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Original Article

Morpho-anatomy of the inflorescence of *Musa* × *paradisiaca*

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ABSTRACT

Bananas and plantains are herbaceous monocotyledonous plants belonging to the genus *Musa*, Musaceae, which has a widespread distribution around the world. Various parts of banana plant are commonly used in traditional medicines. Several species of *Musa* are reported to possess anti-inflammatory, anti-hyperglycemic and antidiabetic properties. This work is aimed at studying the morphological and anatomical characteristics of the inflorescences of *Musa* × *paradisiaca* L., that could contribute to the characterization of these species cultivated in Brazil. Plant materials were collected and prepared in accordance with standard optical microscopy techniques. Morphological characterizations were conducted using morphological descriptors for inflorescences, including some descriptors from International Plant Genetic Resources Institute for *Musa* spp. Microscope slides were prepared using glycol-methacrylate and were stained in toluidine blue. Main features observed for *M.* × *paradisiaca* inflorescence were amphistomatic bracts with tetracytic stomata, fiber caps next to the phloem, adaxial and abaxial uniseriate epidermis, and papillose on the abaxial face. Outer tepals have multilayer epidermis and vascular bundles aligned next to the abaxial face. Free tepal has unilayeredepidermis. Anthers are tetrasporangiate and the locules are separated by the septum. Ovary is inferior and trilocular with external unilayered and internal epidermis. The main morpho-anatomical characteristics of inflorescence of *Musa* × *paradisiaca* are highlighted in this study, contributing to provide more information about the characterization of this species cultivated in Brazil.

Introduction

Bananas and plantains are herbaceous monocotyledonous plants belonging to the genus *Musa* (Musaceae, Zingiberales), which has a distribution range that coincides with the humid tropics and subtropics regions in the Americas, Africa and Asia, extending into Europe and Australia (Heslop-Harrison and Schwarzacher, 2007; Perrier et al., 2011). Most *Musa* species are giant herbs, reaching up to 3 m in height, with no lignification or secondary thickening of stems that is characteristic of trees (Tomlinson, 1969). Banana is one of the world's most important fruit crops (FAOStat, 2018), reaching in the year of 2015 a global annual production of approximately 118 million tons.

Parts of banana plant are commonly used in traditional medicine in many countries (Joshi, 2000). Several studies have been conducted to investigate the biological effects of *Musa* spp., including antimicrobial (Agarwal et al., 2009), antiulcerogenic (Hussain et al., 2011), galactagogue (Mahmood et al., 2012), anti-inflammatory (Lee et al., 2011), anti-hyperglycemic and antidiabetic effects(Abdulrazak et al., 2015; Jawla et al., 2012; Nisha and Mini, 2013; Rai et al., 2009; Vijayakumar et al., 2008), α-glucosidase and α-amylase inhibitory effects (Alarcon-Aguilara et al., 1998) and antioxidant effect (Loganayaki et al., 2010; Mallick et al., 2009).

Moreover, some compounds that are known to have biological effects already been identified, including anthocyanins (Kitdamrongsont et al., 2008), phenolic acids (Bhaskar et al., 2011; Sheng et al., 2014), flavanones (Ganugapati et al., 2012), and terpenoids (Dutta et al., 1983; Martin et al., 2000; Nazaruk and Borzym-Kluczyk, 2015; Tin et al., 2016). Additionally, some morphoanatomical studies that contribute to the characterization of *Musa* spp. have been conducted: leaf, petiole, and root of *Musa paradisiaca* cv. Awak (Sunandar and Kahar, 2017); inflorescence of *Musa acuminata* (Fingolo et al., 2012) and *M. paradisiaca* (Osuji,

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2006); leaf root, and stem of five *Musa* spp. cultivars (Sumardi and Wulandari, 2010).

Despite the wide range of pharmacological activities attributed to the inflorescences of *M.* × *paradisiaca*, there are no reports to date describing morpho-anatomical features for this species cultivated in Brazil. Thus, this study's objective is to analyze the morphological and anatomical characteristics of the *M.* × *paradisiaca* inflorescences that could contribute to the characterization of this species cultivated in Brazil.

