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Labellum vasculature in some monocotyledonous taxa

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Abstract

The vasculature and structure of the labellum are diagnostic and highly significant across monocotyledonous taxa. This study examined the floral vasculature of seven taxa from Cannaceae, Marantaceae, Zingiberaceae (Zingiberales), and Orchidaceae (Asparagales) using light microscopy (LM) to elucidate and characterize the nature and structure of the labellum in selected monocot taxa. The obtained data indicated that the labellum vasculature of *Dendrobium nobile* (Orchidaceae) was significantly different from that of the other examined taxa. The labellum of *Dendrobium nobile* was supplied by three separate vascular bundles: one posterior inner bundle and two postero-lateral bundles, corresponding to the median and marginal regions of the labellum. In *Canna* × *hybrida* and *C. indica* (Cannaceae), the labellum vasculature incorporated two bundles: one derived from the carpellary dorsal trace and another from the antero-lateral carpellary septal trace. The floral vasculature of *Maranta leuconeura* (Marantaceae) showed that the labellum was supplied by a single carpellary septal trace, which subsequently divided to form median and marginal bundles. For *Alpinia zerumbet* and *Hedychium coronarium* (Zingiberaceae), the labellum was supplied by three distinct vascular bundles: two antero-lateral carpellary septal bundles and one anterior carpellary dorsal bundle.

Key Words: Androecium; Floral Vasculature; Orchidaceae; Zingiberales

Introduction

Monocots exhibit diverse flower patterns that vary significantly in form and function and are distinguished by their common trimerous pentacyclic floral Bauplan (Dahlgren *et al*. 1985). Among monocot species, particular attention has been given to the labellum (lip), a special floral structure that is often a modified petal or stamen. The labellum stands out due to its large size, irregular shape, and distinct coloration. The labellum is considered by many taxonomists to be a crucial character for classifying monocotyledonous plants into smaller taxonomic groups.

Previously, two theories about the nature of the labellum have been presented that have either a double or triple structure or nature. Gregory (1936) and Zhang *et al*. (2009) supported the triple nature of the labellum in constitution from the external morphological characters of the flower. Other evidence supports the classical conception that the labellum is a double structure or nature (Payer, 1857; Van Tieghem, 1868, 1871; Pai, 1963; and Sharawy, 2013). However, Liao *et al*. (2005)

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decided in some taxa of Zingiberaceae that the labellum consists of five androecial members rather than two or three as suggested by other authors.

The labellum in Cannaceae and Marantaceae is petal-like, but the fertile portion of the androecium is reduced to a single half-stamen, with staminodes exhibiting extensive morphological variation. This structural diversity has led to ongoing debate regarding homology, developmental identity, and evolutionary pathways underlying labellum formation across monocots. Thompson (1933) suggested that the labellum in Cannaceae originates from fused primordia derived from multiple floral whorls, while Pai (1963) argued that the labellum represents a single organ derived exclusively from the inner androecial whorl. Kirchoff (1983b) proposed that in *Canna indica*, the labellum specifically arises from inner androecial members.

In Zingiberaceae, the labellum is thought to originate from the two inner lateral staminodes, while the outer lateral staminodes develop into petaloid structures (Kress 1990; Kress *et al.* 2002). Gregory (1936) proposed that the labellum in Zingiberaceae is formed by the fusion of three androecial parts, two inner lateral and one outer lateral staminode. In addition, studies of (Rao, *et al.* 1954; Kirchoff, 1988a, 1991, 1997, 1998) confirmed that the labellum forms through fusion of the two inner petaloid staminodes.

In Orchidaceae, floral development follows a highly specialized path (Rudall & Bateman 2002; Kreutz & Çolak 2009). The perianth (three sepals and three petals) protects the gynostemium (a fused gynoecium and androecium structure), and the central petal forms the labellum, distinct from lateral petals in shape, size, and color. The labellum functions as an insect landing platform, often decorated with calli (gland), spurs, and color patterns. Brown (1833) and Darwin (1862) support that the orchid labellum was thought to result from the incorporation of stamens into a modified petal, an idea supported by vasculature studies and floral mutants (Nelson, 1965, 1967). In many orchids, non-expressed stamens (A2, A3) contribute to the labellum's structure, making it highly complex, especially in epidendroids (Swamy, 1948). The floral vasculature has been extensively studied to clarify taxonomic relationships among monocotyledonous plants and to better understand the origins and nature of floral organs (Sharawy, 2018; Kress *et al.* 2001; Li *et al.* 2020; Puri, 2024). Vascular patterns are particularly valuable because they tend to be more evolutionarily conservative, meaning they are less affected by environmental factors than external floral features (Puri, 1951). So, the present study compares labellum vasculature across Cannaceae, Marantaceae, Zingiberaceae, and Orchidaceae to assess the vasculature and the structure of the labellum.

Material and Methods

Sampling

Seven taxa belonging to four monocotyledon families (Cannaceae, Marantaceae, Zingiberaceae, Orchidaceae) were collected during 2019-2020. All studied taxa were identified after Bailey & Bailey (1976) and Huxley *et al.* (1992), and their names updated by IPNI, POWO, and WFO. Herbarium specimens were kept at the Botany Department Herbarium, Faculty of Science, Ain Shams University. The studied taxa and their localities are cited in Table 1 and arranged according to APG IV (2016).

Floral micromorphological investigation

The flower buds of the studied taxa were fixed and preserved in F.A.A., then embedded in paraffin wax, and then serially sectioned from pedicel upward at 10-20 µm according to the conventional method (Johansen, 1940). The sections were double-stained using safranin (2% in 50% ethanol) and light green (1% in absolute ethanol) combination. The serial cross-sections of the flower buds of each taxon were examined and photographed using an Olympus CX23LEDRFS1 light microscope with a digital Canon Power Shot A720 camera. The magnification is given by the Beck stage micrometer, scaled to 0.01 and 0.1 mm. The descriptive anatomical terms related to the floral vascularization are (i) the vascular supply to the floral organ is termed "trace" when it is still in the receptacular tissue and joined with the central stele, and (ii) the same is termed "bundle" when it either separates from the central stele and/or enters the organ.

Table 1. The studied taxa and their localities according to APG IV (2016).

Order	Family	Taxa	Locality
Zingiberales	Cannaceae	*Canna x hybrida* Rodigas (yellow) = *Canna* x *generalis* L. H. Bailey	Mazhar Botanical Garden
		Canna x hybrida Rodigas (red) = *Canna* x *generalis* L. H. Bailey	Mazhar Botanical Garden
		Canna indica L. = *Canna achiras* Gill. = *Canna achiras* Gillies ex D. Don = *Canna altensteinii* Bouché	Ain Shams Botanical Garden
	Marantaceae	*Maranta leuconeura* É. Morren = *Calathea leuconeura* (É. Morren) G. Nicholson	Al - Zohria Botanical Garden
	Zingiberaceae	*Alpinia zerumbet* (Pers.) B. L. Brutt & R. M. Sm. = *Alpinia speciosa* (J. C. Wendl.) K. Schum. Fl. Kais. Wilh. = *Costus zerumbet* Pers.	Mazhar Botanical Garden
		Hedychium coronarium J. Koenig = *Amomum filiforme* W. Hunter ex. Ridl. = *Hedychium chrysoleucum* Hook.	Orman Botanical Garden
Asparagales	Orchidaceae	*Dendrobium nobile* Lindl. = *Callista nobilis* (Lindl.) Kuntze = *Dendrobium chlorostylum* Gagnep.	Florist

Results

Cannaceae Juss.

