

A new purple-flowered *Butia* (Arecaceae) from the highlands of the Chapada dos Veadeiros (Brazil)

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Abstract

Background and aims – The highlands of the Chapada dos Veadeiros region comprise one of the largest savannah areas in central Brazil. The region includes large areas of the rare and little-known cerrado rupestre, which is home to numerous endemic species. During research on the Arecaceae flora of Chapada dos Veadeiros, a new species of *Butia* was discovered, and it is described here.

Material and methods – The morphology and anatomy are described based on field collections. Following the default methodology, pinnae and flowers were analysed using LM (freehand cross- and longitudinal sections) and SEM. The new species is compared to its morphologically similar species from the Brazilian central plateau, and an identification key and distribution map were established.

Key results – At first sight, the new species *Butia soffiae* resembles *B. archeri*, but with staminate and pistillate flowers, which are always purple, different in size, and congested in the rachillae. After close inspection, it is morphologically allied to *B. buenopolensis*, differing mainly by its glaucous peduncular bract – similar size to the inflorescence, herbaceous peduncle, numerous rachillae, purple floral colour, and inconspicuous staminodes. Differences in leaf anatomy, such as the presence of raphides, a cross-sectionally truncated midrib, and the number of accessory bundles on the midrib, also support the description of a new species. Two structures were recorded for the first time for the genus: squamiform trichomes at the base of the pistil and osmophores on the staminodes. The new species is assessed as Critically Endangered based on the restricted area of occurrence and anthropogenic threats.

Conclusion – *Butia soffiae* is the first endemic *Butia* species described in Chapada dos Veadeiros. The type population is located near Chapada dos Veadeiros National Park, which is the subject of a bill that aims to reduce its area by 73%. The discovery of this new species reinforces the uniqueness of the local flora and the importance of maintaining the park.

Keywords

acaulescent, Goiás State, new species, Palmae, plant anatomy, raphides, squamiform trichomes, taxonomy

INTRODUCTION

Among the phytophysiognomies of the Cerrado domain, the cerrado rupestre subdivision is the rarest, least known, and at the highest risk of disappearing in the coming decades, owing mainly to human pressure (Fernandes et al. 2016; Silveira et al. 2016; Pereira and Fernandes 2022). Cerrado rupestre is characterised by mainly shrub-like vegetation, on slopes and rocky outcrops above 800 m elevation on soils originating from the decomposition of sandstone, ironstone, and quartzite

(Pereira and Fernandes 2022). Despite some differences such as floristic composition and tree cover, the shrub-tree cerrado rupestre and the grassland campo rupestre are located side by side. They share similar edaphic and climate conditions, and are often confused (Pereira and Fernandes 2022). In the Brazilian central plateau, one of the most extensive areas of cerrado rupestre is found along the highlands of the Chapada dos Veadeiros region (Lima 2008; Nascimento and Sano 2010; Pereira and Fernandes 2022).

The Chapada dos Veadeiros is considered an exceptional area regarding biodiversity and has a high level of endemism. For instance, there are several species of Arecaceae belonging to several genera in this region, including acaulescent species (Mendonça et al. 2007; Noblick and Lorenzi 2010; Noblick 2017; SpeciesLink Network 2023). In addition, the region is a recognised origin of rare acaulescent *Syagrus* species (Noblick and Lorenzi 2010; Noblick 2017). As stated by Cássia-Silva et al. (2022), acaulescence likely promotes speciation in neotropical seasonally dry neotropical habitats, which probably explains the occurrence of these rare, acaulescent, and microendemic species of *Syagrus* (see Noblick and Lorenzi 2010; Noblick 2017). Some voucher specimens collected in this region correspond mainly to an acaulescent *Butia* species (SpeciesLink Network 2023). Thus, for this study, it was of great interest to focus sampling efforts in this region and to search for specimens in situ to investigate them further.

Over the last two decades, most of the acaulescent species of *Butia* were transferred from the genus *Syagrus*. Such was the case for *Butia campicola* (Barb.Rodr.) Noblick, *Butia leptospatha* (Burret) Noblick, *Butia exospadix* Noblick, and *Butia marmorii* Noblick (Noblick 2004, 2006). During this time, the genus *Butia* comprised only five acaulescent species, including *Butia microspadix* Burret (Noblick 2006). Lastly, *Butia pubispatha* Noblick & Lorenzi (Noblick 2010) was described, and *Butia poni* Hauman ex Burret (Deble et al. 2017) has been resurrected and epitypified. Most recently, *Butia buenopolensis* B.F.Sant'Anna-Santos was discovered (Sant'Anna-Santos 2021). So, there are currently 22 accepted species of *Butia* (Noblick 2010; Soares 2015; Deble et al. 2017; Sant'Anna-Santos 2021), and more than a third of the genus is composed of acaulescent species. However, it is likely that new species of *Butia* are to be found (Noblick 2014). For instance, at least one new acaulescent species of *Butia* is known and remains to be described (Soares 2015: fig. 17).

The Neotropical genus *Butia* is a well-defined monophyletic genus ranging from Central Brazil to Uruguay, Paraguay, and Argentina (Meerow et al. 2009; Noblick 2010, 2014; Soares 2015). The genus is composed of taxa showing complex taxonomic delimitations due to the extremely variable morphology (Noblick 2010, 2014). So, ambiguous species attributions, dubious names, unsolved species complexes, and hitherto misidentified species are commonly pointed out in the literature (see Henderson et al. 1995; Noblick 2010, 2014; Soares 2015; Deble et al. 2017; Sant'Anna-Santos 2021). Morphologically, the *Butia* genus can be recognised by the pinnate leaves; the pinnae forming a “V” with each other in the leaf rachis, frequently with clustered rammenta on the lower vein; the peduncular bract is generally smooth or superficially striate; inflorescences solitary and interfoliar, strongly protandrous; the filaments are often inflexed at the tips; petal tips of pistillate flowers are only slightly valvate; endocarp with 3 pores equatorial or subequatorial (Silberbauer-Gottsberger 1973; Henderson et al. 1995;

Dransfield et al. 2008; Noblick 2010, 2014; Soares 2015). However, even the most experienced specialists find it difficult to differentiate some species of *Butia* and, furthermore, *Butia* can be easily confused with *Syagrus*. In this context, leaf and flower microscopic characters associated with morphological characters have been used to corroborate the identification of *Butia* and the limits of several species (Glassman 1979; Noblick 2010, 2014; Tomlinson et al. 2011; Martel et al. 2013; Sant'Anna-Santos et al. 2015, 2018; Noblick and Sant'Anna-Santos 2021; Sant'Anna-Santos 2021). This approach helps to better understand the evolutionary and the auto-ecology of the genus (Sant'Anna-Santos 2021).

During fieldwork in the Chapada dos Veadeiros region, the discovery of unrecognised acaulescent specimens of *Butia* raised the possibility of whether they represent a new species. After morphological and anatomical analysis collected in situ, it was revealed that the new specimens indeed constitute the first new species of *Butia* endemic to Chapada dos Veadeiros. Because the conservation unit of that region has been the target of a bill being processed in the Brazilian Parliament to reduce its area by 73%, it is essential that all botanical novelties, especially of rare endemic species are brought to the attention of the scientific community and present evidence to strongly justify and support the conservation efforts being made for this vulnerable habitat.

MATERIAL AND METHODS

This study was based on field observations in a cerrado rupestre area in the municipality of Alto Paraíso de Goiás, Goiás State, Brazil. This study also includes information from the specific literature (Glassman 1979; Henderson et al. 1995; Noblick 2004, 2006, 2010, 2011, 2014; Deble and Marchiori 2006; Soares and Longhi 2011; Deble et al. 2011, 2012a, 2012b, 2017; Marchiori 2015a, 2015b; Sant'Anna-Santos et al. 2015; Soares 2015; Noblick and Sant'Anna-Santos 2021; Sant'Anna-Santos 2021; Ressel and Guilherme 2022), herbaria (DIAM, IBGE, Rio Verde Herbarium (Instituto Federal Goiano, campus Rio Verde), MBM, UPCB, SPF, UFG, HEPH, HDCE, RB, Montes Claros Herbarium (Universidade Estadual de Montes Claros, Montes Claros)), and online databases (UB, NY, US, HUFU, MBML, CEN, HUEFS). Morphological and anatomical terminology follows Dransfield et al. (2008), Tomlinson et al. (2011), and Noblick and Sant'Anna-Santos (2021). The circumscription adopted here for *Butia* is based on Soares (2015), Deble et al. (2017), and Sant'Anna-Santos (2021).

