BIOSFER: JURNAL TADRIS BIOLOGI
p-ISSN: 2086-5945 (print), e-ISSN: 2580-4960 (online), DOI 10.24042/biosfer. v14i2.18128
http://ejournal.radenintan.ac.id/index.php/biosfer/index

Short Notes on the Leaf Architecture and Morphometry of *Syzygium* spp. Leaves from the Living Collections of Bogor Botanic Gardens

Shofiyyatuz Zahro[1], Baiq Farhatul Wahidah[2*], Muhammad Rifqi Hariri[3]

[1,2]Universitas Islam Negeri Walisongo Semarang, Indonesia
[3]Pusat Riset Biosistematika dan Evolusi, Badan Riset dan Inovasi Nasional, Indonesia

ARTICLE INFO

Article History
Received : 20-08-2023
Accepted : 15-12-2023
Published : 31-12-2023

Keywords:
Bogor Botanic Gardens; Leaf Architecture; Living Collection; Myrtaceae venation.

*Correspondence email:
baiqfarhatulwahidah@walisongo.ac.id

*Contact number:

ABSTRACT

Studies of leaf architecture and morphometry in *Syzygium* spp. are investigated. Seven species of *Syzygium* are taken for the study with additional *Psidium guineense* Sw. used as comparison. The seven species include *Syzygium urceolatum* subsp. *palembanicum* (Miq.) P.S.Ashton, *Syzygium tinombalum* Sunarti, *Syzygium sexangulatum* (Miq.) Amshoff, *Syzygium hirtum* (Korth.) Merr. & L.M. Perry, *Syzygium boerlagei* (Merr.) Govaerts, *Syzygium racemosum* (Blume) DC., and *Syzygium claviflorum* (Roxb.) Wall ex Steud. A comprehensive description of leaf architecture for the studied taxa was provided including leaf type, laminar shape, leaf attachment, laminar length, laminar width, petiole, leaf margin, apex shape, base shape, leaf color, and laminar symmetry. The pattern showed primary vein framework, major secondary spacing, major secondary angle, major secondary vein framework, and tertiary veins. Taxonomically significant leaf features of examined taxa showed great diversity in leaf attachment opposite, primary vein framework pinnate, and major secondary angle smoothly decreasing towards base.

Arsitektur *Daun dan Morfometri Syzygium spp. Koleksi Kebun Raya Bogor*

ABSTRAK: *Kajian arsitektur daun dan morfometri Syzygium spp. diamati dan dilaporkan. Tujuh spesies Syzygium digunakan dan satu spesies Psidium guineense Sw. sebagai pembanding. Jenis Syzygium yang diamati terdiri dari Syzygium urceolatum subsp. palembanicum (Miq.) P.S.Ashton, Syzygium tinombalum Sunarti, Syzygium sexangulatum (Miq.) Amshoff, Syzygium hirtum (Korth.) Merr. & L.M. Perry, Syzygium boerlagei (Merr. Govaerts), Syzygium racemosum (Bl) DC., dan Syzygium claviflorum (Roxb.) Wall ex Steud. Deskripsi arsitektur daun yang diamati mencakup ciri tipe daun, bentuk helaian, letak daun, panjang helaian daun, lebar helaian daun, tangkai daun, tepi daun, ujung daun, pangkal daun, warna permukaan daun, dan simetri helaian daun. Pola venasi menunjukkan primary vein framework, major secondary spacing, major secondary angle, major secondary vein framework, dan tertiary veins. Ciri dengan nilai signifikan ditemukan pada letak daun berhadapan, primary vein framework menyirip, dan sudut sekunder utama yang secara halus berkurang menuju dasar.*

INTRODUCTION

Myrtaceae is a pan-tropical family of trees and shrubs with nearly about 55,000 species, classified into two subfamilies, 17 tribes and 142 genera (Soh & Parnell, 2011). The plants are predominantly found in the tropical and temperate regions and southern hemisphere with a high diversity in South America, Central America, and Australia (Wilson et al., 2001). Plants from this family are evergreen, with the majority of the members having opposite leaves, containing high essential oil and before internal phloem (Wilson et al., 2001). Myrtaceae are generally found in the environment that is waterlogged and humid rain forest (Hussin et al., 1992).

