécies têm grande potencial para serem incluídas em sistemas agroflorestais e na diversificação de agroecossistemas, o que aumenta suas chances de uso sustentável e conservação.

**Palavras chave:** autoincompatibilidade, etnobotânica, nomes comuns, polinizadores, sinonimização, sistema sexual, visitantes florais, usos.

## ABSTRACT

Areacaceae is of great importance to indigenous and peasant communities that have used them as a source of food, wood, leaves for roofing, hunting grounds, and materials for crafts, among other purposes. The common names and uses of these palms reflect the history of this relationship. However, some of this information is associated with synonymized names, which may be overlooked in ethnobotanical reviews, even though this information is crucial for achieving sustainable use and species conservation. Another relevant aspect in this field is reproductive biology and the identification of floral visitors and pollinators, which reveal the interaction of these plants with the local fauna. In this study, we aimed to determine whether the inclusion of valid scientific names and those that have been synonymized but were previously cited in other works can increase the amount of ethnobotanical information retrieved. We conducted a review of the uses and common names of species in the genus *Euterpe* Mart., distributed from southern Brazil to northern Colombia, commonly known as Açaí, using different databases to determine the amount of information retrieved with each name. We also determined the sexual system, identified the pollinators, and assessed the prospects for sustainable use and conservation of the neotropical palms *Butia lallemantii* and *Bactris setosa*, native to the Pampa and Atlantic Forest biomes, respectively. To achieve this, we conducted pollination experiments to evaluate allogamy, self-pollination, autogamy, geitonogamy, apomixis, and natural pollination. The inclusion of synonyms for species increased the recovery of uses by 11.1% and common names by 17.8%. Thus, excluding synonyms for species results in the loss of relevant ethnobotanical information. We identified that *B. lallemantii* and *B. setosa* are self-compatible and mainly pollinated by beetles, hymenopterans, and dipterans, even though anthesis occurs during the day for the former and both day and night for the latter, indicating the relevance of these information for the reproduction and conservation of these species. Both species have great potential for inclusion in agroforestry systems and the diversification of agroecosystems, which enhances their prospects for sustainable use and conservation.

**Keywords:** common names, ethnobotany, floral visitors, pollinators, self-incompatibility, sexual system, synonymizing, uses.

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## 1. INTRODUCCIÓN GENERAL

Las plantas han jugado un papel fundamental en la vida del hombre, que las utiliza desde el inicio de su existencia para suplir sus necesidades, ya sea como fuente de alimento, medicina, abrigo y ropas, así como en actos rituales y religiosos (Pino & Valois, 2004). Todos estos recursos ayudaron a la expansión de las comunidades humanas en América del Sur (Aceituno & Loaiza, 2015). En particular, las palmeras son consideradas los “árboles de la vida” por haber conformado uno de los ejes de sustento material, cultural y religioso de las comunidades humanas de los trópicos americanos (Bernal & Galeano, 2013).

La importancia social, cultural y económica de las palmeras ha sido de gran interés para los científicos, siendo que el primer compendio científico sobre las palmeras y su uso en la Amazonia fue escrito en el siglo XIX por Alfred Russell Wallace (1853). Las palmeras fueron estudiadas desde múltiples perspectivas, pero actualmente su importancia radica en las posibilidades de uso que representa para las comunidades indígenas y no indígenas (Galeano, 2000; Paniagua-Zambrana et al., 2016; Phillips & Gentry, 1993), así como su potencial para promover el desarrollo de las sociedades. Además de eso, estas plantas representan un buen modelo para el desarrollo de estudios en los trópicos debido a su abundancia, amplia distribución y alta diversificación estructural, anatómica, fisiológica y ecológica (Balslev et al., 2011; Pintaud et al., 2008; Tomlinson, 1990).

Todos los géneros de palmeras neotropicales son citadas en una o más categorías de uso, principalmente en alimenticia, medicinal, construcción y artesanías, y muchas son utilizadas de alguna forma a nivel local, y proveen productos comercializados (Bernal & Galeano, 2013; Borchsenius & Moraes, 2006; Moraes, 2020). Pero las interacciones entre estos servicios ambientales y el bienestar de las poblaciones humanas han sido poco exploradas (Fürst et al., 2014). Usos y nombres comunes de las palmeras son un fuente importante de conocimiento que puede indicar su importancia cultural, económica o ritualista, y son derivados de la interacción del hombre con esas especies (Patterson et al., 2010). Muchos de los nombres comunes y usos permanecen asociados con los nombres científicos actualmente sinonimizados, e el número de sinónimos asociados con una especie se ha convertido en un problema en taxonomía, afectando especialmente estudios de biología comparada y biodiversidad (Dayrat, 2005). Por lo tanto, es importante reconocer los usos

actuales y potenciales de las especies, asociados a nombres válidos y sinonimizados, con el propósito de generar las mejores estrategias para su aprovechamiento racional y conservación.

La biología reproductiva de las palmeras con importancia económica viene siendo centro de atención e investigación en nivel específico (Barfod et al., 2011; Fava et al., 2011; Moraes & Sarmiento, 1992; Nuñez & Carreño, 2017) y genérico (Finn & Barfod, 1999; Henderson et al., 2000; Sosinski et al., 2019). A pesar de esto, pocos estudios abordan la biología reproductiva, como el caso de *Oenocarpus bataua* Mart. En los Andes (Nuñez-Avellaneda & Rojas-Robles, 2008; Rojas-Robles & Stiles, 2009) *Prestoea schultzeana* (Burret) H.E. Moore en la Amazonia (Finn & Barfod, 1999), y *Acrocomia aculeata* (Jacq.) Lodd. ex Mart. en Brasil central (Scariot et al., 1991). En la mayor parte de los estudios no se encuentra la evaluación completa de la biología reproductiva y polinización, raramente las publicaciones abordan un estudio completo (sistema reproductivo, autoincompatibilidad, etc.) con observaciones detalladas del proceso de polinización. La mayoría de las publicaciones abordan aspectos separados (ej: morfología floral, fenología, visitantes florales) y con poca información sobre los polinizadores y su comportamiento en las inflorescencias.