Canna x hybrida Rodigas (yellow)

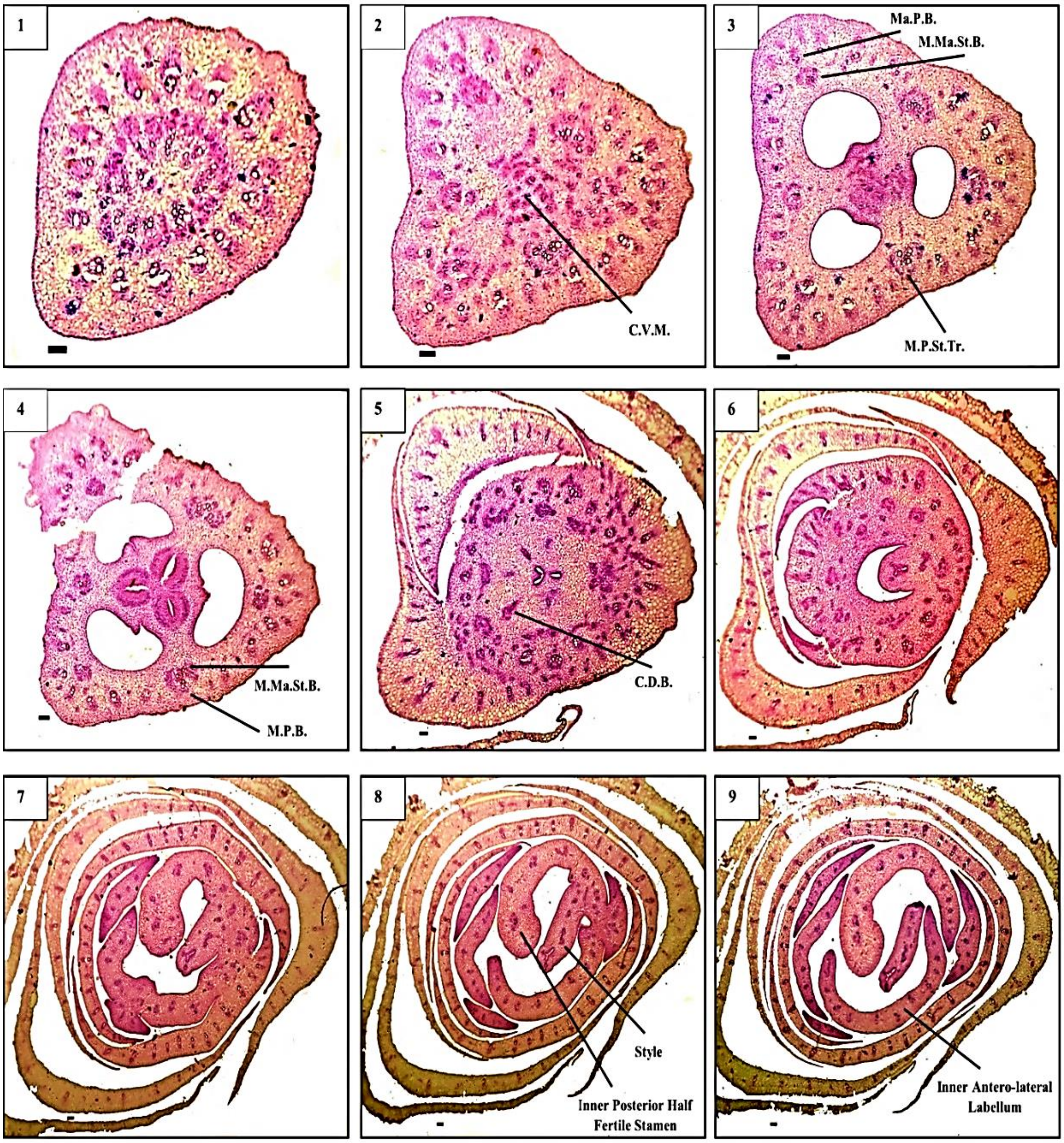
At the pedicel level, the vascular bundles are arranged in two whorls (Plate I; Photo 1). At the receptacular level, these bundles coalesce and form a continuous central vascular mass with peripheral vascular complexes (Plate I; Photo 2). At the base of the ovary, the central vascular mass diverges outwards and becomes differentiated into six groups of vascular complexes. Meanwhile, the remaining vascular mass forming the inner ring undergoes segmentation into numerous vascular bundles, which later become refused and form a continuous central mass (Plate I; Photo 3). Each of the former six groups consists of three outer vascular strands, which become differentiated as follows: three outer vascular traces that lie opposite to the locules. At the base of the ovary, each of these three traces is divided into two vascular bundles (Plate I; Photo 3).

The outer one diverges to form the marginal bundles of the petals. The inner bundle at the top of the ovary diverges into two vascular bundles; one forming the outer median staminal bundles and inner marginal staminal bundles, while the other bundle represents the carpellary dorsal bundle that extends to feed the style. (Plate I; Photo 5). The inner three vascular strands lie at the septal radii; each is composed of three vascular traces (Plate I; Photo 3), which split forming the inner median tepal bundles, and two lateral masses represent the inner median and marginal staminal bundles (Plate I; Photo 4).

The central vascular mass is differentiated into numerous bundles, which are branched at the level of the placental tissue, forming the ovular and septal supplies. At the top of the ovary, these bundles are faded out. The six androecium units (three outer and three inner) form a short tube and are differentiated as follows: the outer three petaloid staminodes are distinct and supplied with numerous vascular bundles, and the inner three units are separated simultaneously. The median inner posterior unit is characterized by one-celled anther adnate to the margin (a hooded half staminode) which connate to the leafy style (Plate I; Photo 8). One of the two inner petaloid staminodes is large and becomes free to form a labellum, which is supplied with numerous vascular bundles originating from outer stamen bundles and inner stamen bundles.

Canna* x *hybrida Rodigas (red)

The floral vasculature of *Canna* x *hybrida* (red) is similar to that of *Canna* x *hybrida* (yellow).



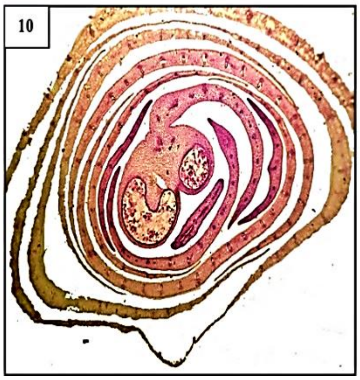


Plate. I. Serial cross-section through a floral bud of *Canna X hybrida* (yellow). Scale =100 µm

Abbreviations: **C.D.B.** Carpellary Dorsal Bundle. **C.V.M.** Central Vascular Mass. **M.Ma.St.B.** Median, Marginal Staminal Bundle. **M.P.B.** Median Petal Bundle. **Ma.P.B.** Marginal Petal Bundle. **M.P.St.Tr.** Median Petal Staminal Trace.

Canna indica L.