Qualitative and quantitative morpho-biometric data and images were recorded in situ for the new species. Data were taken from 20 randomly chosen individuals of the new species. For *Butia archeri* (Glassman) Glassman, *B. buenopolensis*, and *Butia purpurascens* Glassman, the morphological and anatomical data were retrieved from the literature (Glassman 1967, 1979; Noblick 2010, 2014;

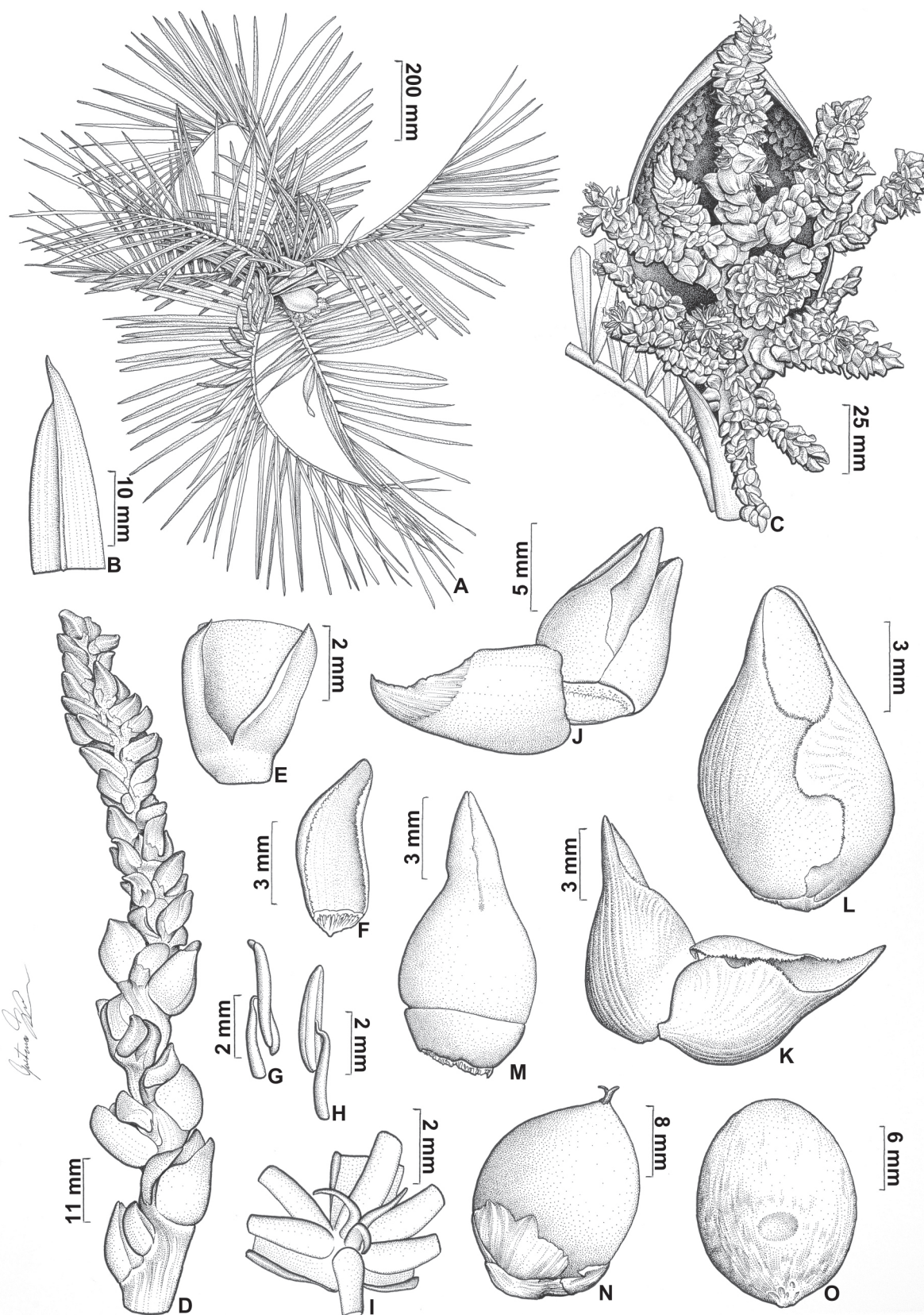


Figure 1. *Butia soffiae*. A. Arched leaves. B. Close-up of an asymmetrical pinna tip. C. Branched inflorescence and congested flowers. D. Rachillae. E. Sepals, connate at the base. F. Petal: ventral view. G. Stamen: lateral view. H. Stamen: dorsal view. I. Close-up of a pistillode. J. Pistillate flower: imbricate sepals. K. Petals, imbricate at the base and valvate at the tip. L. Valvate tip. M. Pistil. N. Fruit: persistent perianth. O. Endocarp pore. A–M from *Sant’Anna-Santos 378* (UPCB, holotype), fruit of N and endocarp of O added from habitat photographs. Illustration by Gustavo Surlo.

Table 1. Differences in morphology between *Butia soffiae*, *B. buenopolensis*, *B. archeri*, and *B. purpurascens*.

Characters	<i>B. soffiae</i>	<i>B. buenopolensis</i>	<i>B. archeri</i>	<i>B. purpurascens</i>
Habitat	Cerrado rupestre	Cerrado rupestre	Cerrado sensu lato	Cerrado sensu lato
Stem	Acaulescent	Acaulescent	Usually above ground	Above ground
Rachis length	45–79 cm	25–40 cm	66–72 cm	84–150 cm
True petiole length	0–3.0 cm	0.8–5.0 cm	2.0–15 cm	0–40 cm
Number of pinnae	33–42	25–29	28–44	38–61
Prophyll length	6.5–14 cm	5–6.5 cm	16–30 cm	12–30 cm
Peduncular bract	Glaucous	Glossy	Glaucous or rarely lepidote	Glaucous
Peduncular bract length	27.5–54 cm	10–20 cm	30–80 cm	70–105 cm
Peduncular bract's inflated portion	18–29 cm × 3.5–8.0 cm	6–10 × 1.8–2.3 cm	30–39 × 1.3–8.0 cm	61–81 × 6.0–13.0 cm
Peduncle length	8.0–15 cm	9.5–15.5 cm	24–40 cm	35–60 cm
Peduncle	Herbaceous	Woody	Herbaceous	Herbaceous
Peduncular bract vs inflorescence size	Similar	Different	Similar	Similar
Inflorescence axis	11–28 cm	4.0–7.5 cm	20–30 cm	60–64 cm
Rachilla number	27–32	4–7	15–35	50 or more
Rachis and rachillae colour	Yellowish-green to rarely purple	Dark purple	White tinged with purple	Yellowish-green to white tinged with purple
Colour of flowers	Light purple	Dark purple	Reddish-yellow to purple	Yellow to purple
Distance of the flowers on rachillae	Congested	Congested	Lax	Lax

Soares 2015; Sant'Anna-Santos et al. 2018; Sant'Anna-Santos 2021). For *B. buenopolensis*, presently considered the most closely allied species of the new species, the known population was visited to record images to show the distinctive features that contrast with the new species in Fig. 7. Samples of flowers of the new species were collected in the field and immediately analysed while fresh, and also stored in ethyl alcohol for further stereomicroscopic analysis (Bioptika L60T) coupled with a CMOS 12mp PLUS camera.

The distribution map was plotted using QGIS v.3.22.13 (QGIS Development Team 2022), using the following data sources: states (IBGE 2020) and elevation (Farr et al. 2007). The distribution data for *B. archeri*, *B. buenopolensis*, and *B. purpurascens* were retrieved from the following herbaria vouchers: DIAM3156 and IBGE84505 for *B. archeri*, IBGE83300 for *B. buenopolensis*, RB745893 and SPF140854 for *B. purpurascens*. The conservation status of the new species was evaluated according to the IUCN guidelines and criteria (IUCN 2022) using the GeoCAT tool (Bachman et al. 2011).