Los estudios de la fenología reproductiva de plantas en los trópicos húmedos ha revelado una amplia variedad de patrones en muchas comunidades (Rojas-Robles & Stiles, 2009), y la polinización en la familia Arecaceae ha sido objeto de múltiples estudios. Las investigaciones sobre domesticación se concentraba principalmente en la palmera africana *Elaeis guineenses* L. y el dátil *Phoenix dactylifera* L. (Pintaud et al., 2013) debido a su importancia en la producción de aceites comerciales (Forster et al., 2017). Pero hoy se ha extendido a especies como *Astrocaryum chambira* Burret (García et al., 2015), *Butia capitata* (Mart.) Becc. (Dias et al., 2022), *Maurita flexuosa* L. f. (Delgado et al., 2007) entre otras. Así, resulta fundamental el desarrollo de investigaciones para el conocimiento de las interacciones ecológicas de las palmeras nativas en todos los biomas, proyectando la obtención de informaciones que ayuden a un mejor gerenciamiento de este recurso de importancia económica. También para ayudar en la toma de decisiones de la situación de amenaza de las especies y en la ejecución de acciones para su conservación. El análisis de

los visitantes florales/polinizadores y su relación con la biología floral y reproductiva de las especies de palmeras permite establecer su relevancia para el mantenimiento de la biodiversidad y definir estrategias para la conservación y aprovechamiento sustentable de estas plantas (Johnson, 2010; Klein et al., 2007).

La palmera *Bactris setosa*, conocida como ‘tucum-do-brejo, tucum-bravo, côco-de-tucum, tucum o ticum’, se distribuye en la Mata Atlántica con algunas poblaciones en el Pantanal (Duarte et al., 2012). Sus hojas han sido usadas como fuente de fibras de alta calidad utilizadas por los indígenas para elaboración de redes, líneas de pesca, cuerdas de arco, cestería, obtención de aceite entre otros (Duarte et al., 2012; Medina, 1959). Sus extractos, especialmente de la cascara, tiene propiedades antioxidantes y antiinflamatorias (Khorsand & Koptur, 2013). Es una palmera de dosel inferior que presenta espinas en estipe, hojas y brácteas florales, y puede llegar a 5 m de altura, porte bajo que puede ser aprovechado para cultivo, cosecha del fruto o como ornamental. *Butia lallemantii*, conocida como Butiá enano, es una palmera cespitosa, de porte bajo, se encuentra en el bioma Pampa, ofrece materias primas para alimentos, bebidas, artesanías, alimentación animal, así como para la industria (Cogo et al., 2020; Silveira et al., 2022). Infelizmente, muchos de esos usos fueron perdidos con el paso del tiempo, y esta especie actualmente es subutilizada. Las pocas poblaciones que aún se encuentran están aisladas y necesitan de manejo para su uso sustentable y conservación (Paim et al., 2019; Paim et al., 2020, 2021; Stringari & Bruno, 2016).

El estudio comparativo de la polinización de estas palmeras permitirá, de un modo general, evaluar las diferencias o semejanzas de polinizadores de los diferentes taxones, permitiendo evidenciar de cuales grupos depende cada especie. Para poder iniciar procesos de aprovechamiento sustentable de poblaciones silvestres o de conservación de *B. lallemantii* y *B. setosa* es necesario entender el papel de esa palmera en el ecosistema y sus interacciones ecológicas.

## 2. OBJETIVOS

El objetivo general de la presente tesis es determinar la relevancia de los nombres científicos sinonimizados en la recuperación de información etnobotánica, así como estudiar la ecología de la polinización y el sistema reproductivo y las perspectivas para su conservación y uso sustentable de

dos especies de Arecaceae neotropicales de los géneros *Butia* y *Bactris* en el sur de Brasil. En consecuencia, determinamos los siguientes objetivos específicos.

- Revisar los usos y los nombres comunes asociados a los nombres científicos válidos e sinonimizados de las especies de palmeras del género *Euterpe*;
- Determinar el sistema reproductivo de *Bactris setosa* y *Butia lallemantii*;
- Discriminar cuáles son sus visitantes florales y polinizadores;
- Describir la ecología de la polinización de estas especies;
- Establecer acciones para la conservación y uso sustentable de estas especies.

La tesis se presenta en tres capítulos, donde se abordaron temas relacionados con la etnobotánica, ecología de la polinización, biología reproductiva, conservación y uso sustentable de palmeras neotropicales de los géneros *Euterpe* Mart., *Butia* (Becc.) Becc. y *Bactris* Jacq. ex Scop.

El primer capítulo titulado Sinónimos de las especies: ¿qué tan importantes son en la recuperación de información etnobotánica? (Species synonyms: How important are they for the retrieval of ethnobotanical information?) se encuentra publicado en la revista *Ethnobotany Research and Application* (Perdomo & Singer, 2020), aquí se abordó la incidencia del uso de los sinónimos de las especies de palmeras del género *Euterpe* en la recuperación de información etnobotánica sobre nombres comunes y usos en diferentes motores de búsqueda de artículos científicos.

El Segundo capítulo se titula Ecología de la polinización, sistema sexual y conservación de *Butia lallemantii* Deble & Marchiori (Arecaceae), una palmera útil de la Pampa (Pollination ecology, mating system, and conservation of *Butia lallemantii* Deble & Marchiori (Arecaceae), a useful palm tree from the Pampa), se encuentra en el formato para la revista *Flora: Morphology, Distribution, Functional Ecology of Plants*. En este capítulo se estudió la ecología de la polinización y la biología reproductiva del Butiá Enano (*B. lallemantii*) en la Pampa brasilera, se identifican los visitantes florales y polinizadores, y se presentan algunas propuestas para la conservación de esta palma emblemática del bioma.

El tercer capítulo tiene por título Polinización, Biología Reproductiva y perspectivas de uso en agroforestería de (Pollination ecology, reproductive biology and perspectives of use in agroforestry of) *Bactris setosa* Mart. (Arecaceae) será sometido a la revista BMC Plant Biology. En este aparte se aborda la ecología de la polinización y la biología reproductiva, así como las perspectivas de uso como un componente de conservación y producción en sistemas agroforestales de la palmera conocida como “tucúm”, nativa de la Mata Atlántica. Esta planta presenta cualidades que permiten su aprovechamiento sustentable y su uso como componente de sistemas alternativos de producción y conservación.

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**3. CAPÍTULO 1** - Species synonyms: How important are they for the retrieval of ethnobotanical information?

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*Euterpe precatoria* var. *longivaginata* (Mart.) A.J.Hend. in anthesis, Caquetá, Colombia.



# Species synonyms: How important are they for the retrieval of ethnobotanical information?

Oscar Perdomo and Rodrigo B. Singer

## Reviews

### Abstract

**Background:** The synonyms of the currently accepted scientific names are binomial names used to designate the same taxon, now in disuse due to the nomenclatural rules. We explore the evolution of the synonymy in the useful palm genus *Euterpe* to investigate if the inclusion of the synonyms affects the recovery of information on the uses and vernacular names.

**Materials and Methods:** We used three search engines (Google Scholar, Scopus and Web of Science) to recover papers associated with the currently accepted scientific names of the *Euterpe* palms and the forty associated synonyms. Then we examined the information recovered on the uses and vernacular names to compare the outcomes.

**Results:** Our results evidence the increase in the recovery of ethnobotanical information (11.1%) and vernacular names (17.8%) when the synonyms are used. Recently described species had less synonyms than their early-described counterparts. In addition, our results revealed that the more useful *Euterpe* species had more vernacular names.