At the pedicel level, the vascular bundles are numerous and scattered (Plate II; Photo 1). At the beginning of carpel detection, these vascular masses are further branched and arrange themselves, forming the vascular floral sets of the perianth, androecium, and gynoecium. (Plate II; Photo 2). At a higher level, where locules are clearly detected, the numerous vascular complexes become arranged as follows: The outer three median vascular bundles of the sepals (calycine) (Plate II; Photo 2). The three vascular traces are opposite the outer median bundles of the sepals. (Plate II; Photo 2). Where, at the level just below the base of the ovary, these three traces are separated into two vascular bundles. The outer one diverges, forming the marginal bundles of the petals (Plate II; Photo 2). At the top of the ovary, the inner bundle diverges into two vascular bundles; one forming the outer median staminal bundles and inner marginal staminal bundles, while the other bundle represents the carpellary dorsal bundle. The latter extends to feed the style. (Plate II; Photo 6).

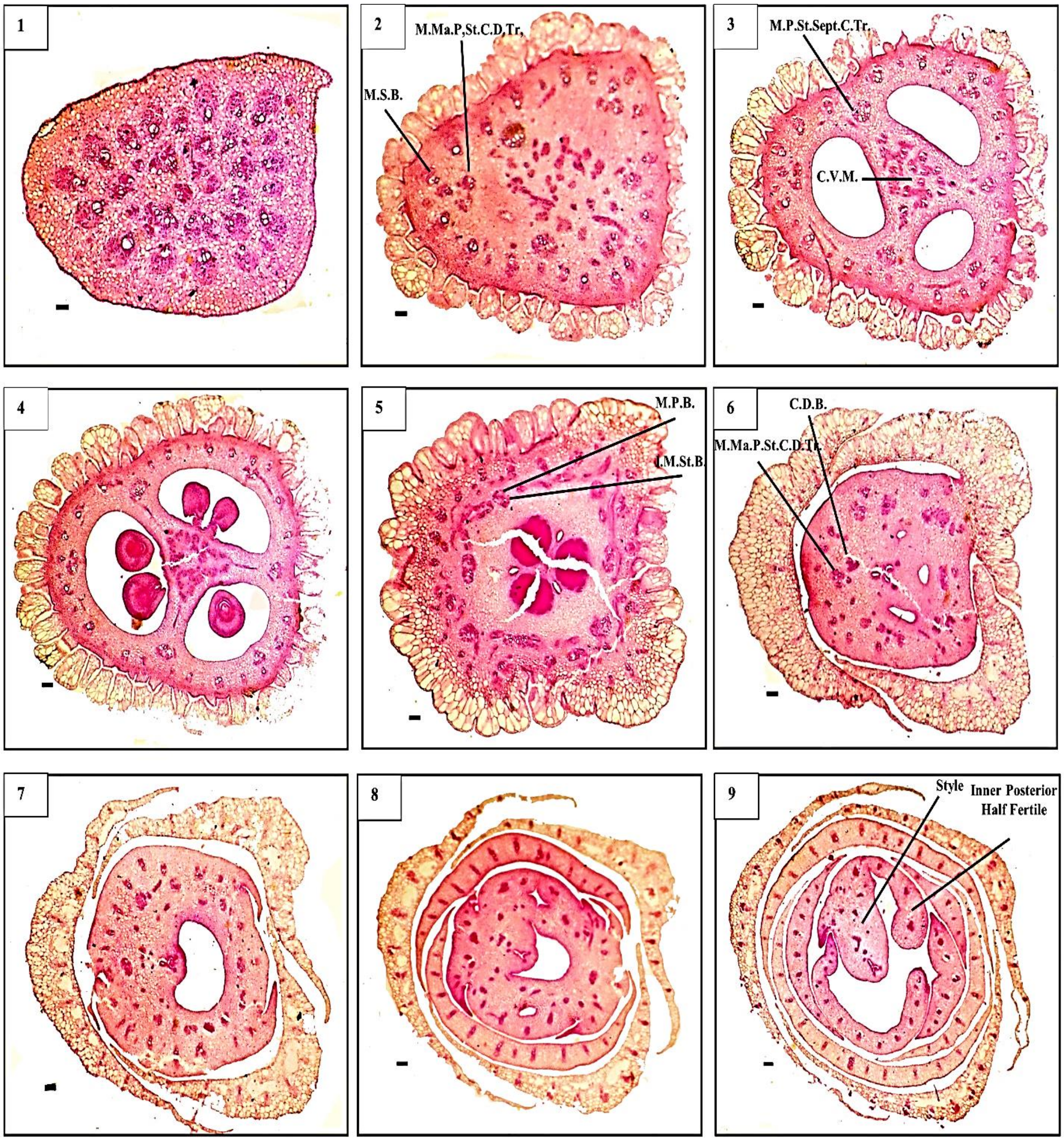
At the level of the locule, three vascular complexes of the petals (coralline) and inner stamens are detected (Plate II; Photo 3). At the top of the ovary, the three complexes undergo division into six bundles forming the petal median bundles and the inner staminal bundles (Plate II; Photo 5). The central vascular mass is differentiated into numerous ventral bundles, which are branched at the level of the placental tissue, forming the ovular and carpellary septal supplies (Plate II; Photo 3). At the top of the ovary, both the carpellary ventral bundles and the carpellary septal supplies fade out (Plate II; Photo 6).

The five petaloid staminodes are forming with the style a very short tube and are differentiated as follows: the outer two postero-lateral petaloid staminodes are distinct, which are supplied with numerous vascular bundles, and the inner three units that are separated simultaneously (Plate II; Photo 9). The inner median posterior unit is characterized by one-celled anther adnate to the margin (a hooded half staminode), which is connate to the leafy style. One of the two inner antero-lateral petaloid staminodes enlarges and becomes free, forming the labellum. It is supplied with numerous vascular bundles that originate from the outer absent petaloid staminode bundles, the outer anterior staminal bundle, and the inner antero-lateral staminal bundle (Plate II; Photo 10).

Marantaceae R. Br.

Maranta leuconeura É. Morren

At the pedicel level, the vascular tissue consists of numerous peripheral vascular bundles and a central vascular stele (Plate III; Photo 1). At the receptacular level, the central vascular stele diverges and becomes dissected into numerous small bundles that feed the ovule of the only one functional locule.



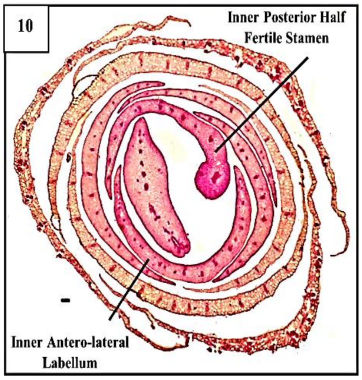


Plate. I1. Serial cross-sections through a floral bud of *Canna indica.* Scale = 100 µm. **Abbreviations**: **C.D.B.** Carpellary Dorsal Bundle. **C.V.M.** Central Vascular Mass. **I.M.St.B.** Inner Median Staminal Bundle. **I.Ma.T.B.** Inner Marginal Tepal Bundle. **M.Ma.P.St.C.D.Tr**. Median, Marginal Petal Staminal Carpellary Dorsal Trace. **M.Ma.St.B.** Median, Marginal Staminal Bundle. **M.Ma.St.C.D.B**. Median, Marginal Staminal Carpellary Dorsal Bundle. **M.P.B.** Median Petal Bundle. **M.P.St.Tr.** Median Petal Staminal Trace. **M.S.B.** Median Sepal Bundle.

