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Fruit morphology in *Anthurium* sect. *Pachyneurium* from Brazil (Araceae) and its taxonomic implications ☆

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Highlights

- The berries can help in the delimitation of Anthurium from Brazil, associated with other vegetative and reproductive morphological characteristics.
- The position of the infructescence and characteristics of the berries and seeds are described.

- An identification key and comparative table with more diagnostic characteristics, illustrations, comments, and distribution were used to separate the 11 species of *A. sect. Pachyneurium* from Brazil.

Abstract

The revision of *Anthurium* section *Pachyneurium* from Brazil provided the opportunity to expand the knowledge of berry attributes. Through examination of infructescence, fruits, and seeds from 11 species *A. sect. Pachyneurium* from Brazil, we aimed to uncover morphological variations in berry shape, size, color, ornamentation, and seed characteristics are crucial for taxonomic insights within the broader *Anthurium* genus. The study presents diagnostic descriptions for 11 *Pachyneurium* species, complemented by an identification key, diagnoses, illustrations, and a comparative table, based on infructescence, fruit and seeds. *Pachyneurium* species have oblong to obovoid berries, rarely globose shape, purple or reddish color and 1–2 seeds per berry, 1 is generally aborted. By elucidating the taxonomic value of these attributes, we provide essential tools for accurate species identification and classification, thus advancing botanical taxonomy and enriching our comprehension of this specific plant group.

Introduction

Araceae Juss. is a Neotropical family, with approximately 144 genera and 3600 species (Boyce & Croat, 2011 onwards). is monophyletic, represented by perennial herbs, usually epiphytic to hemiepiphytic, climbing or arborescent, lithophyte, terrestrial, geophytic or helophytic (Mayo et al., 1997). In Brazil, Araceae are distributed throughout the national territory, with 47 genera and 521 species, 278 of which are endemic (Flora de Brasil, 2022). It is among the families with the highest species richness for the Atlantic Forest Domain (BFG, 2018), being recognized by its spadix inflorescence, associated with a bract, the spathe (Coelho et al., 2009).

The inflorescences in Araceae are generally cylindrical, conical, sometimes globose, and the fruits are little studied regarding their diagnostic value for distinguishing taxa. Knowledge of the structure of fruits and seeds in Araceae is quite scarce (Netolitzky, 1926). Windle (1889) recorded the occurrence of fibers (trichosclereids) and raphids in the fruits of *Monstera* Adans.

Buell(1935) stated that the seeds of *Acorus* L. are sheathed by hard, transparent mucilage which rapidly absorbs moisture and swells into a gelatinous mass when wet. Fruits in Araceae are generally raphids berries, and of the composite type in *Cryptocoryne* Fisch ex Wydler and *Syngonium* Schott, simple in other species. The simple ones are all unilocular and the seeds are striated/non-striated (Kulkarnietal., 1990). The berries are typically succulent, although rarely drier, of membranous consistency, usually indehiscent, green, red, pink, or orange, and almost always free, except in the genera *Syngonium*, in which they form an indehiscent syncarp, and *Cryptocoryne*, which has an apically dehiscent syncarp. Whereas, only in *Lagenandra* Dalzell, do the berries actively open at the base to release the seeds (Mayoetal., 1997).

Anthurium Schott (Schott, 1829) presents pedunculated inflorescences, with free spathe, homogeneous spadix, generally persistent, and bisexual flowers (Coelhoetal., 2009) The fruits in the genus are also berries, generally globose with two seeds (Coelhoetal., 2009), except in the species of section *Tetraspermium* Engl., which have four or more seeds. The seeds are surrounded by hyaline, viscous mucilage, with a smooth to warty surface and varying from yellowish to vinaceous, brownish, in this case, probably in the senile phase; in terms of shape, they can be globose, obovoid, oblong or unilaterally flattened, rounded at both ends to concave at the apex and truncated at the base (Mayoetal., 1997; Coelhoetal., 2009).

In all 20 sections of *Anthurium* accepted in the new classification by Carlsen & Croat(2019) and Croat & Carlsen(2020) for the genus, based on a phylogenetic analysis, berry development is generally similar, with the pistil and tepals gradually increasing in size after pollination. Berries can be supported by rosulate, threadlike, non-colored tepal fibers, which extend the target structure of the infructescence to dispersers such as birds, making fruit collection easier (Croat, 1991).

The color of certain reproductive structures, such as spathe, spadix, and berries, is an important character in the taxonomy and systematics of Araceae, including the genus *Anthurium*, allowing both the distinction of species and sections, such as *Pachyneurium* (Schott) Engl. and *Urospadix* Engl. (Croat, 1991; Coelhoetal., 2009). However, in these works, it is observed that differences in fruit color between taxa are not commented or are very superficially.

Madison(1978) found that color differences in berries can be a good taxonomic character for *Anthurium* species and that most are bicolor, with the upper and lower half in contrast. He

also highlighted that little is known about the possible correlation between the wide range of fruit morphology and the different dispersion mechanisms, as it needs further studies.