The pinna anatomical study was based on 15 samples—collected from the middle of the central pinnae—from herbarium specimens of the collections used to describe the new species and specimens in the field following Sant'Anna-Santos (2021). After rehydration following Meira and Martins (2003), freehand sections of the midrib, intermediate region, and margin were directly

mounted in water and observed under a light microscope (Bioptika B20+) coupled to a digital camera (CMOS 12mo PLUS). To better visualise the raphides, the intermediate region of the pinnae was also longitudinally sectioned. For *B. archeri*, *B. buenopolensis*, and *B. purpurascens*, the leaf anatomy data was retrieved from Sant'Anna-Santos et al. (2015, 2018) and Sant'Anna-Santos (2021). The staminodes were subjected to histochemical testing for lipophilic compounds with Sudan (O'Brien and McCully 1981). To better visualise the xylem endings, the staminodial ring was submitted to polarised light and sectioned longitudinally. Pinnae and flower samples of the new species were also fixed in Karnovsky's solution (Karnovsky 1965) for SEM analysis. After dehydration in ethyl alcohol, the samples were dried in a critical point drier (Balzers CPD 030) and sputter-coated with gold (Balzers SCD 050). The samples were observed using a JEOL JSM-6360-LV scanning electron microscope.

TAXONOMIC TREATMENT

Butia soffiae B.F.Sant'Anna-Santos, **sp. nov.**

[urn:lsid:ipni.org:names:77329027-1](https://nomenclature.ipni.org/names/77329027-1)

Figs 1–7, Tables 1, 2

Diagnosis. *Butia soffiae* is similar to *B. buenopolensis* B.F.Sant'Anna-Santos, from which it differs by congested

pinnae on the leaf rachis (vs lax pinnae); longer rachis (45–79 cm vs 25–40 cm); fibres of the pseudopetiole red (vs brown); true petiole frequently absent (vs always present); longer prophyll (6.5–14 cm vs 5–6.5 cm); glaucous peduncular bract (vs glossy); peduncular bract almost the same size as the inflorescence (vs smaller than the

inflorescence); herbaceous peduncle (vs woody); longer inflorescence axis (11–28 cm vs 4.0–7.5 cm); flowers light purple (vs dark purple); inconspicuous staminodes (vs conspicuous staminodes); more rachillae (27–32 vs 4–7). **Type.** BRAZIL – Goiás • Alto Paraíso de Goiás, Cachoeira dos Cristais; 14°06'05.27"S, 47°30'00.90"W; 1244 m; 22

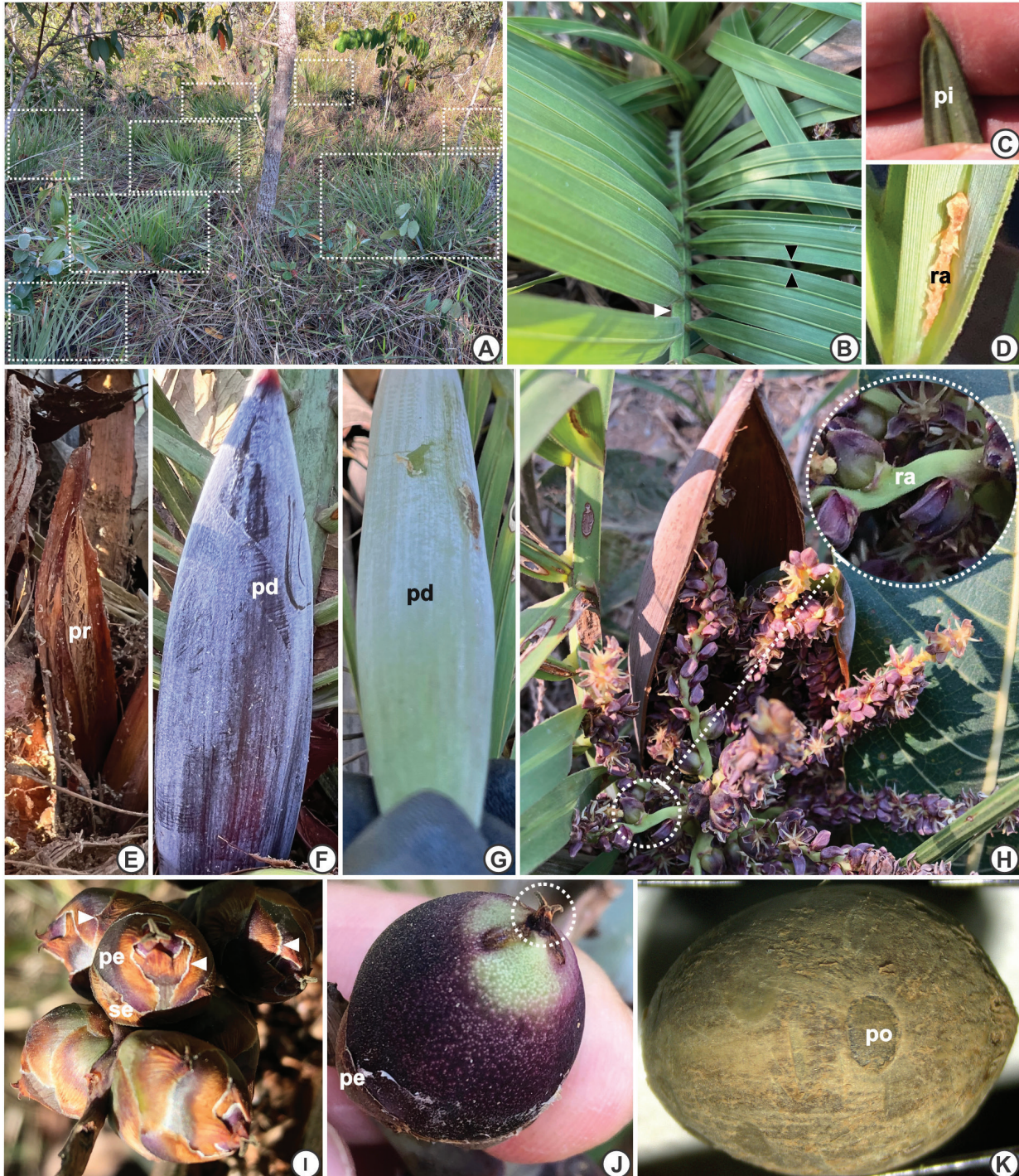


Figure 2. Vegetative and reproductive morphological aspects of *Butia soffiae*. **A.** Solitary habit of specimens (white rectangles) in the understory. **B.** The black arrowheads indicate the congested pinnae. Leaf rachis (white arrowhead). **C.** Asymmetric and acuminate tip of a pinna (pi). **D.** Ramenta (ra). **E.** Prophyll (pr). **F.** Closed peduncular bract (pd) glaucous and purple. **G.** Closed peduncular bract (pd) glaucous and green. **H.** Yellowish-green rachillae (ra). **I.** Early stage of fruit development: sepals (se), petals (pe), and shiny aspect of perianth margins (white arrowheads). **J.** Purple fruit: apical stigmatic remains (white circle) and persistent perianth (pe). **K.** Endocarp in lateral view: subequatorial pore (po). Photographs by Bruno F. Sant'Anna-Santos.