**Conclusions:** The accurate identification of the synonyms for accepted species facilitates and improves the recovery of information by increasing the amount of material retrieved from the web. As expected, most useful palms have more vernacular names. Google Scholar has shown the better performance using synonyms, but the outcomes for the currently accepted scientific names were similar for the three search engines.

**Keywords:** Açai, Asai, *Euterpe*, Google Scholar, scientific names, Scopus, synonyms, uses, vernacular names, Web of Science

## Resumen

**Antecedentes:** Los sinónimos de los nombres científicos actualmente aceptados son nombres binomiales utilizados para designar la misma especie, hoy en desuso debido a las reglas de nomenclatura. Exploramos la evolución de la sinonimia en el útil género de palmas *Euterpe* para investigar si la inclusión de los sinónimos afecta la recuperación de información sobre los usos y nombres vernáculos.

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**Materiales y métodos:** Utilizamos tres motores de búsqueda (Google Scholar, Scopus y Web of Science) para recuperar artículos científicos asociados con los nombres científicos actualmente aceptados de las palmas *Euterpe* y los cuarenta sinónimos asociados a ellas. Luego examinamos la información recuperada sobre los usos y los nombres vernáculos para comparar los resultados.

**Resultados:** Nuestros resultados muestran el incremento en la información etnobotánica recuperada sobre los usos (11.1%) y nombres

vernáculos (17.8%) cuando se usan los sinónimos. Especies descritas recientemente tienen menos sinónimos que sus contrapartes descritas con anterioridad. Adicionalmente, nuestros resultados revelaron que las especies de *Euterpe* más útiles tienen más nombres vernáculos.

**Conclusiones:** La correcta identificación de los sinónimos de las especies aceptadas facilita y mejora la recuperación de información al aumentar la cantidad de material recuperado de la web. Como esperado, las palmas con más usos tienen más nombres vernáculos. Google Scholar ha mostrado un mejor rendimiento usando los sinónimos, pero los resultados con los nombres científicos actualmente aceptados fueron similares para los tres motores de búsqueda.

**Palabras clave:** Açai, Asaí, *Euterpe*, Google Scholar, nombres científicos, nombres vernáculos, Scopus, sinónimos, usos, Web of Science.

## Background

Species names are based on the Linnaean binomial system and are governed by formalized rules of nomenclature (Patterson *et al.* 2010, Remsen 2016, Tuominen *et al.* 2011). These rules determine that only one name must be used to label a particular taxon. However, in a historical context, multiple names may appear associated with one taxon (at generic, specific levels, or both). In such cases the first validly published name is kept and the others are synonymized, remaining available in the scientific literature but unused in taxonomy (Remsen 2016, Rivera *et al.* 2014). Additionally, the taxa may be known by the vernacular or common names, attributed by the local population to designate one or various species. These names vary geographically and historically. Thus, the same species may be known by multiple common names, and one common name may be used to designate different species.

The number of synonyms associated with species-names becomes a fundamental problem in taxonomy, affecting especially studies in comparative biology and biodiversity (Dayrat 2005). These complications led to the creation of engines such as the TNRS - Taxonomic Name Resolution Service - (Boyle *et al.* 2013) and Plantminer (Carvalho *et al.* 2010) and online tools to standardize plant names, websites such as IPNI -International Plant Name Index- and Tropicos, R packages as “*taxonstand*” (Cayuela *et al.* 2012), “*taxize*” (Chamberlain & Szöcs 2013) or “*taxa*” (Foster *et al.* 2018) as well as other similar services and tools to search and manage taxonomic information, helping the researchers in the corroboration and correction

of scientific names. These tools are of particular interest in the revision of the scientific literature that aims to collect the most relevant information about any taxonomic entity, because the synonyms may link to information not recovered by the species name in current use.

In the revision of traditional botanical knowledge, also called ethnobotanical knowledge, the information about uses and vernacular names is of great interest because it is the result of the relation of human populations and their environment. Thus, ethnobotanical knowledge represents the historical record of this interaction between human societies and plants. In this scenario, the inclusion of the synonyms appears as a tool to improve the retrieval of information about any taxon, by incorporating its historical background. The use of the vernacular and scientific names on the internet is similar and highly correlated. The use of both remains constant across the internet pages standing out their relevance to link to the information contained in the web (Correia *et al.* 2017). The retrieval of information from the web concerning the uses, vernacular names and other kind of topics in ethnobotany, allows to establish the relevance of any species for a human community. The recovered information reflects the ethnobotanical importance of a particular taxon, as well as the human perception of the plant species, helping to improve our knowledge and understanding of this narrow relationship. By gathering this information, we can have an overview of the relevance and use perspectives of the species, recovering and saving this ancient knowledge. In turn, this could ultimately promote the elaboration of strategies dealing with a sustainable use of resources on socially acceptable and culturally fair grounds.

Palm species are key components in ecosystems networks and play an important role as the origin of many resources for human communities (Bernal *et al.* 2011, Macía *et al.* 2011, Moraes 2020, Tomlinson 2006). Some of the palm species in the genus *Euterpe* Mart. are currently used for the extraction of fruits and palm heart (“palmito” or “palmetto”) for a growing industry based on these resources (Bernal *et al.* 2011, Brokamp *et al.* 2011). But these palms are also used by the local communities for medicine, construction, handicraft, and many other uses (Brokamp *et al.* 2011, Mesa & Galeano 2013, Paniagua-Zambrana *et al.* 2017, Paniagua-Zambrana *et al.* 2020). The type species of the genus is *E. oleracea* Mart., described in 1823 (Martius 1823). The most recently described species is *Euterpe luminosa* A.J.Hend., Galeano & Meza, in 1991 (Meza *et al.* 1991). Thus, we considered the genus *Euterpe* an adequate taxonomic group to

explore their synonymy and usefulness. This contribution aims to address the following questions; i) can the inclusion of the synonyms affect the recovery of information on the uses and vernacular names of the palm species?, We hypothesize that the papers linked to synonyms contain some information not included in the papers linked exclusively to currently accepted names; ii) in which way the number of uses and vernacular names are correlated? We hypothesize that the more useful species are known by more vernacular names, as expected for this correlation, evincing the representativeness of the sample used in the analysis. iii) can the chosen search engine influence the recovery of scientific information? We hypothesize that there may occur differences in the information recovered by the different search engines.

## Materials and Methods

### Group of study

For this review we used all the palm species of the genus *Euterpe* Mart. This genus was originally described in 1823 by Karl Friedrich Philipp von Martius and currently comprises seven species used in different ways by Indigenous People and South American farmers (Henderson & Galeano 1996, Paniagua-Zambrana *et al.* 2020). We used this group of palms because their ecologic importance, the economic, social and cultural relevance for the local communities, and the perspectives for their use in a sustainable exploitation, agroecosystems design and implementation, as well as for ecological restoration.