At the level of detection of the locules, the former peripheral vascular bundles are arranging themselves into: outer three vascular bundles and six inner vascular complexes.

The former three vascular bundles represent the three median vascular bundles of the three sepals (Plate III; Photo 2). The six inner vascular complexes become arranged as follows: at carpellary radii, three vascular complexes; each divided into three outer and three inner vascular bundles. Each of the three outer bundles splits laterally into one median and two marginal bundles. One of these median bundles (postero-lateral) supplies the inner posterior callose staminode (thick, fleshy sterile stamen), the other second median bundle (postero-lateral) also supplies the callose staminode and the outer postero-lateral petaloid staminode, and the anterior third median bundle supplies the outer anterior petaloid staminode. The remaining marginal bundles of the three vascular complexes represent the marginal bundles of the three petals. The three inner vascular bundles feed the style and stigma. (Plate III; Photo 4).

At the septal radii, three septal complexes, each divided into outer and inner bundles. The three outer bundles feed the median and marginals of the three sepals. While the three inner bundles become differentiated as follows: one bundle supplies the inner posterior staminode (callose staminode), the second inner bundle supplies the inner antero-lateral functional stamen, and the third one gives rise to the inner antero-lateral hooded staminode (hood-like sterile stamen) (Plate III; Photo 4). At the top of the ovary, the three sepals and the five androecium units (two outer and three inner) form a tube with the style which is differentiated as follows: the outer two petaloid staminodes are distinct, and the inner three that are separated simultaneously as; median posterior callose staminode, two antero-lateral; functional stamen and the hooded staminode (labellum) (Plate III; Photo 8).

Zingiberaceae Martinov

Alpinia zerumbet (Pers.) B. L. Brutt & R. M. Sm.

At the pedicel level, the vascular tissues are arranged in two rings; the outer ring consists of numerous vascular bundles, and the inner ring is composed of more or less fused vascular bundles. (Plate IV; Photo 1). At the base of the receptacle, the outer ring is further branched, forming numerous vascular complexes. The inner ring is composed of six vascular complexes, arranged as three large vascular complexes alternating with three small vascular complexes (Plate IV; Photo 2).

At the base of the ovary, the three large vascular complexes of the inner ring become oriented higher in the ovary wall as the three carpellary dorsal bundles, which eventually enter the style. The remaining three small vascular complexes are divided into six: three carpellary septal vascular traces and three carpellary ventral bundles. The latter three bundles are divided into six bundles, two for each carpel, and then fade out at the top of the ovary.

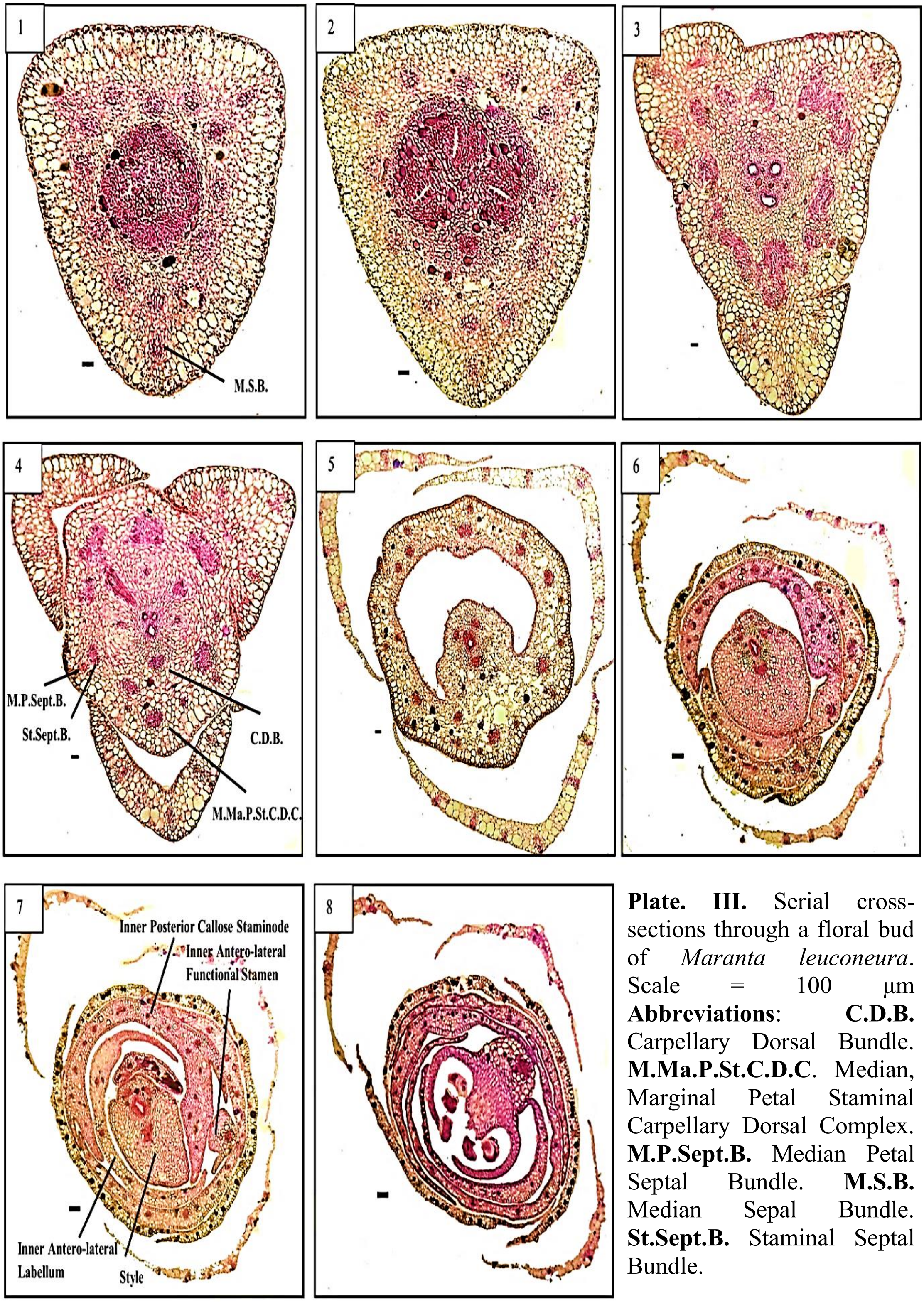


Plate. III. Serial cross-sections through a floral bud of *Maranta leuconeura*. Scale = 100 µm **Abbreviations**: **C.D.B.** Carpellary Dorsal Bundle. **M.Ma.P.St.C.D.C**. Median, Marginal Petal Staminal Carpellary Dorsal Complex. **M.P.Sept.B.** Median Petal Septal Bundle. **M.S.B.** Median Sepal Bundle. **St.Sept.B.** Staminal Septal Bundle.

Meanwhile, the three carpellary septal vascular traces increase in size, are divided into numerous bundles, and fuse to form an anastomosing vascular plexus. Some bundles of the outer ring are associated with this plexus, but the median and marginal bundles of the sepals remain unaffected (Plate IV; Photo 6). Many vascular bundles are separated from the anastomosing vascular plexus to supply petals, glands, androecium, and style.