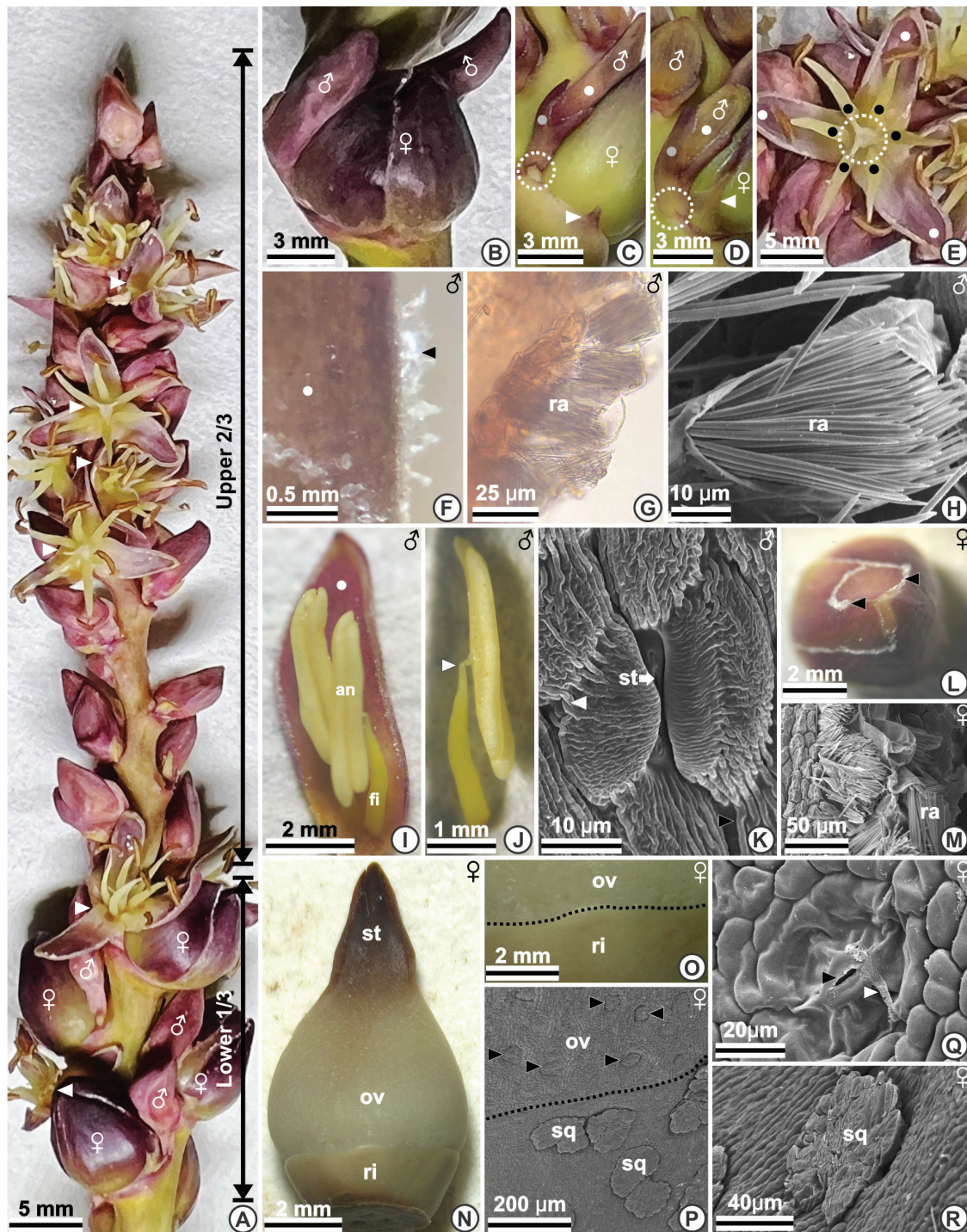


Figure 3. Floral morphology of *Butia soffiae*. A. Rachillae bearing only staminate flowers on its upper 2/3 and triads on its lower 1/3: staminate flowers in anthesis (white arrowheads). B. Triad: a central pistillate flower flanked by two staminate flowers. C. Briefly pedicellate staminate flower (dotted white circle) and floral bracteole (white arrowhead). Sepals (grey dot). Petals (white dot). D. Sessile staminate flower (dotted white circle) and floral bracteole (white arrowhead). Sepals (grey dot). Petals (white dot). E. Petals (three white dots), stamens (six black dots), and trifid pistillode (dotted white circle). F. Shiny aspect of petal margin (black arrowhead). Petal (white dot), stereomicroscopy. G. Raphides (ra) on petal margin, LM. H. Raphides (ra) on petal margin, SEM. I. Frontal view of stamens showing the anther (an) and filament (fi). Petal (white dot). J. Lateral view of stamen showing the connective (white arrowhead). K. Detail of the striate pattern of cuticle deposition of the anther epidermis (white arrowhead) with a stoma (st), SEM. L. Upper view: shiny aspect (black arrowhead) of sepal margins. M. Raphides (ra) on petal margin, SEM. N. Pistil: stigma (st), ovary (ov), and staminodial ring (ri), stereomicroscopy. O. The dotted line shows the boundary between the ovary (ov) and staminodial ring (ri), stereomicroscopy. P. Squamiform trichomes (sq) uncovered after removing the staminodial ring. Ovary (ov), stomata (five black arrowheads), SEM. Q. Stomata (black arrowhead) and secretion (white arrowhead). R. Squamiform trichome (sq). Photographs by Bruno F. Sant'Anna-Santos.

Table 2. Differences in pinnae anatomy between *Butia soffiae*, *B. buenopolensis*, *B. archeri* and *B. purpurascens*.

Characters	<i>B. soffiae</i>	<i>B. buenopolensis</i>	<i>B. archeri</i>	<i>B. purpurascens</i>
Cross-sectional shape of the midrib	Truncate	Triangular	Truncate	Rounded
Raphides	Present	Absent	Absent	Absent
Expansion tissue stratification (cell layers)	4	4	3	3
Number of accessory bundles	14–19	26–31	8–13	20–25
Number of accessory bundles with reinforced sheath	2	1	1	0
Number of collateral bundles	2	2	3 or more	3 or more
Isolated or small group of fibres on mesophyll	Absent	Present	Absent	Absent
Non-vascular fibre bundle on midrib	Absent	Present	Absent	Absent

Jun. 2022; fl.; *Sant'Anna-Santos* 378; holotype: UPCB; isotypes: DIAM, HCF, MBM.

Description. Small palm, solitary, 40–60(–80) cm tall. Stem usually acaulescent or with a short stem 5–15 × 3–5 cm. Leaves 6–11 in the crown, 78–110 cm long, arched, concolourous, green; leaf sheath plus petiole (pseudopetiole) 5–10 cm long, 0.7–1.0 cm wide, flat on the adaxial surface and abaxially rounded, margins of the apparent petiole (pseudopetiole) smooth, unarmed, with barely membranaceous red fibres; true petiole absent to 3 cm long; leaf rachis 45–79 × 0.5–0.7 cm, with 33–42 pairs of pinnae; pinnae regularly arranged in a single plane (and the two sides forming a V with each other), with asymmetric and acuminate tips, clustered rammenta on the lower vein near the rachis; basal pinnae 17–22 × 0.2–0.5 cm, middle pinnae 17–40 × 0.7–2.0 cm, apical pinnae 9.8–13.4 × 0.2–0.4 cm. Inflorescences axillary, branched to one order, prophyll 6.5–14 cm long; peduncular bract 27.5–37(–54) cm long, glaucous, superficially striated, green or purple when immature (external surface), with inflated portion 18–29 × 3.5–7.3 cm (including an apical beak 0.5–0.8 cm long), 5.5–9.0 cm perimeter and 1 mm thickness; peduncle 6.0–14.0 × 0.6–1.3 cm, glabrous; inflorescence axis (the branched portion of inflorescence) 11–28 cm long, rachis 6–21 cm long, rachillae 27–32, yellowish-green to rarely purple, glabrous or with white indument, 5–17 cm long. Staminate flowers 5.3–9.8 × 2.2–4.3 mm, triangular, light purple, arranged in triads on the lower portion of the rachillae (a central pistillate and two lateral staminate flowers); the upper portion of the rachillae only with staminate flowers, staminate flowers sessile or briefly pedicellate (on the lower portion of the rachillae); sepals 3, 2.1–4.6 × 0.5–1.1 mm, acute apex, glabrous, narrow, triangular, purplish yellow or purple, connate at the base, valvate, with raphides on margins; petals 3, 4.9–8.8 × 2.0–3.0 mm, ovate, valvate, raphides on margins, no visible veins; stamens 6, 4.4–7.2 mm long, anthers 3.0–4.6 mm long, filaments 2.5–4.0 mm long, pistillode 1.3–1.4 mm long (shorter than the filaments), trifid. Pistillate flowers 9.9–13.3 × 6.2–7.8 mm, sessile, ovoid, glabrous; sepals 3, 6.3–11.5 × 5.2–7.5 mm, purple, glabrous, with raphides on the margins, no visible veins,

broadly imbricate; petals 3, 6.3–10.8 × 4.5–6.4 mm, glabrous, imbricate; pistil 6.0–9.6 × 4.0–5.3 mm, glabrous, stigmas 3, 1.5–3.0 mm long, glabrous, staminodial ring slightly lobed. Fruits greenish-purple, ovoid, 20–27 × 15–17 mm, with a short beak and apical stigmatic remains; epicarp smooth, the basal third covered by a persistent perianth; mesocarp fibrous; endocarp 13–17 × 10–13 mm, bony, brown, with 3 subequatorial pores below the equator end (pores subequatorial), endosperm whitish and homogeneous embryo opposite the endocarp pores, one seed. Germination and eophyll were not observed.

Distribution. The type population of *Butia soffiae* was found in the Chapada dos Veadeiros region, in the municipality of Alto Paraíso de Goiás (Fig. 4).