Material and methods

Plant material

The aerial parts of specimens of *Musa* × *paradisiaca* L., Musaceae, cultivar (cv.) Terra were collected at Estrada do Areal, city of Morretes, state of Paraná, Brazil (coordinates 25°29′ S and 48°48′ W, and 11 m altitude) in September 2015. The botanical materials were identified by E. Barboza and compared with the voucher specimens

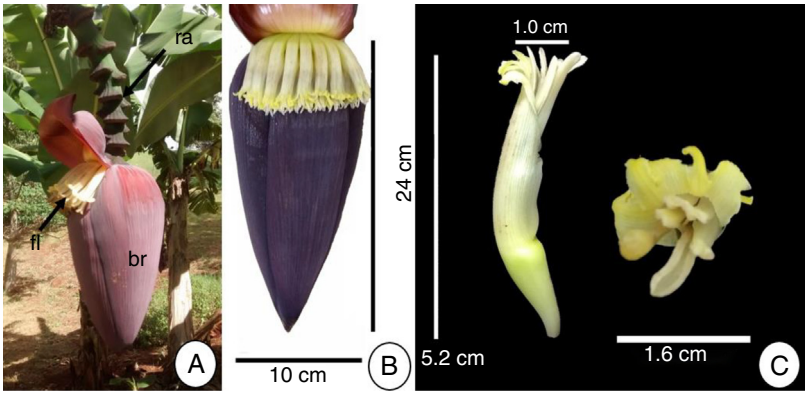

Fig. 1. Morphology of *Musa* × *paradisiaca*. (A) Inflorescences on a banana plant showing flowers (fl), bracts (br) and rachis (ra). (B) Details of bracts and cluster of flowers. (C) Views of a bisexual flowers.

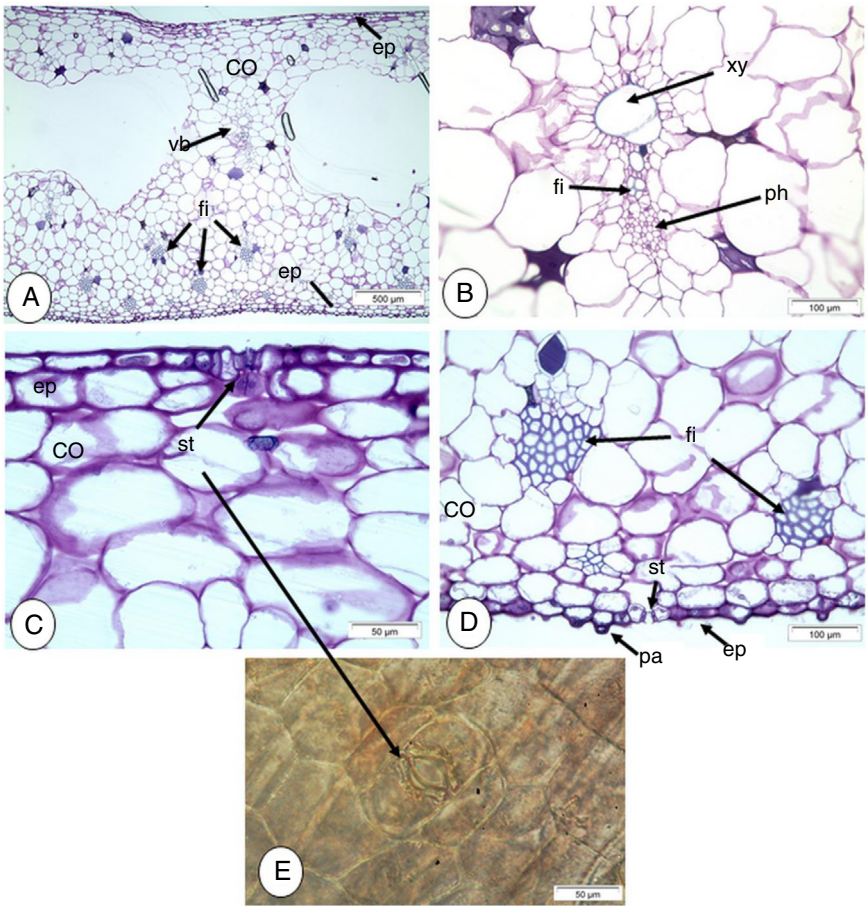

Fig. 2. Photomicrographs of bracts anatomy of *Musa* × *paradisiaca*. (A–D) Transverse sections and (E) surface view. Co, collenchyma; ep, epidermis; fi, fiber; pa, papillae; ph, phloem; st, stomata; vb, vascular bundles; xy, xylem.

deposited in the Municipal Botanical Museum of Curitiba (voucher number: MBM 343145). The plant material was collected before approximately 60 days of fruit development.

Morphological analyses

Bracts and flowers were measured (length and width) and quantified. Morphological descriptors for inflorescences were used to characterize the plant material, including some descriptors from International Plant Genetic Resources Institute for *Musa* spp. (IPGRI, 1996).