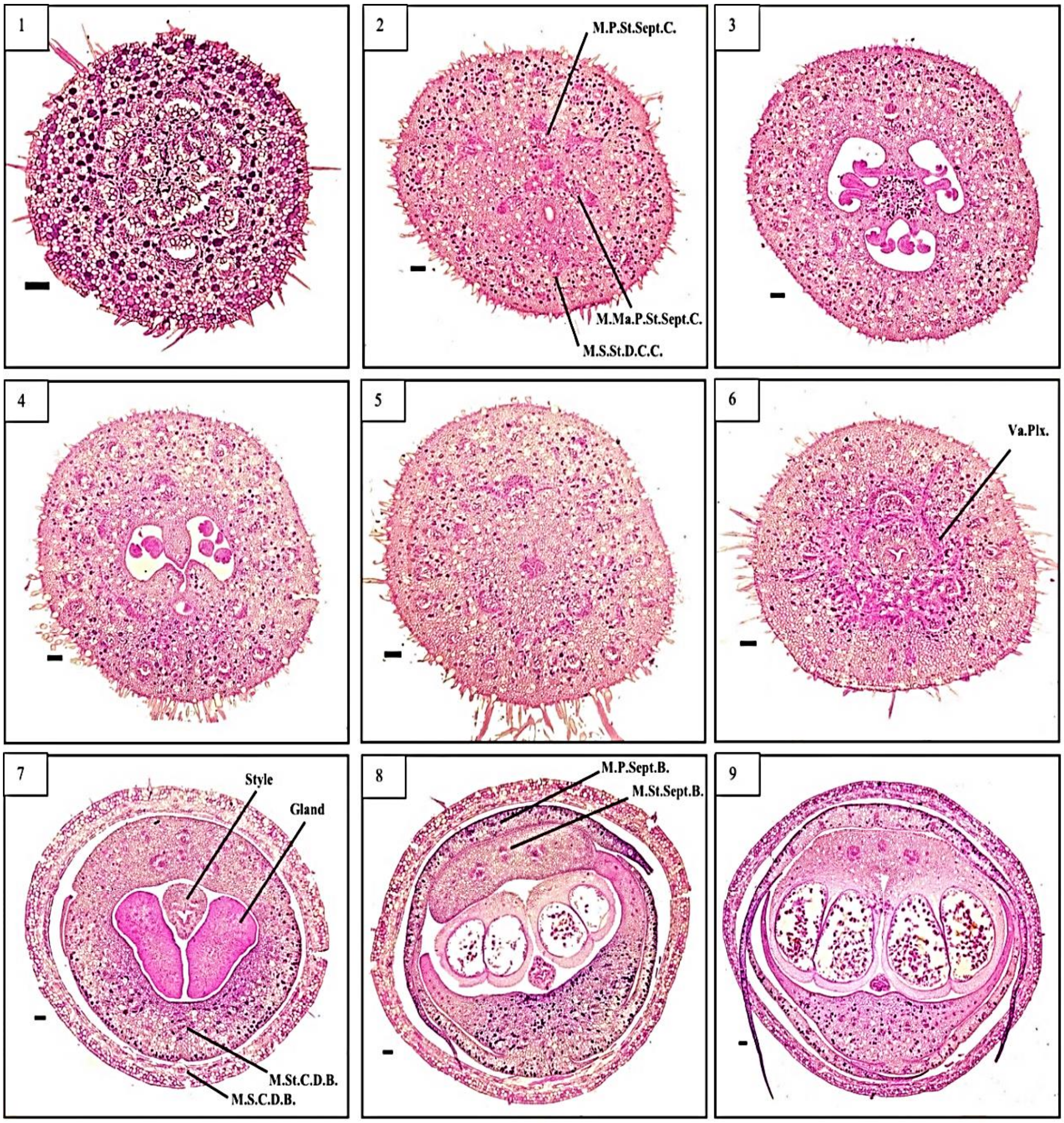
At a higher level, the corolla tube becomes distinct following the full separation of the calyx tube. It subsequently detaches from an inner cylinder and differentiates into three petals-the larger posterior petal enclosing the two smaller antero-lateral ones. The outer three stamens are morphologically absent; the vasculatures of the outer two postero-lateral stamens are not detected. The remaining inner cylinder represents the fused bases of the two inner antero-lateral petaloid staminodes (labellum) and the posterior fertile stamen. The two fused antero-lateral petaloid staminodes contain five bundles; one median represents the outer staminal bundle, and four lateral traces represent the vasculatures of the inner two antero-lateral stamens. In the upper part of the labellum, the median bundle splits into small bundles and each travels toward the laterals and undergoes further splitting, forming the marginal supplies of the labellum (Plate IV; Photo 7).

The filament of the fertile stamen is mostly slender and deeply grooved. In such a groove, the style extends between the anther cells and the capitate stigma. This style has a flattened canal, and three bundles continue into the stylar tissue to feed the stigma.

Hedychium coronarium J. Koenig

At the receptacular level, the vascular tissue is arranged into two whorls; the outer is composed of numerous vascular bundles, and the inner whorl consists of six large vascular traces (Plate V; Photo 1). The six large traces of the inner whorl consist of three carpellary septal bundles alternating with three carpellary dorsal bundles. At the base of the ovary, the latter bundles split into six small carpellary ventral bundles that feed the ovules and completely fade out at the base of the style.

At the beginning of the separation of the calyx tube, the remaining vascular bundles of the outer ring and the inner three carpellary septal fused and form an anastomosing vascular plexus (Plate V; Photo 3). At a little higher, the corolla tube develops as three petals, one posterior and two in antero-lateral position. After the separation of corolla leaves, the outer two postero-lateral petaloid staminodes separate from the inner three androecium units. The inner whorl of the androecium consists of one posterior fertile stamen and two antero-lateral petaloid staminodes fused, forming a large compound labellum (Plate V; Photo 6). As *Alpinia zerumbet,* the remaining tissue of the anastomosing vascular plexus is differentiated into six vascular complexes, which can be identified from their location in the plexus



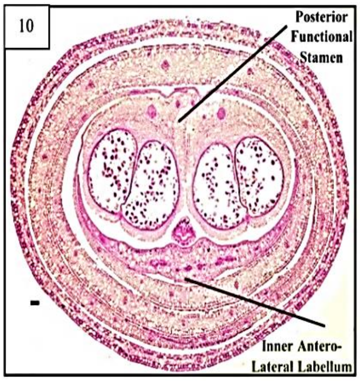


Plate. IV. Serial cross-section through a floral bud of *Alpinia zerumbet*. Scale = 100 µm. **Abbreviations**: **M.Ma.P.St.Sept.C.** Median, Marginal Petal Staminal Septal Complex. **M.P.Sept.B.** Median Petal Septal Bundle. **M.P.St.Sept.C.** Median Petal Staminal Septal Complex. **M.S.C.D.B.** Median Sepal Carpellary Dorsal Bundle. **M.St.C.D.B.** Median Staminal Carpellary Dorsal Bundle. **M.S.St.C.D.C.** Median Sepal Staminal Carpellary Dorsal Complex. **M.St.Sept.B** Median Staminal Septal Bundle. **Va.Plx.** Vascular Plexus.

as the outer three small complexes at the same location as locules of the ovary, alternating with the inner three large complexes

The outer three small complexes are represented by two large postero-lateral bundles and one anterior small bundle. The former two postero-lateral bundles supply the median and marginal bundles of the sepals and the vascular supplies of outer postero-lateral petaloid staminodes, while the anterior small bundle supplies the median and marginal supplies of the anterior sepal and the median supply of the inner fused antero-lateral petaloid staminodes (labellum). In the upper part of the labellum, this median bundle divides into small bundles that travel laterally as marginal supplies of the labellum (Plate V; Photo 6).