### Searching synonyms, uses and vernacular names

We used the package “taxize” (Chamberlain & Szöcs 2013) in Rstudio (RStudio Team 2018) to get the list of species names and varieties of the genus *Euterpe* Mart. and its synonyms from the site Tropicos.org. Then, we used Google Scholar (GS), Scopus (Sc) and Web of Science (WoS), three widely-used search engines, to search scientific papers reporting uses or vernacular names for all the species names and synonyms retrieved. The term “uses” is herein used in the sense of Ledezma-Rentería & Galeano (2014). We configured the search engines without time restriction, ordered the results by relevance, employing quotation marks and search commands to exact matches. Then, we developed individual searches for each scientific name in its complete form (e.g. “*Euterpe luminosa*”).

For every search outcome we recorded the number of results obtained by the search engines. For the study we included up to the first 20 scientific papers of the outcomes. The criteria to select the informative

papers were the report of vernacular names or information concerning the uses of the *Euterpe* species. The uses and vernacular names found for the species names and the synonyms were individually recorded and lumped under the accepted species. We included papers with primary or secondary information sources and used only documents that reported new data for the scientific name studied, avoiding repetitions. When two papers containing the same information were found, we used for the analysis the first one recovered by the searches (*i.e.* the most relevant). We developed the searches from March to May 2019, the data collected from the informative papers included: year of publication, title, author(s), DOI or URL, uses and vernacular names reported.

### Data analysis

To analyse the recovery of information associated with the studied species, the uses and vernacular names recovered were classified into three groups: 1) exclusive for species names, 2) exclusive for synonyms and 3) shared. These groups were used to calculate the proportions in Table 1 employed to determine the proportion of uses and vernacular names associated exclusively with synonyms or scientific names, and to answer the first question of the review.

To answer the second question, we used the package “ggplot2” (Wickham 2016) in RStudio (RStudio Team 2018) to perform a linear correlation to evaluate the association between the uses and vernacular names recovered for the studied species and to determine if the sample was representative of the ethnobotanical knowledge about it. The normality of the data (required to use Pearson’s correlation) was tested using a Lilliefors test from the package “nortest” (Gross *et al.* 2015). When necessary, the data were transformed by Log to accomplish the normal distribution of the observations. Applying the same methodology, we performed an additional linear correlation for the number of synonyms and the years from the publication of the accepted species to observe the evolution in time of the taxonomy for the genus *Euterpe*.

The indicator 1 of the Table 2 revealed the proportion of useful papers recovered by each search engine and answer the third question of the review. The indicator 2 evaluated the effectivity of the papers retrieved by the search engines to recover the information of interest. Finally, we compared the search engines retrieval of useful papers by species names using Levene’s Test from the package “car” (Fox & Weisberg 2011) in RStudio (RStudio Team 2018). The data for synonyms were not sufficient to



develop a statistical analysis, and then we present a descriptive analysis instead.

## Results

We found 40 synonyms for the seven species of the genus *Euterpe*, 5.7 on average (Supplementary Table 1), varying from 20 for *E. precatoria* to zero for *E. luminosa*. 11.1% of the information regarding uses and 17.8% of the vernacular names were exclusively associated with the synonyms (Table 1), confirming our hypothesis for the first question. We found 94 informative papers (Supplementary Table 2) for uses and vernacular names, 25% of them being recovered through the synonyms. We retrieved useful papers for 100% of the currently accepted names and 35%

of the synonyms. For the genus *Euterpe* as a whole, 107 vernacular names and 63 uses were recovered. *E. precatoria* was the species with more uses and vernacular names (Table 1). The use of the heart of palm (palmetto) was recorded for five of the seven species of the genus, and the name “açai” was the most widespread in the studied species (Supplementary Table 3). We recovered uses for six species (85.7%) and seven synonyms (17.5%), vernacular names for 7 species (100%) and 14 synonyms (35%), and the percentage of uses and vernacular names recovered by the accepted names were higher than the recovered by synonyms, but the shared ones were very similar (Table 1).

Table 1. Synonyms (Syn), Uses and Vernacular Names recovered from Scientific names (SN) and synonyms (Syn), and the shared ones (Sh), for the *Euterpe* Mart. species studied.

	Syn	Uses			Vernacular names				
		Total	SN	Syn	Sh	Total	SN	Syn	Sh
<i>E. broadwayi</i> Becc. ex Broadway	4	7	1	2	4	10	2	3	5
<i>E. catinga</i> Wallace	10	6	5	0	1	16	13	4	1
<i>E. edulis</i> Mart.	3	14	11	4	1	14	10	2	2
<i>E. longibracteata</i> Barb. Rodr.	1	0	0	0	0	3	2	0	1
<i>E. luminosa</i> A.J. Hend., Galeano & E. Meza	0	1	1	0	0	2	2	0	0
<i>E. oleracea</i> Mart.	4	24	20	1	3	14	10	4	0
<i>E. precatoria</i> Mart.	20	32	29	2	1	55	45	7	3
Summation	42	84	67	9	10	114	84	20	12
Consolidated	40	63	55	7	1	107	79	19	9
Proportion (%)	--	100	87.3	11.1	1.6	100	73.8	17.8	8.4

Table 2. Indicators and values used to analyse the recovery of information about uses and vernacular names associated with the *Euterpe* Mart. species.

#	Indicator	Formula	Value (%)	Components
1	Percentage of useful papers recovered by each search engine	$\%P_{\text{useful}} = (P_{\text{info}} / P_{\text{recov}}) * 100$	<b>0,23 (GS)</b> <b>0,62 (Sc)</b> <b>2,95 (WoS)</b>	$P_{\text{info}}$ = number of informative papers. $P_{\text{recov}}$ = papers recovered from the search engine
2	Utility of the papers to recover uses and vernacular names	$I_{\text{Up}} = U_{\text{total}} / P_{\text{info}}$ $I_{\text{VNp}} = P_{\text{info}} / \text{VN}_{\text{Total}}$	<b>0,71</b> <b>0,76</b>	$P_{\text{info}}$ = number of informative papers. $U_{\text{total}}$ = total uses recovered. $\text{VN}_{\text{total}}$ = total vernacular names recovered.

Our results revealed a positive correlation ( $R^2=0.707$ ) for the uses and vernacular names of *Euterpe* species (Fig. 1B); this is, more vernacular names were recovered for species with more uses. The species with more uses and vernacular names was *E. precatoria* followed by *E. oleracea*, whilst *E. luminosa* and *E. longibracteata* were the less diverse in both items. When the four varieties (two of *E. precatoria* and two of *E. catinga*) were added to the

analysis, the correlation of the uses and vernacular names slightly decreases ( $R^2=0.657$ ) (Supplementary Figure 1) as a consequence of the new elements added that modify the correlation as a whole. This high correlation shown the representativeness of the data sample confirming our hypothesis for the second question, and validated the methodology used to recover the papers and the information.