Habitat and ecology. Chapada dos Veadeiros is among the regions with the highest altitudes in the Cerrado domain, with average altitudes ranging from 800 to 1600 m (Ribeiro and Walter 1998; Felfili et al. 2007). The predominant form of relief is a strong undulating plateau, mountainous and steep with shallow and stony soils (Ribeiro and Walter 1998). The region is characterised by dry winters and rainy summers, with mean annual temperatures between 24–26°C and mean annual rainfall ranging from 1500 to 1750 mm (Felfili et al. 2007). The new species was found in a cerrado rupestre area. Despite being poor in nutrients, these areas present a tree cover ranging from 5% to 20%, an average height of 2 to 4 m, and a highlighted shrub-tree stratum because they have less stony and deeper soil compared to grassland campos rupestres (Pereira and Fernandes 2022). In addition to the great diversity of eudicotyledonous families (Mendonça et al. 2007; SpeciesLink Network 2023), the vegetation of Chapada dos Veadeiros is characterised by a high density and important structural component of monocotyledons in the tree-shrub community, as shown by Lenza et al. (2011), mainly comprising Velloziaceae and Arecaceae (Fig. 5A–B). These families possess endemics for Chapada dos Veadeiros (Noblick and Lorenzi 2010; Noblick 2017; CNCFlora 2023). For palms, for example, the endemic and rare *Syagrus caerulea* Noblick & Lorenzi (Fig. 5B) grows in the municipality of Alto Paraíso de Goiás (see Noblick and Lorenzi 2010; Noblick 2017), near

the area where *B. soffiae* was discovered. During the flowering time, the light-purple flowers of *B. soffiae* stand out from the understory green and emit a pleasant and sweet scent, acting at a distance to attract bees, observed visiting staminate flowers during anthesis (Fig. 5C–D). Bees have already been reported as one of the main pollinators of other *Butia* species (see Silberbauer-Gottsberger 1973; Silberbauer-Gottsberger et al. 2013). The staminate flowers of *B. soffiae* release large amounts of pollen (Fig. 5E) and small viscous and sweet droplets (Fig. 5F), suggesting nectar production. Flowers of other *Butia* species produce nectar, and staminate flowers also produce large amounts of pollen, which still function as a floral reward (Silberbauer-Gottsberger 1973; Mercadante-Simões et al. 2006; Silberbauer-Gottsberger et al. 2013). Bees collecting pollen and feeding on nectar in staminate flowers were reported for other *Butia* species (Silberbauer-Gottsberger 1973; Silberbauer-Gottsberger et al. 2013). Beetles were also frequent visitors of *B. soffiae* flowers (Fig. 5G). The staminodial ring of pistillate flowers has inconspicuous staminodes, composed of cells of dense cytoplasm and compact arrangement (Fig. 5H), they are markedly vascularised by xylem ends (Fig. 5H–J) and release oil-like droplets (Fig. 5K–L). The epidermis near the staminodes tested positive for lipophilic compounds

(Fig. 5L), corroborating the presence of osmophores in these functional staminodes. Moreover, the floral scent was considered especially relevant for cantharophily and melittophily in some palms (Knudsen et al. 2001). In the field, small, sweet droplets were observed on the surface of the anther (Fig. 5F), but it was impossible to ascertain whether the stamens secrete these droplets or whether they oozed from another flower region. Furthermore, aphids and ants were commonly observed during the development of the fruits (Fig. 5M). The constant presence of these insects (bees, beetles, ants, and aphids) could be the reason for the marked presence of raphides in the flowers and fruits of *B. soffiae*. Ecologically, raphides are seen as a common defence strategy against herbivores and are often present in many organs of palms, such as flowers (Dransfield et al. 2008).

Phenology. The new species was collected with flowers and fruits in June of 2021 and 2022.

Etymology. The epithet honours Dr Patrícia Soffiatti, affectionately called Soffi by her friends and mentees. She is a Brazilian scientist and professor at the Department of Botany at the Federal University of Paraná (UFPR), mainly devoted to studying Cactaceae. Her deep knowledge of the environment where cactuses and palms cohabit and her expertise in plant anatomy were essential

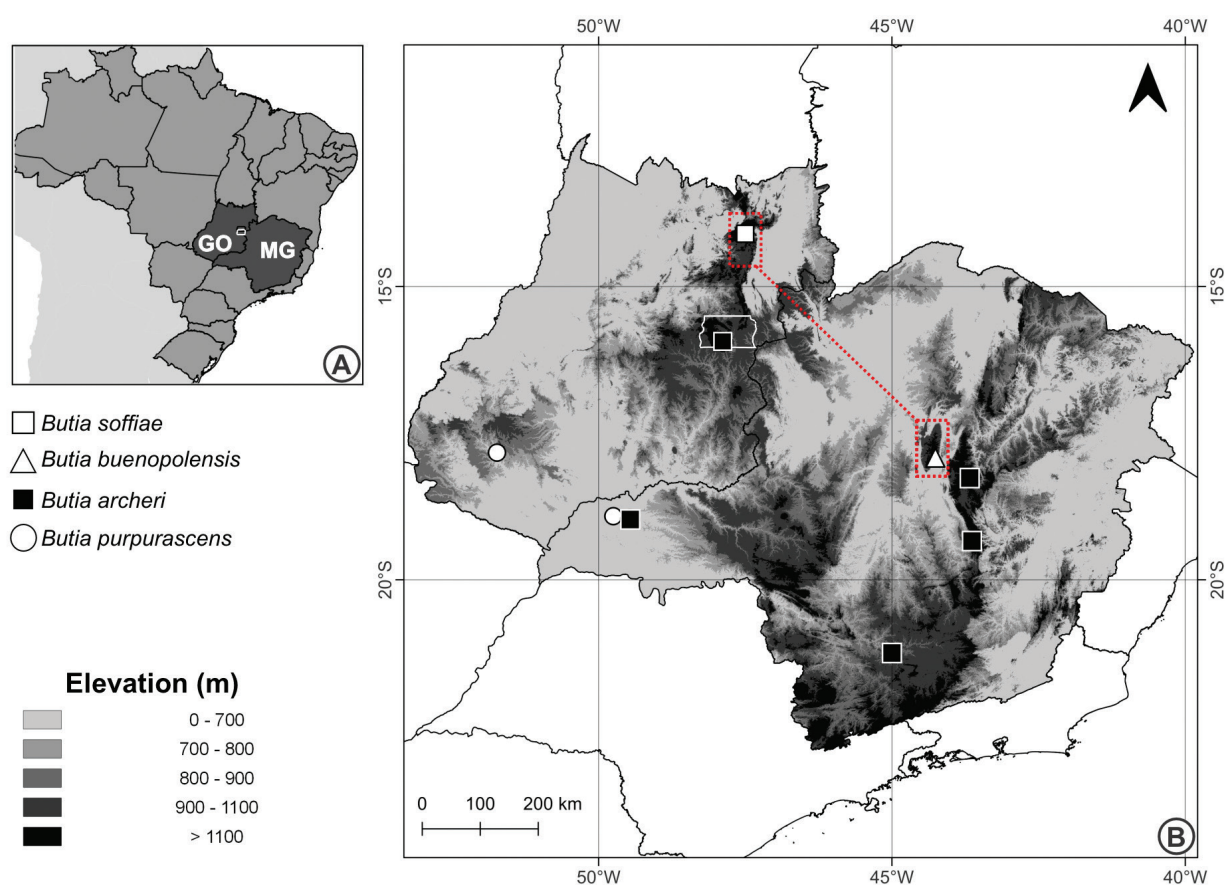


Figure 4. Distribution map of *Butia soffiae*, *B. buenopolensis*, *B. archeri*, and *B. purpurascens*. State names were abbreviated as follows: Minas Gerais (MG), Goiás (GO), the Distrito Federal is demarcated by a white line within the state of Goiás. **A.** Distrito Federal, Goiás, and Minas Gerais states in Brazil. **B.** Location of *B. soffiae*, *B. buenopolensis*, *B. archeri*, and *B. purpurascens*: the dashed red line shows the geographical distance between the Chapada dos Veadeiros and the Serra do Cabral massif.