The Myrtaceae family presents a multitude of challenging and thought-provoking issues in terms of nomenclature and systematic classification (Cardoso & Sajo, 2004). The genus *Eugenia*, which was named after Francois Eugene de Savoie-Carignan, a prominent figure in art, science, and literature during the 17th and 18th centuries, has posed significant challenges and sparked debates in the field of angiosperm taxonomy (Schmid, 1972). Since the era of Linnaeus, numerous species from both the Old and New World have been classified under the genus *Eugenia*. According to Defaveri et al. (2011), approximately 2500 species were identified as members of, or reassigned to, this particular genus by Defaveri et al. (2011), further reported the publication of 100 additional binomial names under *Eugenia* by 1950. Furthermore, Index Kewensis documented an extra 200 names by 1965, and Mc Vaugh (1969) introduced 22 new names in a recent publication. Approximately 35 generic names, both legally and invalidly published, which are derived from different Old World taxa, have been or have the potential to be consolidated into *Syzygium* P. Browne ex J. Gaertner (1788) (Schmid, unpublished data). If the taxonomic classification of *Syzygium* is revised to *Eugenia*, as has been undertaken by numerous scholars, the inclusion of these 35 or more names could significantly increase the count of generic synonyms associated with *Eugenia* s. I. to approximately 70. This is due to the fact that over 30 primarily American genera (Ribeiro et al., 2019) have been regarded as congeneric with *Eugenia* s. s. by different researchers. The genus *Eugenia* has evidently become cumbersome, giving rise to a complex synonymy and intricate taxonomy (Mahmoud et al., 2021). There exist three distinct perspectives concerning the distribution of *Eugenia* and its Old World counterparts, as documented in historical literature (Kausel, 1956); (Riaz & Abid, 2021).

The current study focuses on leaf architecture, specifically utilizing the *Psidium* outgroup as a means to observe the particular characteristics of both *Syzygium* and *Psidium*. The leaf architecture of seven species within the *Syzygium* genus is examined in this study. The first effort to systematize the description of the vegetative leaf architecture with his classification of venation pattern carried out by (Maulia & Susandarin, 2019). Leaf architectural characters have proved valuable taxonomic and systematic data both in fossil and living plants (Widodo, 2011). Leaf architecture and venation pattern studied in different families of dicotyledons; amongst others such as Cucurbitaceae, Dipterocarpaceae, Araceae, Rubiaceae, and Anacardiacea (Andrés-Hernández & Terrazas, 2009; Masungsong et al., 2022; Meinata et al., 2021; Guddad et al., 2022).

The investigation of leaf architecture and venation patterns in various dicotyledonous families has been documented in several studies. Verghese (1969) explored these characteristics in the Scrophulariaceae family. Banerjee and Despande (1973) as well as Ravindranath and Inamdar (1982) focused on the Compositae family. Sehgal and Paliwal (1974) and Levin (1986) examined the genus Euphorbia. Singh et al. (1978) studied the Berberidaceae family, while Jain (1978) investigated the Bignoniaceae family. Tyagi and Kumar (1978) explored the Labiatae family, while Merrill (1978) focused on one genus within the Rosaceae family. Inamdar and Murthy (1978) studied the Solanaceae family, while Frank (1979) examined one species within the Betulaceae family. Inamdar and Shenoy (1981) investigated the Convolvulaceae family, and Avita et al. (1981) explored the Ranunculaceae family. Lastly, Mohan and Inamdar (1982) studied the Apocynaceae family. The taxonomic classification of Brassicaceae was established by Rall and Inamdar in 1983, while the classification of Oleaceae was proposed by Mohan and Inamdar in the same year.