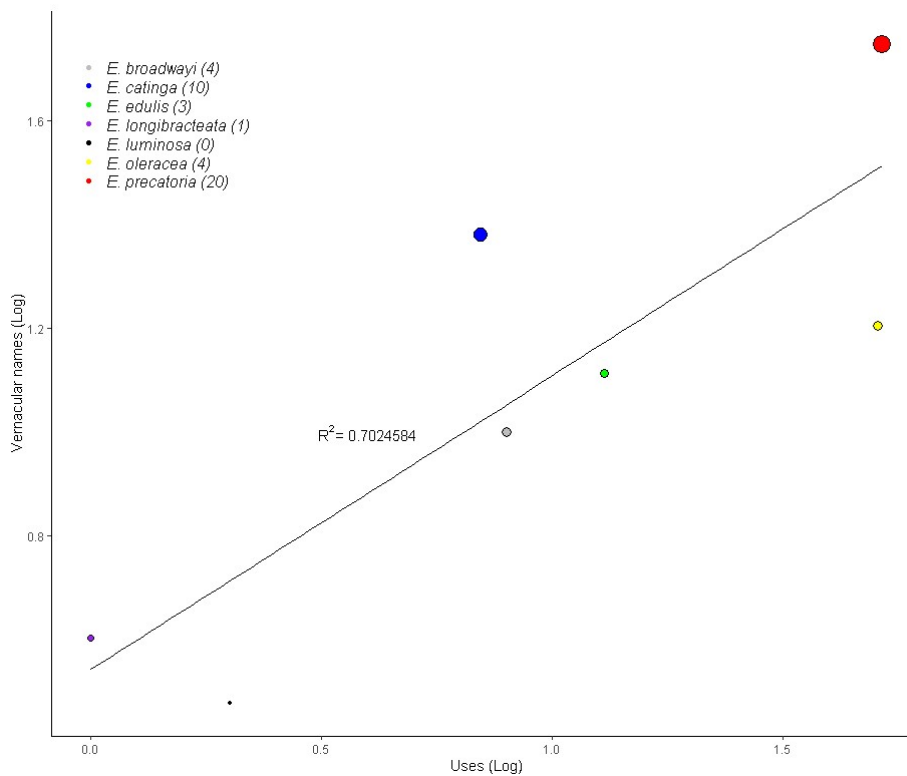


Figure 1. **A.** Correlation of uses and vernacular names (data normalized by Log) recovered for the palm species of the genus *Euterpe* Mart.

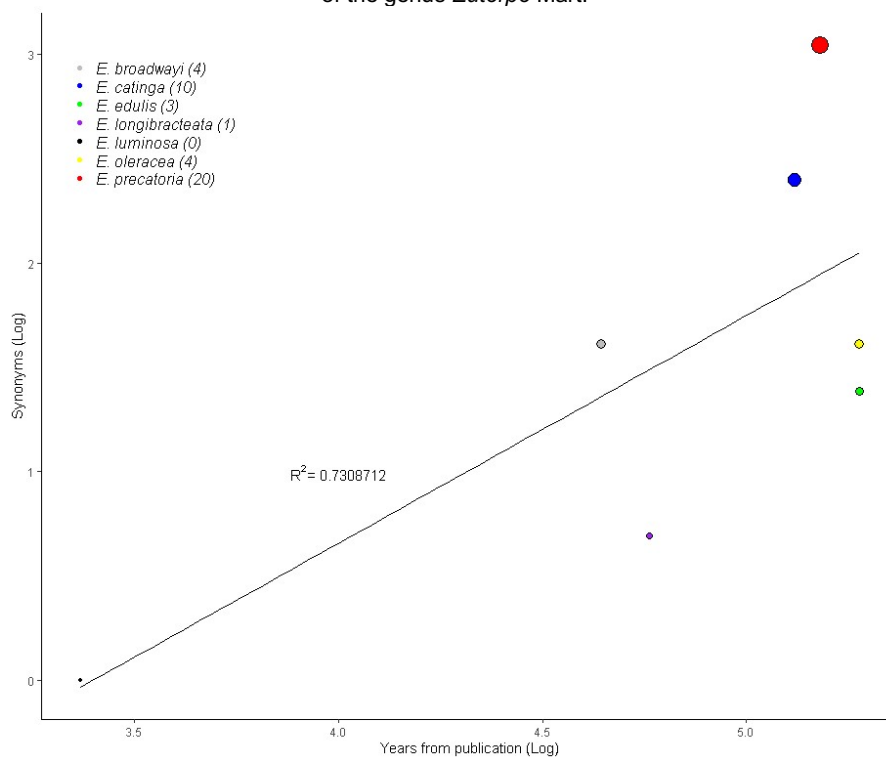


Figure 1 **B.** Correlation of the number of synonyms and years from publication (data normalized by Log) for the species of the genus *Euterpe* Mart. The size of the dots in each graphic indicates the number of synonyms of the species (data below the species name).