Anatomical analyses

The bracts and flowers were carefully separated manually from inflorescences and fixed in FAA_{50} solution (formalin, glacial acetic acid, and 50% ethanol, 1:1:18, *v/v*) (Johansen, 1940), and stored in 70% ethanol. For the preparation of permanent slides, the plant materials were washed in water, dehydrated, sectioned and mounted in glycol-methacrylate (Leica Historesin®). Longitudinal and transverse sections were made with a Leica R-2145 microtome and the sectioned tissues were stained in toluidine blue (O'brien et al., 1964; Raman et al., 2018). Photomicrographs were captured by a light microscope Olympus CX 31 equipped with a C 7070 control unit in the Department of Botany, Federal University of Paraná.

Results and discussion

The inflorescence in *M.* × *paradisiaca* is a branched spadix located at the distal end of main stalk. It consists of a pendulous peduncle, and several flower clusters each subtended by a bract that is usually purple-red in color (Fig. 1A). Each nodal cluster consists of two rows of flowers ranging from 10 to 14 units, one above the other, and enclosed in a large subtending bract (Fig. 1A and B). Female flowers occur at the lower part of the inflorescence and develop into fruits. Male flowers found toward the distal end of the inflorescence. Neutral or hermaphrodite flowers may be present between the male and female regions. The flowers measure around 5.2–6.2 cm in length and 1–1.6 cm in width, showing coloration ranging from light yellow to yellow and no visible sign of pigmentation (Fig. 1C), unlike the pink pigmentation found by Sunandar and Kahar (2017) *M. paradisiaca* cv. Awak tepals. Each bract is an oval-lanceolate red/purplish structure that becomes completely reflexed as the flowers develop. Bracts show longitudinal nerves aligned along the long axis. They are invaginating, spiraling around the main stem and measuring around 17–25 cm in length and 12–14 cm in width (Fig. 1A and B). When fresh, the outermost bracts are deep purple in the adaxial face and reddish in the abaxial face, and the inner ones are reddish purple, orange and yellow, respectively. The color of internal bracts apex is tinted with yellow as observed in *M. paradisiaca* cv. Awak bracts (Sunandar and Kahar, 2017). The bracts and their clusters of flowers are aligned spirally around the main axis of the inflorescence. The bracts closely overlap each other, forming a tight conical inflorescence.

Musa × *paradisiaca* presents amphistomatic bracts and tetracytic stomata (Fig. 2E and F). From the surface view, the bracts show straight and thin anticlinal walls on both adaxial and abaxial epidermises (Fig. 2E). The bracts, in cross-section, present uniseriate epidermis on both sides, yet papillose on abaxial side (Fig. 2A and E). According to Osuji (2006), the presence of tetracytic stomata on both faces is characteristic in several cultivars of *Musa* spp. However, there was no agreement regarding the presence of papillose, since such author describes the absence of papillose on the abaxial face in *M.* × *paradisiaca* as a differential characteristic between the cultivars belonging to the AAB genome group (group of cv. Terra) (absence of papillae) and AAA group (presence of papillae). Papillose appearance was also found in the epidermis of *Musa acuminata* Colla (Fingolo et al., 2012).

The mesophyll is homogeneous, formed by smaller cells near the epidermal layers and larger cells in the middle region, where