The present work was undertaken to give detail account of the venation pattern and leaf architecture in seven species of genus *Syzygium* as no report exists on the subject. It is a contribution towards better understanding the role of leaf architecture, assessing the range of variation among species by applying multivariate analysis.

METHOD

Plant materials

Seven species of *Syzygium* from Bogor Botanic Gardens' living collection, consisted of *Syzygium urceolatum* subsp. *palembanicum* (Miq.) P.S.Ashton (labeled as *Syzygium palembanicum* Miq. (c.f) in the garden), *Syzygium tinombalum* Sunarti, *Syzygium sexangulatum* (Miq.) Amshoff, *Syzygium hirtum* (Korth.) Merr. & L.M. Perry, *Syzygium boerlagei* (Merr. Govaerts), *Syzygium racemosum* (Bl) DC., *Syzygium claviflorum* (Roxb.) Wall ex Steud, were observed in this study (Figure 1). To represent the outgroup, *Psidium guineense* Sw. leaf samples were also procured. Ten mature and fully expanded leaves were collected from each species to be observed further.

Leaf Architecture and Morphometry Measurement

The selection of leaf morphometric characters were based from manual of leaf architecture with modifications (Ash et al., 1999). Leaf characters evaluated include leaf type, laminar shape, leaf attachment, laminar length, laminar width, petiole, leaf margin, apex shape, base shape, leaf color, laminar symmetry, primary vein framework, major secondary spacing, major secondary angle, major secondary vein framework, and tertiary veins.

Data Analysis

The measurement of the similarity index was based on the similarity coefficient of qualitative data. This similarity matrix is used for grouping analysis of Sequential Angglomerative, Hierarchical and Nested (SAHN) clustering using the Unweighted Pair group method with arithmetic average (UPGMA) method using the NTSys-pc version 2.1 (Rolf, 1993). Moreover, to visualize the individual differences of *Syzygium* species, ordination analysis using Principal Component Analysis (PCA) was also carried out (Kremer et al., 2002). Statistical analyses were done using Minitab 16 (Hadijah, 2013).

RESULTS AND DISCUSSION

Leaf Characters of *Syzygium* and *Psidium*

The eight observed species shared many similar laminar features. All leaf samples, including the outgroup, were observed to have primary vein framework, opposite leaves (Figure 2). These characters are commonly observed in most species under Myrtaceae family. Symmetrical leaves with elliptic shape, entire margin, and acute apices were also observed across the species analyzed. The same features were exhibited by *P. guineense* leaves except for its obtuse apex.

Leaf architecture of *Syzygium* the leaf shape is elliptical with length ranging from 5 to 15 cm and width ranging from 3 to 8 cm. The base and the end of the leaf are pointy. The upper part of the leaf is dark green with lighter green on the lower part. The leaf petiole is about 0.5–1 cm (Ismail et al., 2019). In general, *Syzygium* has elongated to long lanceolate leaf blades and leaf widths ranging between 6-30 cm and 4-15 cm (Mukaromah, 2020).

The leaves of the *Psidium* plant have a single leaf structure. The position of the leaves is crossed with the location of the leaves facing each other and the leaf veins are pinnate, the shape of the leaves is oval, oblong, and inverted egg-shaped (Romalasari et al., 2017). Genus *Psidium* laevis leaf surface, entire leaf margin, pinnate leaf veins, acuminatus leaf tips, and base of obtusus leaves (Zulkarnain et al., 2019). The major secondary vein framework was the camptodromous brochidodromous mixed venation pattern, followed by the brochidodromous pattern (Oliveira et al., 2017).

The arrangement of secondary veins relative to the midrib in the leaves of the studied species produces angles with divergences ranging from 45◦ to 75◦ . According to Cardoso et al. (2009), the divergence angles ranging from 45◦ to 60◦ are most striking in species with mixed venation patterns (camptodromous–brochidodromous), as recorded in the present study for *P. laruotteanum, P. myrsinites, and P. guineense.* The divergence angles cannot be considered to be taxonomic characters for distinguishing species, as in the present study, all species showed wide variations among the angles in leaves from the same individual (Oliveira et al., 2017).