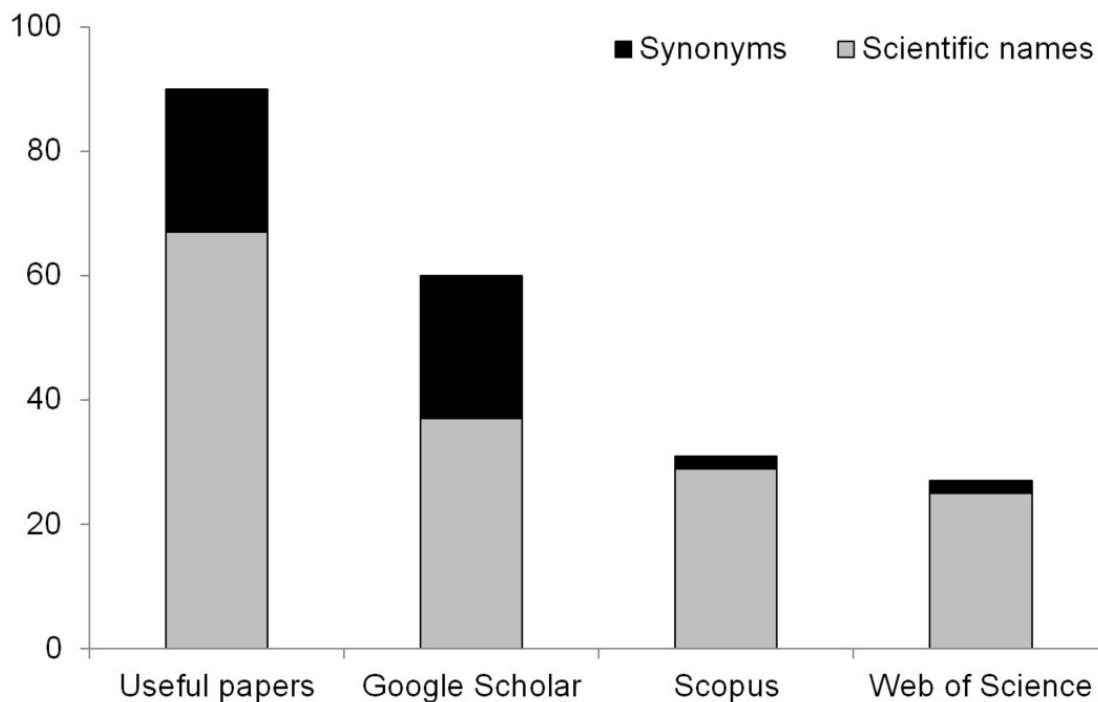


Figure 2. Useful papers recovered for the species and synonyms of the genus *Euterpe* Mart. in the used search engines.

We recovered 55% of the useful papers associated with the species names in Google Scholar, 43% in Scopus and 37% in Web of Science (Fig. 2). Nevertheless, each search engine recovered unique papers (i.e. only recovered by this engine). The search engines used in this research did not differ statistically in the retrieval of the total number of useful papers, nor by the species names ( $F_{(2, 117)}=2.7322$ ,  $p = 0.06923$ ). In the Figure 2 is clear that Google Scholar retrieved most of the useful papers when the synonyms or the species-names were used as a search term. Indeed, 100% of useful papers retrieved by the synonyms were found in Google Scholar, 8.7 % in Scopus and 8.7% in Web of Science. When considering the synonyms, no articles were unique for Scopus or Web of Science, and 85% were retrieved only in Google Scholar. Web of Science had a superior performance retrieving useful papers from the total recovered in the search. All these results confirm our hypothesis for the third question about the differences in the information retrieved by each search engine.

The papers recovered by uses and vernacular names presented a similar utility to retrieve information. The percentage of useful papers from the total recovered was higher in WoS than Sc and GS (Table 2), but the number of papers recovered by SN and Syn was superior in GS (25874/724) followed by Sc (4936/81) and WoS (901/13). Additionally, in GS we recovered information for the 7 currently accepted *Euterpe* species and 14 of the

40 synonyms. In Sc and WoS for 5 species and only 2 synonyms. We found that 25% (10) of the synonyms were published before 1900, 53% (25) between 1900 and 1950. After 1950, eight synonyms were published; the last one was *E. espiritasantensis* H.Q.B. Fernandes, in 1989 (Fernandes 1989). We found a positive correlation ( $R^2= 0.73$ ) between the years from the description of the species and the number of synonyms recorded (Fig. 1A) showing a decrease in the number of synonyms for the species described more recently. In other words, more recently described species have less synonyms than more early-described taxa. This fact highlights the importance of including the synonyms in the researches and reviews, especially for species described long ago.

## Discussion

The recognition of sibling species and synonyms as well as the need for funding for primary taxonomic research are enormous (Godfray 2002, Regan *et al.* 2001). In papers published between 2000 and 2003, the reference of 1,015,000 binominals registered at the Index Kewensis were used to estimate the number of accepted seed plant species and the results have shown that the rates of synonymy varied from 58 to 78% (Scotland & Wortley 2003). The number of published binomial names, accepted names and synonyms were used to estimate the number of species of flowering plants, seed plants, vascular plants and land plants and compared with the estimates presented in papers published from

2000 to 2016. The results showed a high variability in the number of accepted names and synonyms used in calculations (Lughadha *et al.* 2016). The high number of perceived synonyms points out their relevance for the search of scientific literature searching, especially for revision purposes.

The importance of synonyms in literature searching has been demonstrated in other cases such as the relevance of botanical nomenclature and plant taxonomy in biomedical research (Bennett & Balick 2014), the recovery of citations for species recorded in ITIS (Guala 2016) and the retrieval of webpages linked to the scientific names and synonyms of bird species in a culturomic assessment (Correia *et al.* 2018). These researches were developed extracting information of a high number of species from the Web. In contrast we used a small taxonomic group, composed of seven species and 40 synonyms, to extract information from the scientific papers linked to these names. In this way we were able to develop the comparisons of the retrieval of uses and vernacular names for species names and synonyms, the relation of the uses and vernacular names and the performance of the search engines.

For the genus *Euterpe* we found that the number of synonyms of the currently accepted species increases in time, being lower in the most recently described and higher in those described a long time ago. Even though the scientific name of any organism is a stable entity permanently linked to its type; the specimen of reference standard for a taxon (*i.e.* the voucher, biologic collection or exsiccate) used for the first description of the species (Winston 1990), the synonymy is an inevitable phenomenon in taxonomy. This phenomenon derives from human fallibility in the recognition of already described taxa, deficient sampling and/or the lack of accessibility to the species protologues to compare with the material suspected to be a new species (Eastop & Blackman 2005, Winston 1990). These facts entail to the description and publication of information about already known species but linked to a new name posteriorly synonymized. Hence, the number of synonyms identified for any taxon and the date of their publication becomes a clear signal of the existence of information associated with them.

The proportions included in Table 1 support the inclusion of the synonyms in the searches as a factor that increases the number of recovered uses and vernacular names retrieved by the search engines. In this research we recovered 11.1% of uses and 17.8% of vernacular names linked exclusively to the synonyms and found that the relevance of synonyms is higher for species described long ago, that have more synonyms. This fact highlights that the inclusion of the synonyms in literature revisions is a

factor that improves the recovery of relevant scientific information (Guala 2016). Consequently, we recommend the identification of the synonyms for the studied species as a tool to understand the taxonomy of the studied group, and as a resource to recover scientific information that may be hidden after the synonymization.

The species with more synonyms generally are the most useful and known by more vernacular names, a strong correlation that highlights the importance of these palms for the human populations, and the relevance of the synonyms for the recovery of information about ethnobotanic or any other topic of research. Whereas many studies deal with the uses and vernacular names of some plant species (Bjorå *et al.* 2015, Cedano & Villaseñor 2004, Fernández 1992, Kunwar & Adhikari 2005, Kunwar & Bussmann 2006, Macía 2004), to the best of our knowledge, none of them addresses the interrelationship of these two kinds of ethnobotanical information. The pattern we observed for this group of palm-trees seems logic: a plant widely used is known by many vernacular names derived from the different groups of people that use it. Further studies reviewing this kind of information may detect this pattern in other groups of plants and animals.

Additionally, the values of the indicator for the utility of the papers (Table 2) evidence the number of papers needed to obtain a single useful record. In the present contribution, the values for uses (0.71) and vernacular names (0.76) indicate that a similar effort is needed to retrieve the information, and quantitatively similar information may be found in papers about both topics.