Some studies show that these characteristics of reproductive structures may have diagnostic value in distinguishing taxa, such as those by Schott (1860) Brazilian, Engler (1898) and Temponi (2006), who characterize the *Urospadix* section for having globose, green to greenish and yellowish berries, such as *Anthurium comtum* Schott, *Anthurium cleistanthum* G.M. Barroso, *Anthurium harrisii* (Graham) G. Don., *Anthurium intermedium* Kunth, *Anthurium narae* Camelo, Nadruz & Temponi, *Anthurium temponiae* Nadruz & Theófilo and *Anthurium parasiticum* Schott, yellow berries in *A. binotii* Linden, *A. gaudichaudianum* Kunth and *A. sellowianum* Kunth

In the section *Tetraspermium* (Engler, 1905), the species have globose, lilac to pinkish or white berries, as in *Anthurium scandens* (Aubl.) Engl. and *Anthurium obtusum* (Engl.) Grayum, with four to ten seeds (Croat & Sheffer, 1983), unlike the rest of the species of the genus that have one or two. In section *Pachyneurium* the berries are oblong to ellipsoid, and the colors vary from purple, orange or red, rarely green, yellow, or white, which can distinguish some species (Croat 1991). According to this author, the species of the section *Pachyneurium* found in Central America and the West Indies tend to have red or orange to yellowish berries, and in the species from the rest of South America, purple berries predominate. While the species belonging to the section *Multinervia* (Croat) Carlsen & Croat, endemic to Ecuador, Colombia and Bolivia (Carlsen & Croat, 2019) have orange-colored berries, such as *Anthurium oxyphyllum* Sodiro. However, among all these colors, purple is the most predominant among taxa (90%) from the Amazon and Andean regions. While the colors red to orange are only found in 10% of species, it explicitly does not make any association of these color differences with evolutionary relationships between groups of species.

Fruit and seed characteristics were used to distinguish species in the reestablished section *Andiphilum* (Schott) Croat (Croat & Hormell, 2017), characterized by orange fruits, with pasty mesocarp, and large greenish-white seeds. On the other hand, Carlsen & Croat (2019) point out that although the species of section *Polyphyllium* Engl. present black seeds, this characteristic has not been used as a diagnostic character for the group. These authors also point out that both sections are monophyletic, and circumscribed by unique sets of fruit and seed characters, but that on the other hand, in relation to other sections (eg. *Tetraspermium* and *Porphyrochitonium* (Schott) Engl.), do not constitute good synapomorphies.

In Brazil, the knowledge of fruit colors and their importance in *Anthurium* taxonomy are still poorly investigated. It is known, so far, that the non-green coloration is not very common in the genus and that the species of section *Urospadix*, restricted to the Atlantic Forest Domain, generally have greenish berries (Temponi, 2006). Regarding the fruits, the colors are still very little explored, mainly due to the difficulty of finding specimens with ripe fruits, even in cultivation.

Currently, Camelo (2023b) (in preparation) have been carrying out taxonomic studies on *Anthurium* sect. *Pachyneurium* in Brazil and have found not only taxonomic and nomenclatural novelties (Camelo et al., 2021; Camelo et al., 2023a in press) but also morphological characteristics in the fruits that are potentially diagnostic for the distinction of taxa in the genus.

Thus, the present study aims to analyze the importance of morphological attributes of infructescences, fruits, and seeds in the systematics of *Anthurium* in Brazil, based on the species of *A. sect. Pachyneurium*. The investigation of these characters revealed that the morphology and coloration of the berries, associated with other vegetative and reproductive characteristics, have great taxonomic value in *Anthurium* genus.

We present diagnostic descriptions for 11 studied species of the section *Pachyneurium* occurring in Brazil, complemented by an identification key, diagnoses, illustrations, and a comparative table, based on infructescences, fruits and seeds and to assist in the identification of specimens collected in the fruiting stage.

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Materials and methods

A botanical study was undertaken involving the collection of fruiting species and analysis of specimens deposited in herbaria from the Araceae family, specifically focusing on the *Anthurium* sect. *Pachyneurium*. This study encompassed the process of herborization, as outlined by Croat (1985), with the collected specimens being preserved in the RB herbarium with duplicate specimens were also deposited in the UNOP herbarium.

The examination of morphological characteristics was a key aspect of this...

Results

Through field observations and cultivation, it was possible to identify unprecedented particularities of *Anthurium* from Brazil- the infructescences, berries, and seeds can be distinguished by position, shapes, sizes, colors, and ornamentation (Fig. 1). The infructescences of the genus can be erect or pendent, with persistent or deciduous spathe, entire or marcescent. Berries range from oblong to ellipsoid, obovoid, rarely globose, red, vinaceous, or purple, rarely orange, white, pink to...

Discussion

Through the observations of specimens in the field, it was possible to identify previously unreported morphological particularities of *Anthurium* from Brazil with emphasis on *Pachyneurium* section. It can be observed that the berries can help in the distinction of the sections of the genus, even when associated with other vegetative morphological characteristics, such as consistency of the leaf blade, coriaceous, chartaceous to membranaceous, concolorous or discolorous and primary lateral veins...

Conclusion

Regarding the fruits, the colors are still very little explored, mainly due to the difficulty of finding specimens with ripe fruits, even in cultivation. So far, the knowledge we have of fruit morphology and coloration are of only a few species of *Anthurium* sections that occur in Brazil, making it even more necessary to investigate them in order to fill knowledge gaps, both in relation to the taxonomy and biology of the other species....

CRedit authorship contribution statement

Mel de Castro Camelo: Conceptualization, Methodology, Writing – original draft, Writing – review & editing. **Lívia Godinho Temponi:** Conceptualization, Methodology, Visualization. **Marcus Alberto Nadruz Coelho:** Conceptualization, Methodology, Visualization, Resources. **José Fernando A. Baumgratz:** Resources, Supervision....

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper....

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