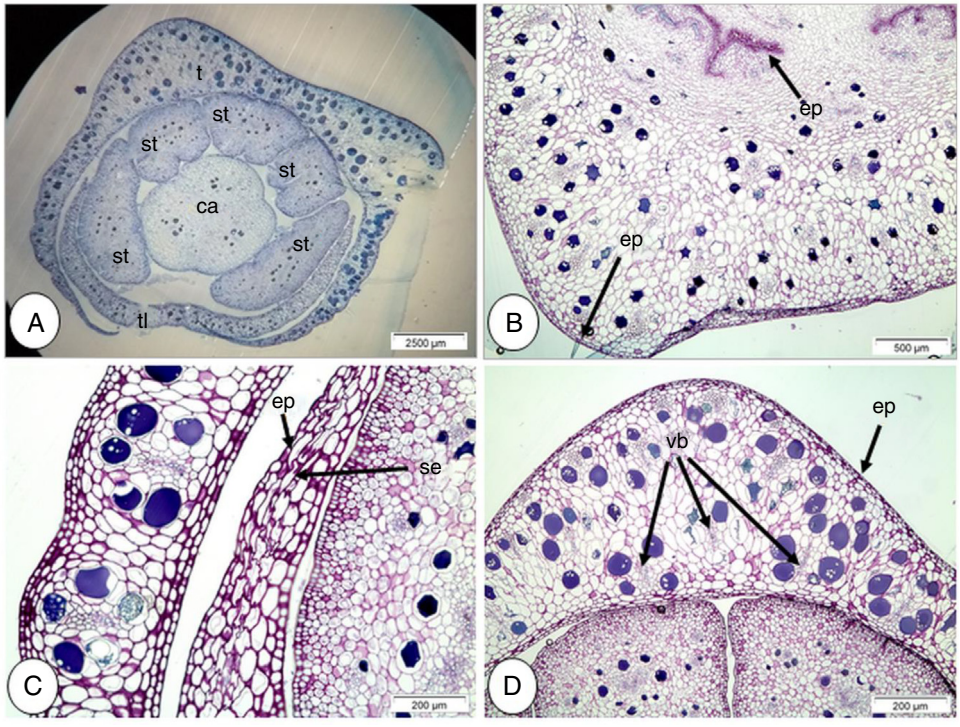

Fig. 3. Photomicrographs of flowers and ovary anatomy of *Musa* × *paradisiaca* – transverse sections. (A) Carpel (trilocular ovary), five stamen, free tepal, and outer tepals. (B) Ovary. (C) Internal tepal. (D) External tepal. Ca, carpel; ep, epidermis; se, subepidermal layer; st, stamen; t, tepals; tf, free tepal; vb, vascular bundle.

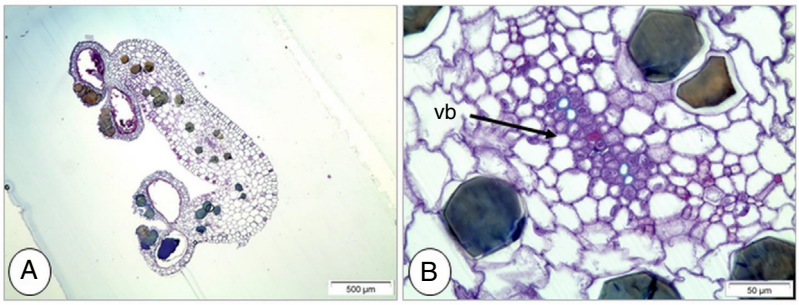

Fig. 4. Photomicrographs of anther anatomy of *Musa* × *paradisiaca* – transverse section. (A) Tetrasporangiate anther. (B) Connetive region. Vb, vascular bundle.

aeration chambers with branched parenchyma can be seen (Fig. 2A). Small collateral vascular bundles are immersed in the mesophyll (Fig. 2A and D). These features were reported for *M. acuminata* (Fingolo et al., 2012). Fibers are found not only adjoined to the phloem (Fig. 2B) but also spread in the mesophyll (Fig. 2D).

The male flower is zygomorphic and has five tepals, as described by White (1928). The free tepal has homogeneous mesophyll and unilayered epidermis and subepidermal layers (Fig. 3C). The outer tepals have a multilayered epidermis, homogeneous mesophyll, parenchyma and collateral vascular bundles (Fig. 3D). The bundles are located closer to the abaxial face, aligned and of the same size.

The anthers are tetrasporangiate and the locules are separated by the septum (Fig. 4A). The connective region has the epidermis and a single collateral vascular bundle (Fig. 4B). The region of the pollen sacs (Fig. 3C) presented uniseriate epidermis with round cells, endothecium with thickening ring and collapsed inner layers. Spherical grains of pollen were occasionally visible in the locules.

The ovary is inferior and trilocular with unilayered external and internal epidermis (Fig. 3A and B), which agrees with the findings for the genus *Musa* (Abbas et al., 2015; Kirchoff, 1992). No ovules were observed in the analyzed samples, indicating the non-functionality of the gynoecium.

Conclusion

The main morpho-anatomical characteristics of inflorescence of *M.* × *paradisiaca* are highlighted in this study. Features as uniseriate epidermis, fiber caps next to the phloem, and tetracytic stomata on both faces are helpful to characterize the bracts. Besides that, the presence of papillose in bracts is a finding different that reported in the literature for this botanical. Additionally, the main characteristics of tepals include the presence of multilayered epidermis and vascular bundles aligned next to abaxial face. As expected, tetrasporangiate anthers with single vascular bundle in male flowers and trilocular ovary in female flowers with uniseriate epidermis were observed. Thus, the features described in this study contribute to provide more information about the characterization of this species cultivated in Brazil.

Authors' contributions

ROV contributed in collecting plant sample and identification, confection of herbarium, running the laboratory work, analysis of the data and drafted the paper. BMM contributed to in collecting plant sample and identification, confection of herbarium, running the laboratory work. JMB contributed to analysis of the data and critical reading of the manuscript. EA was responsible for preparing the permanent slides and contributed to analysis of the data and critical reading of the manuscript. IJTMR contributed to critical reading of the manuscript. RP designed the study, supervised the laboratory work and contributed to critical reading of the manuscript. All the authors have read the final manuscript and approved the submission.

Conflicts of interest

The authors declare no conflicts of interest.

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