The 51 binomial names associated with the genus *Euterpe* (*i.e.* species, varieties and synonyms) were published between 1824- year of description of *E. oleracea* (Martius 1824)- and 1996, when the varieties were recognized in the revision of the genus (Henderson & Galeano 1996). We found that 79% of the synonyms were published before 1950 and some of them were published in the same year. This is the case of *Catis martiana* OF Cook and *E. badiocarpa* Barb.Rodr., synonyms of *E. oleracea*, described in 1901, and *E. petiolata* Burret and *E. subruminata* Burret synonyms of *E. precatória* described in 1940. In consequence, many papers about the *Euterpe* species were published in this time-lapse and contain information linked to these synonyms.

The strong correlation between the number of synonyms with the number of years from the species description reflects the improved understanding of the taxonomy, the advances in the species delimitation for the species of the genus *Euterpe*,

and the enhanced access to the scientific information derived from the development of the telecommunications. Today the telecommunication technology allows to access a great part of the herbaria collections, the papers and books with the description of the species, and instantaneous communication with other researchers, reducing the probability of misidentification of specimens and parallel descriptions of species. But the latter phenomena still happen, new species are described every year and the revision of taxonomic entities continuously highlights new synonyms, increasing the number of papers that reference synonyms as species and, consequently, the information about the biology, distribution, traditional knowledge or other kinds of research topics that may be overlooked (Patterson *et al.* 2010).

We obtained the best outcomes of useful papers for the synonyms using Google Scholar, retrieving higher number of useful papers than Scopus and Web of Science. Nevertheless, for the currently accepted scientific names, all search engines presented similar performances. Although we limited our review to the first 20 scientific papers in the outcomes, only five species names, two varieties and six synonyms exceed this limit for the Google Scholar results. The same happened with three species and a synonym for Scopus, and three species for Web of Science. This limit reduced the number of papers reviewed and retrieved a good amount of information represented in the uses and vernacular names recovered by species names and synonyms.

Some researchers have criticized the use of Google Scholar to retrieve scientific information arguing that it offers results of inconsistent accuracy, problems regarding citation information (Falagas *et al.* 2007, Wadhwa *et al.* 2020), as well as the lack of a history function and tools to optimize the queries or to export a large number of citations (Boeker *et al.* 2013). We don't disagree; Google Scholar has fewer options to filter the results and tools to manage the outcomes and requires more time to manually select the papers from the outcomes. Nevertheless, Google Scholar is considered the most comprehensive academic search engine (Gusenbauer 2019) and our results showed its better performance to retrieve information about synonyms.

The selection of the searches engine and its performance to recover scientific information depend on the scope of the research and the papers of interest (Bakkalbasi *et al.* 2006). For the synonyms, the amplitude in time of the Google Scholar searches (not revealed by the site but considered unlimited) plays an important role in the retrieval of information

because most of the synonyms for the genus *Euterpe* were published between 1900 and 1950, a period not covered in Scopus, and partially covered in Web of Science (from 1945 to present / only for science). Therefore, we recommend the use of Google Scholar for searches linked to plant synonyms. Google Scholar is thus an efficient free-access tool to recover useful papers and retrieves scientific information from a wide lapse of time and a great number of sources.

## Conclusions

The identification of the synonyms for accepted species leads to the recovery of the taxonomical history of the studied group and facilitates the retrieval of information that otherwise could be ignored or overlooked. For the genus *Euterpe* the most useful species have more vernacular names; a relation that points out the strong relation of some palms with the human populations. This confirms the hypothesis we formulated. Google Scholar presented a better performance than Scopus and Web of Science for the recovery of information about synonyms supporting our hypothesis, but the outcomes for the currently accepted scientific names were similar for the three search engines. The time from the description of a species is a factor that increases the number of synonyms and the information linked to them. As expected, the inclusion of synonyms improved the recovery of information for the species by increasing the amount of information retrieved from the web. So, researchers planning ethnobotanical research have to seriously consider the inclusion of the pertinent synonyms in order to maximise the recovery of relevant information.

## Declarations

**List of abbreviations:** SN: Scientific name, Syn: Synonyms, GS: Google Scholar, Sc: Scopus, WoS: Web of Science.

**Ethics approval and consent to participate:** Not applicable.

**Consent for publication:** Not applicable.

**Conflict of interests:** The authors declare that they have no conflict of interests.

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**Author contributions:** OP designed the study, OP and RBS conducted the review; analysed the data; wrote, read, corrected and approved the manuscript.

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**4. CAPÍTULO 2 – Pollination ecology, mating system, and conservation of *Butia lallemantii* Deble & Marchiori (Arecaceae), a useful palm tree from the Brazilian Pampa**

Artículo a someter en la revista: **Flora: Morphology, Distribution, Functional Ecology of Plants.**



**Inflorescência de *Butia lallemantii* Deble & Marchiori em fase estaminada.**



Pollination ecology, mating system, and conservation of *Butia lallemantii* Deble & Marchiori (Arecaceae), a useful palm tree from the Pampa