The inner three large complexes, the two antero-lateral complexes, are divided into numerous small bundles. The outer bundles supply the median bundles of the two antero-lateral petals, while the remaining inner bundles supply the marginal bundles of the inner fused antero-lateral petaloid staminodes (labellum) (Plate V; Photo 7). The posterior complex is also divided into six small bundles; the outer bundle supplies the median bundle of the posterior petal, while the remaining five inner bundles enter the inner posterior functional stamen (Plate V; Photo 8). The filament of the fertile stamen is mostly slender and deeply grooved. In such a groove, the style extends between the anther cells and the capitate stigma. This style has a flattened canal, and three bundles continue into the stylar tissue to feed the stigma.

Orchidaceae Juss.
Dendrobium nobile Lindl.

At the pedicel level, the vascular tissue consists of six vascular bundles arranged in two whorls. At the receptacular level, these bundles appear as three outer vascular traces alternating with three inner vascular traces (Plate VI; Photo 1). The three outer vascular traces consist of two postero-lateral and one anterior trace. The two postero-lateral vascular traces give the vascular supply of the two postero-lateral sepals, the marginal supplies of the posterior petal (labellum), and feed the stigmas. The third anterior vascular trace divides at the upper part of the ovary and gives the vascular supply of the anterior sepal, the marginal supplies of the two antero-lateral petals, and the column vascular bundle that extends in the operculum until the pollinial sac.

The inner three vascular traces are divided into three outer and three inner vascular bundles. Each of the outer three vascular bundles is divided laterally to give three vascular bundles which represent the marginal vascular bundles for each sepal, a median bundle for the posterior petal (labellum), and a median bundle for the two antero-lateral petals each (Plate VI; Photo 2). Each of the inner three vascular bundles is divided laterally to give three vascular bundles that represent the marginal vascular supplies of the three petals, including the labellum. (Plate VI; Photo 8).

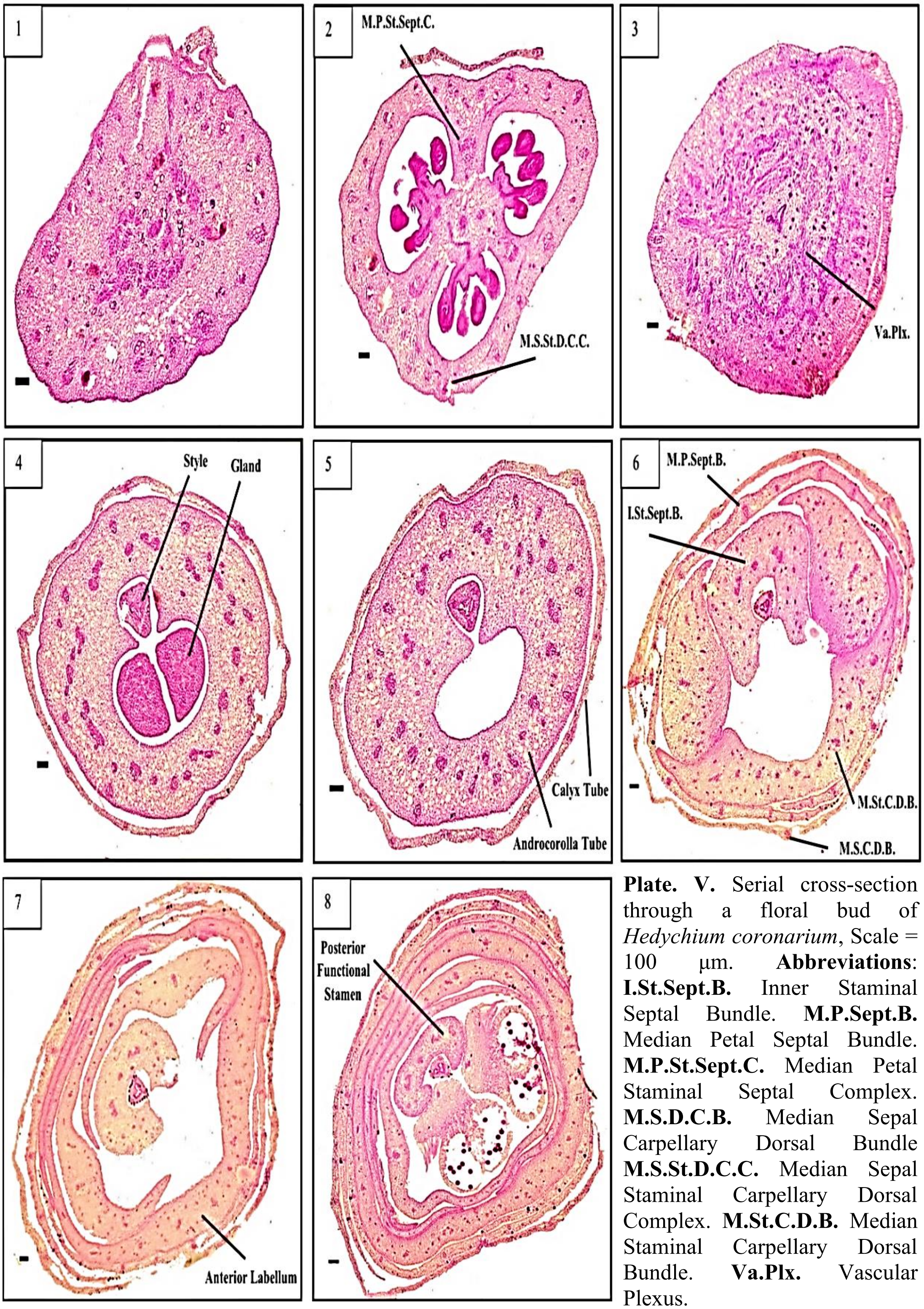


Plate. V. Serial cross-section through a floral bud of *Hedychium coronarium*, Scale = 100 µm. **Abbreviations**: **I.St.Sept.B.** Inner Staminal Septal Bundle. **M.P.Sept.B.** Median Petal Septal Bundle. **M.P.St.Sept.C.** Median Petal Staminal Septal Complex. **M.S.D.C.B.** Median Sepal Carpellary Dorsal Bundle **M.S.St.D.C.C.** Median Sepal Staminal Carpellary Dorsal Complex. **M.St.C.D.B.** Median Staminal Carpellary Dorsal Bundle. **Va.Plx.** Vascular Plexus.

Discussion

In monocot plants, the study of labellum is considered a useful diagnostic feature that helps in distinguishing and classification of some monocot taxa (Eichler, 1884; Heywood, 1978; Cronquist, 1981; Dahlgren, *et al.* 1985; and Lie, *et al.* 2020). The present study separated the studied taxa into two distinct orders, *viz.* Zingiberales and Asparagales according to the morphological and vascular characters of the labellum. As regards the vasculature patterns, the labellum of Orchideceae (Asparagales) is separated from the other studied taxa of Zingiberacea, Canaceae, and Marantaceae (Zingiberales). This result is in agreement with the previous studies supported by APG II (2003), depending on morphological and molecular evidence.