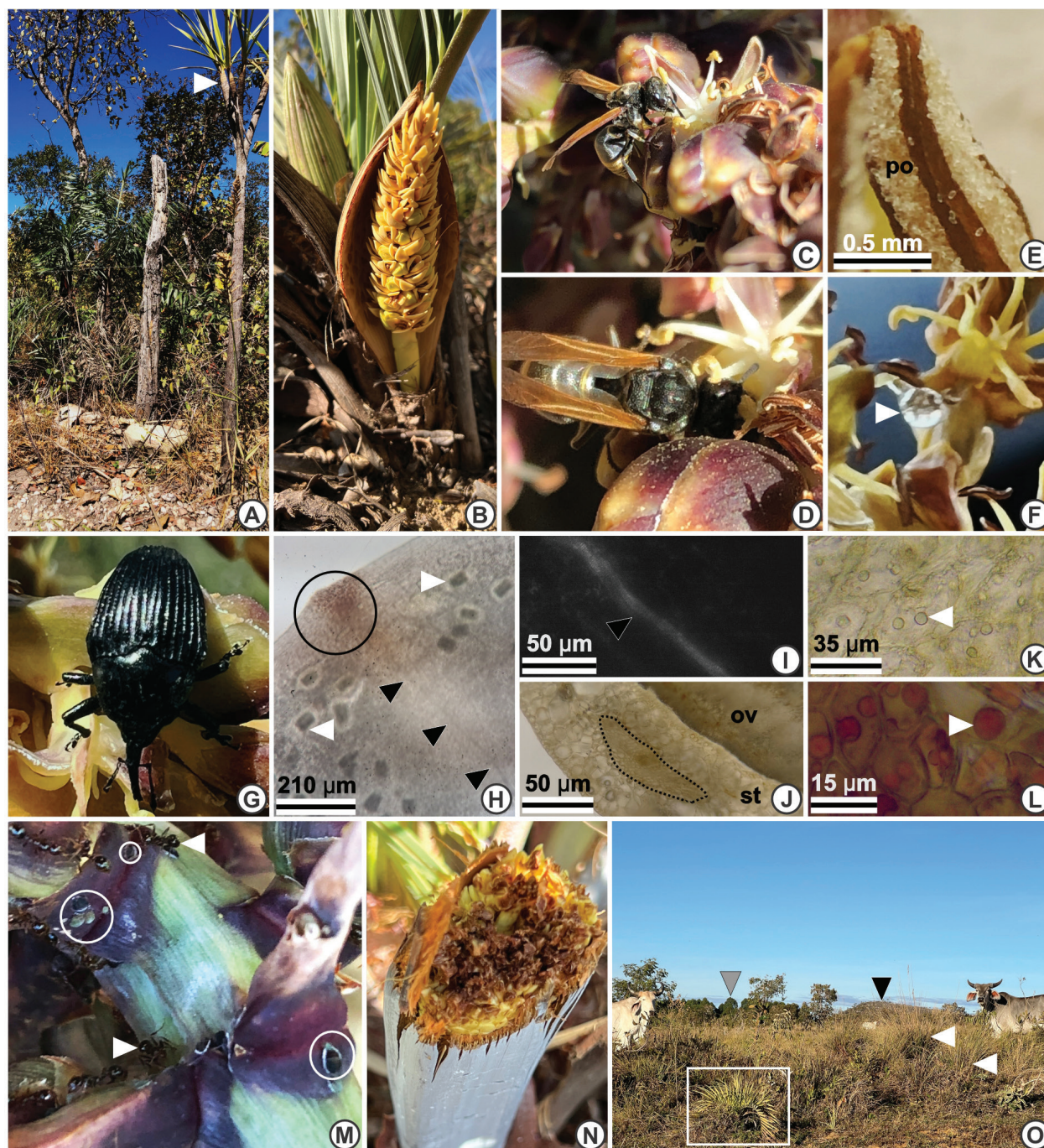


Figure 5. Habitat and morphoanatomical aspects of *Butia soffiae* with ecological implications and threats in the vicinity of the type population. A. Specimen of Velloziaceae (white arrowhead). B. Inflorescence of the endemic and rare *Syagrus caerulea*. C. Bee visiting a stamen. D. Bee visiting a petal. E. Pollen (po). F. Droplet of nectar (white arrowhead). G. Beetle visiting a petal. H. Frontal view of staminodial ring: staminode (black circle), raphides (white arrowheads), and vascularisation (black arrowheads), LM. I. Detail of H: vascularisation (black arrowhead) under polarised light, LM. J. Cross-section of the staminode's vascularisation (black dotted), LM. Ovary (ov). Staminode (st). K. Frontal view of staminode showing the oil-like droplets (white arrowhead). L. Sudan staining of lipophilic compounds (white arrowhead). M. Infructescence: aphids (white circles) and ants (white arrowheads). N. Inflorescence at pre-anthesis grazed by cattle. O. Landscape view of a pasture nearby the type population showing a rocky outcrop (black arrowhead), a *Eucalyptus* sp. plantation (grey arrowhead), cattle, and non-native grasses (white arrowheads). *Butia soffiae* (white rectangle) in the foreground. Photographs by Bruno F. Sant'Anna-Santos.

to the description of the newly acaulescent *Butia* and *Syagrus* species discovered by our team on the Serra do Cabral massif.

Preliminary IUCN conservation assessment. The single population of the new species was recorded just outside Chapada dos Veadeiros National Park. The park and the surrounding region are very susceptible to wildfires due to the dry season conditions, such as low rainfall, low relative humidity, and wind associated with the combination of human activities and climate change (Balch et al. 2018; Fidelis et al. 2018). For instance, in 2017, a megafire event burned 78% of Chapada dos Veadeiros National Park (Fidelis et al. 2018). In addition to the enormous extent of burning, megafires are more difficult to extinguish than common wildfires, which happen annually in the region (Fiedler et al. 2006; Ferreira-Leite et al. 2017). Near the boundaries of Chapada dos Veadeiros National Park, where *B. soffiae* occurs, cattle raising is also common (Fig. 5O). In addition to cattle feeding on plant parts (Fig. 5N), ranchers burn the vegetation to promote grass regrowth for the cattle (Fig. 5O), increasing the risk of accidental fires (Ramos-Neto and Pivello 2000; Fidelis et al. 2018). *Eucalyptus* sp. plantations (Fig. 5O), and charcoal production are also economic activities in the region (Felfili et al. 2007), severely threatening the native vegetation of the area. Other regional threats, such as soil degradation and the spread of exotic grasses, also hinder conserving the Cerrado domain (Klink and Machado 2005). Taking into account the area of occupancy (AOO = 20 km²) and the extent of occurrence (EOO = 2,854 km²), and according to the IUCN (2022) categories and criteria, *B. soffiae* should be considered Critically Endangered: CR B1ab(i,iii).

Additional material examined. BRAZIL – Goiás • Alto Paraíso de Goiás, Portal da Chapada, trilha suspensa; 14°07'57.00"S, 47°30'36.00"W; 11 Sep. 2011; fl., fr.; Faria et al. 1715; UB • Alto Paraíso de Goiás, Rodovia entre Teresina de Goiás e Alto Paraíso; 14°07'57.00"S, 47°30'35.99"W; 25 Sep. 2011; fl.; Pastore 3371; HUEFS.

Pinnae anatomy. The pinnae are amphistomatic and covered by two types of epicuticular waxes: horizontal

plates and hook-shaped filaments (Fig. 6A–B). The hook-shaped filaments cover the small depressions above the stomata (Fig. 6A–B). The subsidiary cells are arciform in the leaf transverse section, and are positioned entirely below the cuticle level (Fig. 6A–C). The hypodermis forms one to two layers of cells longitudinally elongated to quadrangular shaped on both surfaces (Fig. 6D–F, H). The hypodermis forms two layers above the vascular bundles, but below the stomata, it is interrupted by substomatal chambers (Fig. 6D–F, H). The lamina is isobilateral, with two bands of palisade parenchyma near the hypodermis on both surfaces and a central chlorenchyma between them, composed of cells of bulky elongate-spherical shape (Fig. 6D, H). Both adaxial and abaxial tertiary vascular bundles are connected to the hypodermis, have no distinguishable phloem and are always partially surrounded by a sclerenchymatous sheath (Fig. 6D–F, N). Secondary and primary vascular bundles are also connected to the hypodermis on both surfaces, and the phloem is always noticeable (Fig. 6D–F, N). The secondary vascular bundles are partially surrounded by a sclerenchymatous sheath, while the primary vascular bundles are always fully surrounded by fibres (Fig. 6D, G). The primary vascular bundles always have a larger diameter, four phloem poles and noticeable protoxylem and metaxylem elements (Fig. 6G). The raphide-containing idioblasts are found in the central chlorenchyma region (Fig. 6I). The midrib is transversally truncated (Fig. 6J) and adaxially projected (Fig. 6J–L). The main vascular system of the midrib consists of two collateral bundles, surrounded by a fibrous ring and 14–20 accessory bundles, 2 of them with reinforced sheath (Fig. 6J–M). The smaller accessory bundles are sharper under polarised light (Fig. 6L). The expansion tissue is interrupted and four-layered (Fig. 6J, M). Non-vascular fibre bundles were absent from the midrib of *B. soffiae*. In cross-section, the margin is quadrangular and possesses 2 tertiary vascular bundles; the abaxial one is larger and occupies more than half of the margin (Fig. 6N). Table 2 compares the pinna anatomy of *B. soffiae*, *B. buenopolensis*, *B. archeri*, and *B. purpurascens*.