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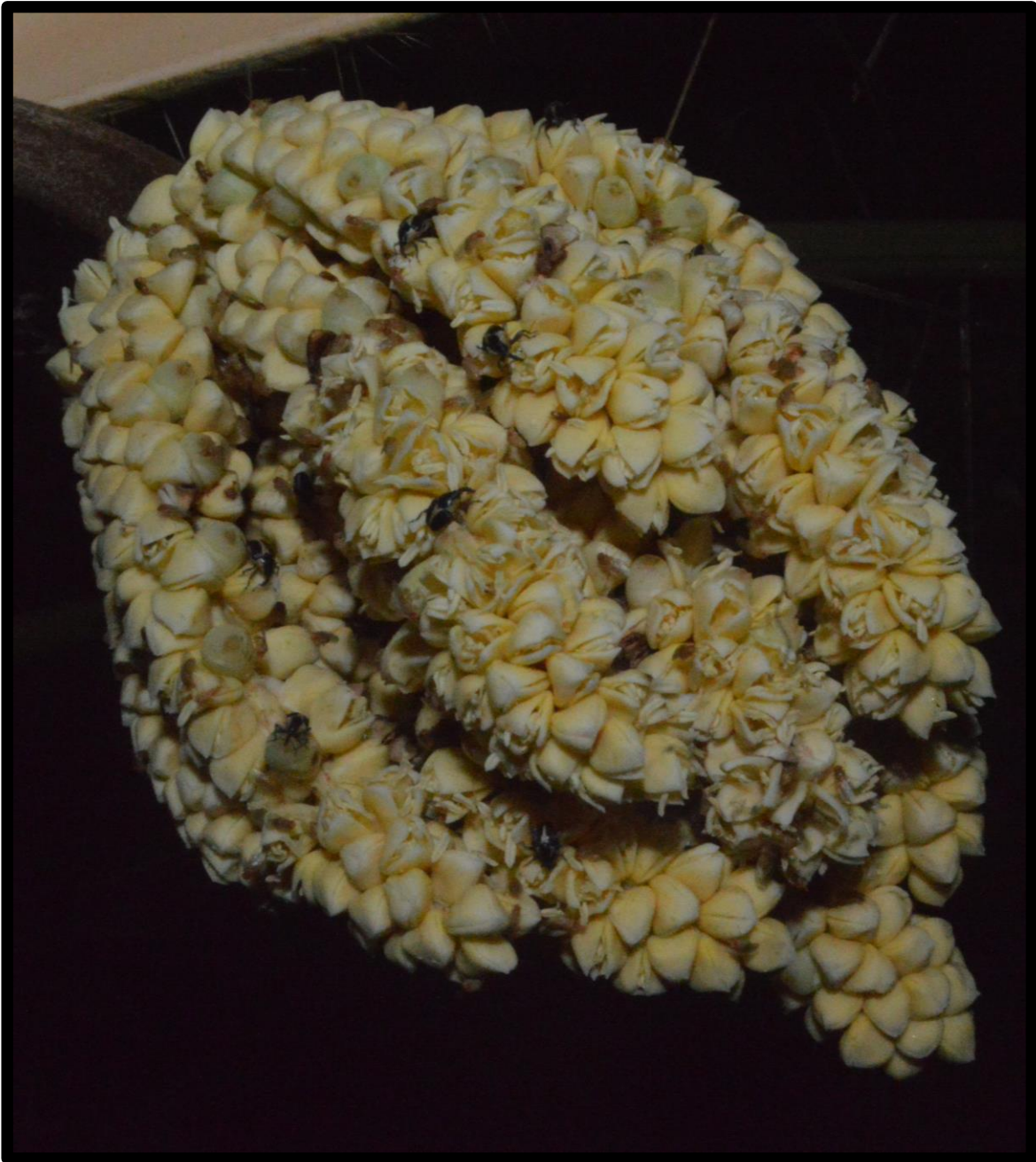
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**Material aguardando publicação**

**CAPÍTULO 3** – Pollination ecology, reproductive biology and agroforestry perspectives of *Bactris setosa* Mart. (Areaceae)

Artículo a someter en la revista: **Flora: Morphology, Distribution, Functional Ecology of Plants.**



**Inflorescência de *Bactris setosa* Mart. (Areaceae) no início da antese estaminada**

Pollination ecology, reproductive biology and agroforestry perspectives of *Bactris setosa* Mart. (Arecaceae)

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## CONSIDERACIONES FINALES

La conservación y uso sustentable dos recursos naturales son de las mayores preocupaciones hoy para la humanidad, en un planeta que cada día pierde una gran área de bosques y con ellos muchas interacciones vitales para plantas, animales y microorganismos. Así, conocer los nombres comunes y los usos actuales y potenciales de las especies es fundamental para establecer estrategias y políticas de conservación de las especies, sus interacciones y el hábitat donde se desarrollan. En el proceso de identificación de este tipo de datos etnobotánicos es fundamental incluir los sinónimos de las especies con la intención de recuperar la mayor cantidad de información para establecer las prioridades para su uso y conservación. Polinización es una de las interacciones con mayor importancia en la naturaleza ya que de ella depende la producción de frutos y semillas, y los sucesivos eventos de dispersión y frugívora, y eventos de especiación. Aunque muchos estudios han abordado el sistema sexual y la polinización de diferentes especies de palmeras, pocos han evaluado todas las formas posibles de reproducción: autogamia, geitonogamia, autopolinización, apomixia, alogamia y polinización natural.

De la misma forma, los polinizadores y sus interacciones han sido poco estudiados y los datos resultan incompletos por la falta de una clara definición para diferenciarlos de los visitantes florales. Para la presente investigación planeamos y aplicamos una metodología que permitió estudiar de forma completa el sistema sexual de las palmeras y la diferenciación entre visitantes florales y polinizadores.

Para *B. lallemantii*, o butiá enano, determinamos que es autocompatible, presenta antesis diurna, y protandria, con un periodo de inactividad entre las fases estaminada y pistilada. Esa fase inactiva que se extiende por dos a cuatro días es una estrategia que evita la autogamia y favorece la polinización cruzada. Identificamos que la polinización es mediada por abejas, escarabajos y moscas principalmente, pero las inflorescencias son visitadas por otros insectos en busca de presas y para reproducirse. En total la antesis puede extenderse por ocho a doce días, ofreciendo recursos alimenticios para la entomofauna y favoreciendo la partida y llegada de polen proveniente de diferentes individuos, lo que favorece la diversidad genética de la especie.

En el caso de *B. setosa*, o Tucúm, fue identificado que es parcialmente autoincompatible, solamente algunos individuos tienen la capacidad de reproducirse con su propio polen. La antesis dura 36 horas aproximadamente, es protógina, y presenta termogénesis con un pico de máxima temperatura que marca el inicio de la fase pistilada. Los visitantes florales son atraídos por el calor emitido por la inflorescencia, los compuestos volátiles atrayentes y los recursos alimenticios ofrecidos; polen y néctar. Además, la inflorescencia sirve como refugio y sitio de caza y reproducción. Los principales polinizadores de esta especie son abejas, escarabajos y moscas, que visitan las inflorescencias durante el periodo de la antesis tanto en el día como en la noche, asegurando así un mayor flujo genético.

Tanto *B. lallemantii* cuanto *B. setosa* presentan condiciones favorables para su inclusión en agroecosistemas diversificados y sistemas agroforestales con miras a su conservación y uso sustentable. La cantidad de usos identificados para estas especies señalan su potencial para ser incluidas en procesos de agroindustrialización y promoción de productos tradicionales obtenidos de esas palmeras. Así mismo, la importancia cultural de las especies genera un espacio para el desarrollo de estrategias que puedan promover un mayor uso a nivel local y un mayor interés por su cultivo y agroindustrialización. En consecuencia ambas especies se proyectan como alternativas de producción y conservación que pueden tener un gran impacto en la sociedad que las usa y convive con ellas.

Este estudio contribuye para el desarrollo de investigaciones completas sobre el sistema sexual, polinización y conservación de las especies de palmeras. Es importante mencionar que *B. lallemantii* se encuentra en peligro de extinción y de las pocas poblaciones existentes, solo una se encuentra dentro de un área protegida. Por lo tanto, es imperativo iniciar un proceso que permita la protección de la especie al tiempo que se brindan alternativas productivas para los campesinos. *B. setosa* tiene una distribución más amplia y no se encuentra amenazada de extinción, pero también es una alternativa económica por la cantidad de usos que se han identificado y la relevancia cultural que posee.