Since the nineteenth century, researchers have proposed differing views on the nature of the labellum, suggesting it may have either a double or triple nature based on morphology. The classical double-nature theory supported by Payer (1857), Van Tieghem (1868, 1871), Gregory (1936), Pai (1963), Pandy (1989), and Sharawy (2013) states that the labellum results from the fusion of two inner stamens (Zingiberaceae) or two petals (Orchidaceae). Conversely, Heywood (2001) and Zhang *et al.* (2009) proposed a triple nature, viewing the labellum as a structure derived from three floral parts. while Liao *et al.* (2005) reported a five-lobed labellum in *Alpinia hainanensis*.

The morphological characters of the labellum in the studied taxa are described as follows: in *Dendrobium nobile* (Orchidaceae), it is tri-lobed (posterior petal), in *Alpinia zerumbet* (Zingbaraceae) is tri-lobed and represented by the union of two inner staminodes, while in *Hedycium coronarium* (Zingbaraceae) is bilobed and represented by the union of two inner staminodes. The three taxa of *Canna* (Cannaceae) are bilobed from the union of two staminodes; one from the outer whorl and the other from the inner whorl. In *Maranta leuconeura* (Marantaceae), the labellum is one-lobed of the inner anterio-lateral staminode (Plate VII).

The current study distinguished *Dendrobium nobile* (Orchidaceae) from the other studied taxa based on the labellum vasculature pattern. In *Dendrobium nobile*, the labellum supply arises from three distinct vascular bundles: one posterior inner (petal) bundle, which divides to represent the median and the marginal labellum vasculature, and two posterior lateral (sepal) bundles that form the labellum marginal bundles. So, the vasculature supports that the labellum of *Dendrobium nobile* is a triple structure. Rudall *et al.* (2013) in their study on Musk orchid observed that the median petal (labellum) was supplied by three vascular bundles, and these have been observed in the present study. Brown (1833); Endress (1994); Kocyan & Endress (2001) stated that the labellum of Orchidaceae originates from a single petal but may incorporate non-expressed stamen traces, leading to complex vasculature.

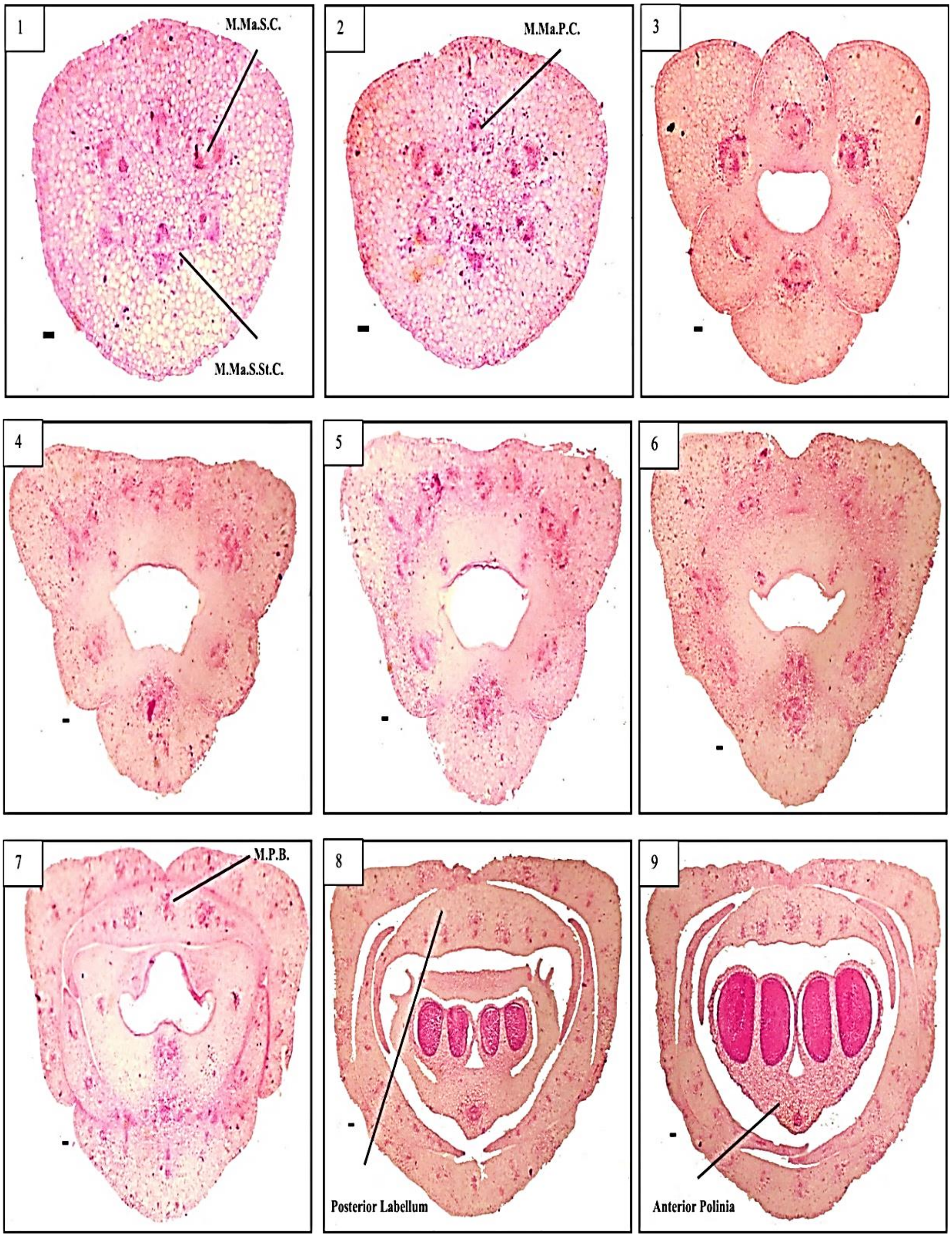


Plate. VI. Serial cross-sections through a floral bud of *Dendrobium nobile*. Scale = 100 μm **Abbreviations**: **M.Ma.P.C.** Median, Marginal Petal Complex. **M.Ma.S.C.** Median, Marginal Sepal Strand. **M.Ma.S.St.C.** Median, Marginal Sepal Staminal Complex. **M.P.B.** Median Petal Bundle.

Gregory (1936) and Zhang *et al*. (2009) in the study of the labellum in some taxa of Zingbarales assumed that the labellum is a triple structure. Liao *et al.* (2005) indicate that the labellum of *Alpinia hainanesis* incorporates elements of five organs. While Sharawy (2013) supports the old classical concept that the labellum is a double structure rather than a triple or five-parted structure that was suggested by previous authors. Our observation on the floral vasculature of red and yellow cultivars of *Canna* x *hybrida* indicates that the labellum is of double structure and incorporates one trace from the carpellary dorsal trace (constituting one member of the outer androecial whorl) and one trace from the antero-lateral carpellary septal bundle (constituting one member of the inner androecial whorl). The former bundle represented the median bundle of labellum, while the latter bundles represented the marginal bundles of labellum (Plate VII).