Key to distinguish between *Butia soffiae* and *Butia buenopolensis*, *Butia archeri*, and *Butia purpurascens*

1. Small plant size, stem subterranean; congested flowers, staminate and pistillate flowers different in size; peduncle 8–15.5 cm long; inflated portion of peduncular bract 6–29 cm long..... **2**
- Plant size moderate to tall, stem usually erect; lax flowers, staminate and pistillate flowers of similar size; peduncle 24–60 cm long; inflated portion of peduncular bract 30–81 cm long **3**
2. Congested pinnae; glaucous peduncular bract, peduncular bract and inflorescence of similar size; herbaceous peduncle; 27–32 rachillae, yellowish-green rachillae and rachis (rarely purple); inconspicuous staminodes..... ***Butia soffiae***
- Lax pinnae; glossy peduncular bract, peduncular bract shorter than inflorescence; woody peduncle; 4–7 rachillae, dark-purple rachillae and rachis; conspicuous staminodes..... ***Butia buenopolensis***
3. Moderate plant size; leaf rachis length 66–72 cm long, middle pinnae length 36–40 cm long; pseudopetiole length 6.0–22.0 cm long; inflated portion of peduncular bract 30–39 cm long; inflorescence axis length 20–30 cm long, rachillae length 10–19 cm long, 15–35 rachillae..... ***Butia archeri***
- Tall plant size; leaf rachis length 84–150 cm long, middle pinnae length 44–60 cm long; pseudopetiole length 49–75 cm long; inflated portion of peduncular bract length 61–81 cm long; inflorescence axis length 60–64 cm long, rachillae length 23–26 cm long, 50 or more rachillae..... ***Butia purpurascens***

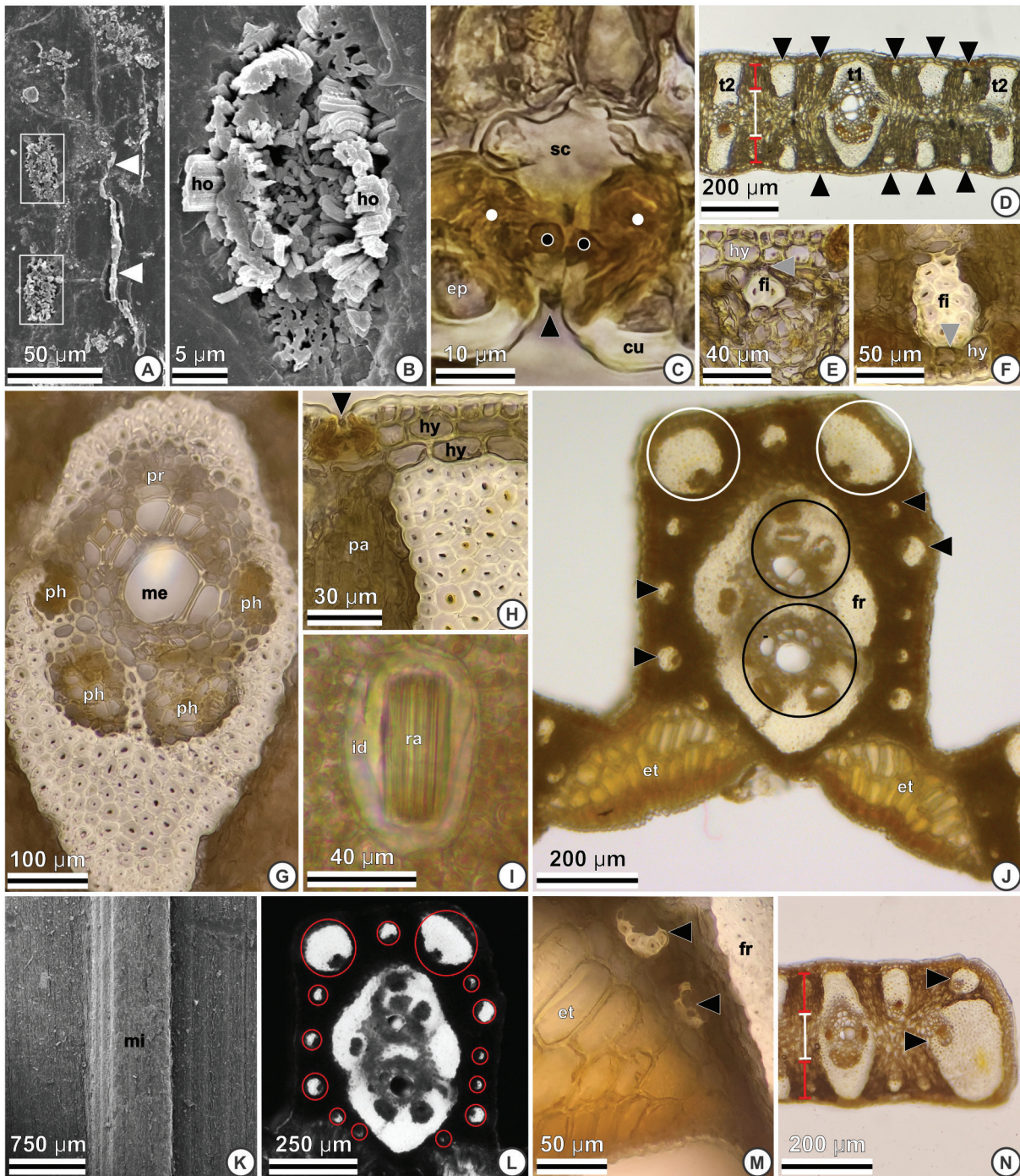


Figure 6. Pinna anatomy of *Butia souffiae* using SEM (A–B, K) and LM with cross- (C–H, J–N) and longitudinal (I) sections. **A.** Adaxial surface: horizontal plates of epicuticular waxes (white arrowheads) and stomata (white rectangles). **B.** Abaxial surface: stomata coated by hook-shaped filaments (ho) of epicuticular waxes. **C.** Abaxial surface: guard cells (black dots) and lateral subsidiary cells (white dots) are sunken within the epidermis (ep) forming small depressions on the surface (black arrowhead). Cuticle (cu), substomatal chamber (sc). **D.** Primary (t1), secondary (t2), and tertiary vascular bundles (black arrowheads) connected to the adaxial and abaxial hypodermis; palisade parenchyma (red lines); central parenchyma (white line). **E–F.** The grey arrowheads indicate the fibres (fi) of the tertiary vascular bundles connected to the adaxial and abaxial hypodermis (hy), respectively. **G.** Primary vascular bundles with conspicuous metaxylem (me), protoxylem (pr), and four phloem poles (ph). **H.** Detail of the secondary vascular bundle connected to the adaxial biseriolate hypodermis (hy). Stomata (black arrowhead), palisade parenchyma (pa). **I.** Idioblast (id) containing raphides (ra). **J.** Expansion tissue (et) interrupted; two collateral bundles (black circles); accessory bundles (black arrowheads), and two accessory bundles with reinforced sheath (white circles); fibrous ring (fr). **K.** Midrib (mi) adaxially projected, SEM. **L.** Midrib with all accessory bundles highlighted under polarised light (red circles). **M.** Detail of expansion tissue cells (et); accessory bundles (black arrowheads) and fibrous ring (fr). **N.** Pinna margin with reinforced vascular bundles (black arrowheads). Palisade parenchyma (red lines), central parenchyma (white line).