In *Canna indica,* the labellum vasculature is the same as the other two cultivars (*Canna* x *hybrida*). Rao & Donde (1955) and Pai (1963) supported that in *Canna* the vasculature of the outer androecial whorl derives from the carpellary dorsal bundles and that of the inner whorl derives from the carpellary septal bundles. This observation has been observed in the specimens of *Canna* studied here. On the other hand, this observation contradicts the interpretation based on other data sources. Kirchoff (1983b) and Kunze (1984) interpreted that the labellum of Cannaceae consists of a single petaloid stamen (from only one organ).

The floral vasculature of *Maranta leuconeura* (Marantaceae) indicates that the labellum vasculature originated from one vascular trace: a carpellary septal trace that divides and supplies the labellum as median and marginal bundles. One inner staminode forms a large labellum, and the other forms the lateral staminodes. The previous studies provided by Tilak & Pai (1966, 1968, 1970), Liao *et al.* (1998, 2001, 2005), Tang *et al*. (2000, 2002), Xie (2002) and Ming-Zhi *et al.* (2014) on morphological and anatomical characters of family Marantaceae consistent with the present study and support the conception that the labellum of Marantaceae is of a single structure rather than double or triple structure.

In *Alpinia zerumbet* and *Hedychium coronarium* (Zingiberaceae), the labella are of triple structure and their vasculatures arise from three different vascular bundles: two antero-lateral carpellary septal bundles (antero-lateral inner staminodes) and one anterior carpellary dorsal bundle (anterior outer staminode). The earlier evidence provided by Rao *et al.* (1954), Rao & Donde (1955), Rao & Pai (1959, 1960), Pai (1961, 1963, 1965), Rao & Gupte (1961), Rao (1963), Tang *et al.* (2000), Liao *et al*. (2001), Xie (2002) and Lin *et al*. (2007) on the vasculature of inner androecial whorl in some taxa of Zingiberaceae may will be agreed with the present study and support the conception that the labellum of Zingiberaceae is a triple structure rather than double classical conception that suggested by Sharawy (2013) and Ming-Zhi *et al*. (2014), or five nature by Liao *et al.* (2005). However, the

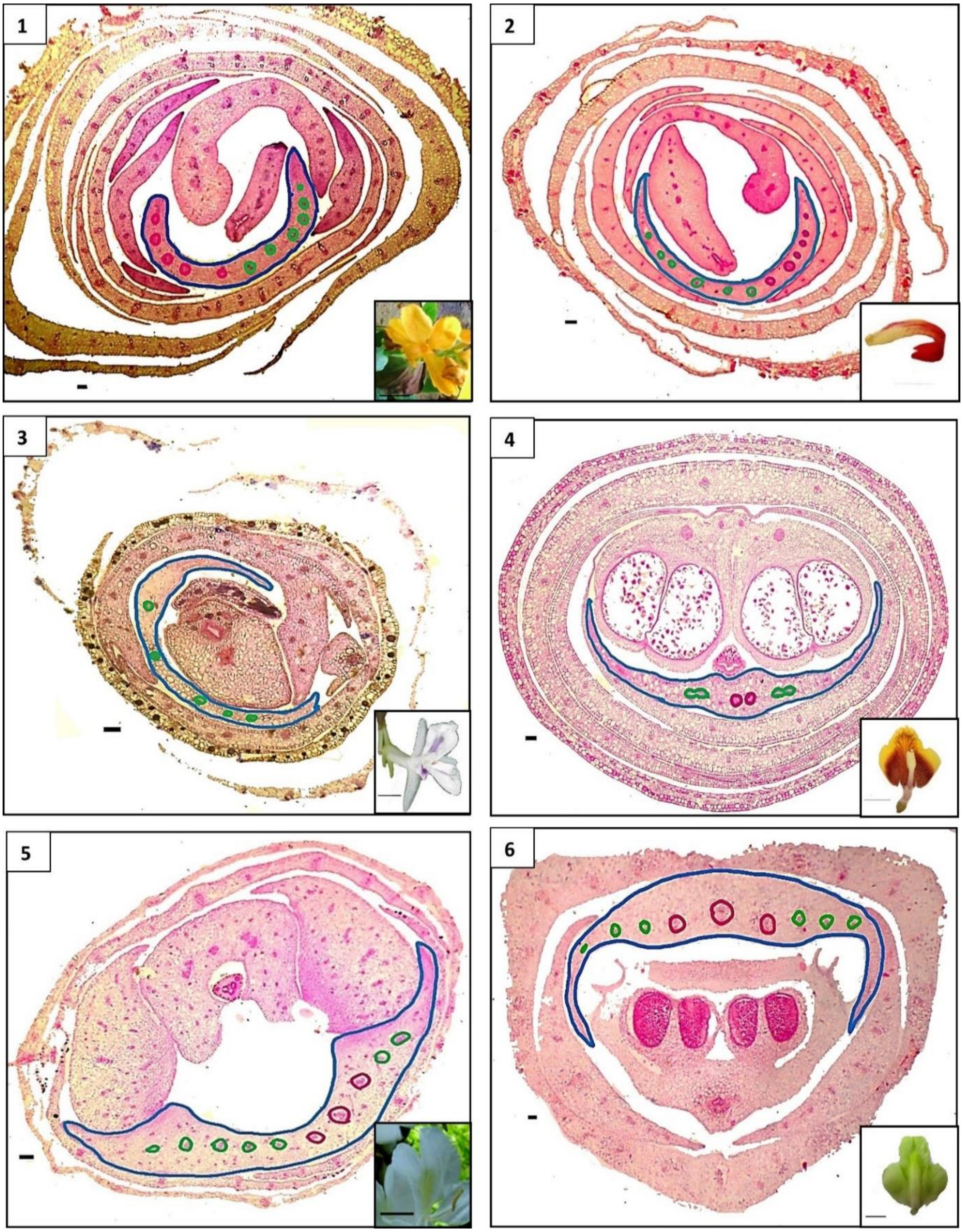


Plate VII. Schematic representation of the floral vasculature and morphology of labellum of the studied taxa. Diagrams of transverse-sections from the flower of 1. *Canna* x *hybrida* (yellow). 2. *Canna indica.* 3. *Maranta leuconeura*. 4. *Alpinia zerumbet*. 5. *Hedychium coronarium*. 6. *Dendrobium nobile*. Scale = 10000 µm. The colored vascular bundles represent different supply sources.

morphological characters support the previous study of Lestiboudois (1829); Eichler (1884); Schachner (1924), who investigated labellum development in Zingiberaceae, particularly in the genus *Hedychium,* as it develops from the union of two inner staminodes. On the other hand, the present study confirms the contribution of the inner and outer stamens in the labellum structure.

Conclusion

The present study concluded that the labella of *Dendrobium nobile* (Orchidaceae), *Alpinia zerumbet,* and *Hedychium coronarium* (Zingiberaceae) are triple-structured. While the labella of the two cultivars *Canna* x *hybrida* and *C. indica* (Cannaceae) are double-structured, and those of *Maranta leuconeura* (Marantaceae) are mono-structured. Consequently, the morphology and the vasculature of the labellum are essential as diagnostic characters for the differentiation between monocot species.

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