Figure 7. Morphological differences between the acaulescent *Butia soffiae* (A, C, E, G, I, K) and *Butia buenopolensis* (B, D, F, H, J, L). **A.** Plant with longer leaves. **B.** Plant with shorter leaves. **C.** Red fibres (fi) of the pseudopetiole. **D.** Brown fibres (fi) of the pseudopetiole. **E.** Congested pinnae (pi), inflorescence with several rachillae (ra) and glaucous peduncular bract (pn). **F.** Lax pinnae (pi), inflorescence with few rachillae (ra) and glossy peduncular bract (pn). **G.** Herbaceous peduncle (pe), yellowish-green rachillae (ra), and light purplish-green flowers (white circles). **H.** Woody peduncle (pe), dark purple rachillae (ra), and dark purple flowers (white circles). **I.** Peduncular bract (pn) almost the same size than inflorescence (in). **J.** Peduncular bract (pn) smaller than the inflorescence (in). **K.** Staminal ring (sr) with inconspicuous staminodes, stereomicroscopy. **L.** Staminal ring (sr) with conspicuous staminodes (white arrowheads), stereomicroscopy. Photographs by Bruno F. Sant'Anna-Santos.

DISCUSSION

The diversity of the *Butia* genus in Chapada dos Veadeiros is still an open question. Current species of *Butia* are divided into two groups (Noblick 2014): the small acaulescent species and those that are caulescent (with above-ground stems). In Chapada dos Veadeiros, both *Butia* groups have been recorded (Mendonça et al. 2007; SpeciesLink Network 2023). The caulescent *Butia* species were first studied in this region by Martins (2012), who recorded *B. archeri* and *B. purpurascens*. The first species is usually caulescent (Soares 2015: fig. 1; Sant'Anna-Santos 2021: fig. 2) and has the widest distribution in the Brazilian central plateau (Noblick 2010, 2014; Soares 2015). The second species is also caulescent, larger in height (Soares 2015: fig. 14; Ressel and Guilherme 2022: fig. 1), and restricted to the southwestern Goiás State and surrounding localities (Noblick 2010; Soares 2015) – far away from Chapada dos Veadeiros. Moreover, neither species seems to occur in Chapada dos Veadeiros according to the distribution maps of the most recent revision of *Butia* (Soares 2015). Nevertheless, Noblick (2010) considered Chapada dos Veadeiros as an occurrence of *B. archeri*. Despite the similarity of some voucher specimens to *B. archeri* or *B. purpurascens*, the occurrence of these species in the region remains uncertain. My preliminary field observations (not documented) show that these caulescent specimens are not as tall as *B. purpurascens*, and their heads are not as compact as *B. archeri*. Thus, a broad sampling of specimens, especially during flowering, will be essential to solving the issue of the caulescent *Butia* in the region.

What about the hitherto unknown acaulescent *Butia* species from Chapada dos Veadeiros? At first sight, the acaulescent *Butia soffiae* resembles a dwarf form of *B. archeri*. Thus, some collectors have misidentified *B. soffiae* as *B. archeri* or only identified it to the genus level. Justifiably, the occurrence on the Brazilian central plateau and the lack of spines or teeth on the pseudopetiole pointed to *B. archeri* (see Noblick 2010; Soares 2015). Additionally, *B. buenopolensis* had not yet been described by Sant'Anna-Santos (2021), which explains the identification at the time. So, from a morphological standpoint, *Butia soffiae* is more closely allied morphologically to *B. buenopolensis*.

Despite the noteworthy similarities between *B. soffiae* and *B. buenopolensis*, such as the lack of spines or teeth on the pseudopetiole, congested purple flowers that differ in size (staminate vs pistillate), small size and acaulescence, there is enough difference to separate them. Morphologically, the size of the leaf rachis (Fig. 7A–B) and the colour of the pseudopetiole fibres (Fig. 7C–D) are vegetative characters useful to distinguish the two species. Regarding inflorescences, reliable characters to recognize *B. soffiae* as a distinct species from *B. buenopolensis* are: the rachilla number (Fig. 7E–F), peduncular bract size (Fig. 7E–F), peduncle colour (Fig. 7G–H), the size difference between inflorescence and peduncular bract (Fig. 7I–J) and the staminodes (Fig. 7K–JL). The detailed comparison between the two species is shown in

Table 1 and the identification key. Therefore, despite the resemblance to *B. buenopolensis*, there is strong evidence supporting *B. soffiae* as a new species.

Regarding the habitat, both species are from the highland cerrado rupestre. However, the closest population of *B. buenopolensis* is at least 545 km from the Chapada dos Veadeiros (Fig. 4B). Furthermore, like the Serra do Cabral massif, the Chapada dos Veadeiros present a strong insular component, even compared to neighbouring areas (Felfili et al. 2007; Firmo et al. 2021; Sant'Anna-Santos 2021). So, the region is a cradle of endemics, including palms, and new endemics of several botanical families continue to be discovered (Noblick and Lorenzi 2010; Silva and Sodré 2014; Silva and Souza 2014; Noblick 2017; Pastore 2018; Villarroel et al. 2018; Santos et al. 2022; Silva and Santos 2023).

The pinna anatomy also supports *Butia soffiae* within the genus and as a new species. The mirrored mesophyll is the most striking pinnate character for determining the genus of the new species. Including *B. soffiae*, all the 19 valid *Butia* species anatomically studied possess this feature (Tomlinson et al. 2011; Noblick 2014; Sant'Anna-Santos et al. 2015, 2018; Noblick and Sant'Anna-Santos 2021; Sant'Anna-Santos 2021). Thus, this character is probably a synapomorphy for *Butia* (Noblick 2014; Sant'Anna-Santos et al. 2015, 2018; Noblick and Sant'Anna-Santos 2021). The raphides are also important to differentiate between species within the genus (Sant'Anna-Santos et al. 2015, 2018). Nine out of 19 valid species anatomically studied, including *B. soffiae*, have raphides on the pinnae (see Sant'Anna-Santos et al. 2015, 2018; Sant'Anna-Santos 2021). Among the four species compared here (*B. archeri*, *B. buenopolensis*, *B. soffiae*, and *B. purpurascens*), only *B. soffiae* has raphides. Thus, this character is reliable for identifying *B. soffiae* – even in non-reproductive specimens from the Chapada dos Veadeiros.

Raphides on flowers are also important for supporting the cohesive unit of *Butia* since they are lacking in *Syagrus* and *Jubaea* (Martel et al. 2013; Sant'Anna-Santos 2021). Epidermal raphide-containing idioblasts were first shown by Martel et al. (2013) on petals of staminate flowers of 13 *Butia* species. The same character was recently found in sepals and petals of staminate and pistillate flowers of *B. buenopolensis* (Sant'Anna-Santos 2021) and now in *B. soffiae*. Therefore, 15 *Butia* species have raphides in the perianth (Martel et al. 2013; Sant'Anna-Santos 2021), another possible synapomorphy of the genus. Among the microscopic characters, the presence of osmophores in *Butia* is confirmed here for the first time. Recently, similar structures were shown in *B. buenopolensis* (Sant'Anna-Santos 2021). Osmophores were also reported in some other neotropical Arecaceae, such as *Acrocomia aculeata* (Jacq.) Lodd. ex R.Keith and *Syagrus cabraliensis* (Noblick and Lorenzi) Sant'Anna-Santos (Mazzottini-dos-Santos et al. 2015; Sant'Anna-Santos et al. 2023a). Despite the low potential for taxonomical purposes, osmophores are important for elucidating the auto-ecology of the species, as showed in Fig. 5C–L. SEM analysis of *Butia*

soffiae flowers showing squamiform trichomes below the staminodial ring (Fig. 3P, R) – also the first report for the genus. Unfortunately, these trichomes were not noticed in the field and so fresh flowers were not analysed in histochemical tests – an important tool to clarify their function. Similar trichomes were shown in *Syagrus inajai* (Spruce) Becc. by SEM analysis (Genovese-Marcomini et al. 2013: fig. 5), but, similarly, their function was not investigated. Nevertheless, these trichomes might be taxonomically relevant for *Syagrus*, as they have not been observed in *Syagrus aristae* B.F.Sant'Anna-Santos, *Syagrus cabraliensis*, and *Syagrus carvalhoi* B.F.Sant'Anna-Santos (Sant'Anna-Santos et al. 2023a, 2023b, 2023c). Hence, evaluating the taxonomical potential of this trait for *Butia* will be important.

The newly discovered endemic acaulescent *Butia* from the highlands of the Brazilian central plateau display unprecedented characters with taxonomic, evolutionary, and ecological potential. *Butia soffiae* is the first endemic species of *Butia* formally described for the Chapada dos Veadeiros. The type population of *B. soffiae* is located near Chapada dos Veadeiros National Park, the target of a bill being processed in the Brazilian Parliament to reduce its area by 73%. Thus, the discovery of *B. soffiae* reinforces the uniqueness of the palm flora and the importance of maintaining or even increasing the park area.

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