According to Gomes et al., (2009), in most surveys of *Psidium*, the marginal ultimate venation pattern is the looped type, formed by complete arches, consistent with the results obtained in the present study. The marginal ultimate looped type venation pattern is common in most species of the Myrtaceae family, followed by fimbrial and incomplete loop types. Vieira (2020) registered the fimbrial and looped types in two and seven species, respectively, of the nine species of *Myrcia* DC. (Myrtaceae) studied in Federal District, Brazil.

The influence of leaf architecture on plant adaptability to various environments is a result of the combined effects of genetic factors and external environmental conditions (Montojo, 2020). This is in agreement with Saputri et al. (2019) and Sani et al. 2020) that environmental changes such as decreasing temperature, increasing humidity and decreasing light intensity affect morphology in plant leaves. The available literature indicates that there has been limited research conducted on leaf architecture and venation patterns in dicotyledonous families (Maulia & Susandarin, 2019). Consequently, this study aims to address this gap by investigating 13 species within the Malvaceae genus *Hibiscus*. The major venation pattern, also known as the primary venation pattern, refers to the arrangement and distribution of veins in the leaves of plants (Talwara, Grout, & Toldam-Andersen, 2013). This pattern plays a crucial role in the transportation of water, nutrients, and the species examined in this study, as described by Liu et al. (2022), exhibit a consistent adherence to the characteristic pinnate actinodromous pattern. This pattern appears to be a consistent trait within the genus, suggesting its potential value as a significant criterion for taxonomic classification. The areoles displayed a notable level of development and commonly showcased vein endings that were either accompanied or unaccompanied by terminal tracheids. The absence of isolated tracheids and the lack of loop formation by tracheids were not detected in the specimens belonging to the genus under investigation (Medina et al., 2011). Across all observed species, it was found that the venation pattern exhibited a notable degree of incompleteness. The position of the gland was observed to be either laminar or basilaminar in nature. Intersecondary veins were found to be prevalent and were observed in all species under investigation, with the exception of *H. jicuinells*. The species under discussion include *H. puncracus*, *H. sabdariffa*, *H. solandra*, and *H. suralensis*. According to Bhat (1995), it can be inferred that the presence of interscondary veins should not be regarded as a reliable taxonomic criterion.

The unusually extensive range in leaf venation patterns of angiosperms has been categorized by, for example, (Maulia & Susandarin, 2019; Hickey, 1973). In the following, the widely used system of (Hickey, 1973) and its terminology is utilized. Whereas (Maulia & Susandarin, 2019) solely addressed leaf venation, the scheme of (Hickey, 1973) also includes additional features of leaf architecture in the classification process, such as leaf shape or the structure of the leaf margin. The classification of an angiospermic venation pattern starts with the principal vein, or, if more than one primary vein is present, with all primary veins entering the leaf from the petiole and the subsidiary veins branching of the major vein (Sosnovsky et al., 2017). Primary and secondary veins are designated the major vein class and represent lower order veins (Patel, 2012). The classification goes with progressively higher order veins until the areolation which finishes the vein system (Mohamed et al., 2023). This approach indirectly leverages a basic property of angiospermic leaf venation patterns (Hickey, 1979). The vein diameter at the point of origin of the vein represents the basic criterion in determining the vein order (Cardoso et al., 2009). This classification system does not only consider the geometric arrangement of diferent vein classes (Marques et al., 2004). The arrangement of veins of a specific order in respect to other architectural elements of the leaf is also crucial in defining a certain venation type. This is shown by the following examples (Soh & Parnell, 2011).

The leaf shape of angiosperm plants exhibits variation among different taxonomic groups. The foliage of plants has a wide range of diversity, characterized by a multitude of leaf venation patterns (Seixas et al., 2012). The morphological structure of leaf venation plays a significant role in characterizing the distribution and arrangement of the vein system within leaves. Leaf veins serve the purpose of providing structural reinforcement to orient the leaf towards light, while also housing the xylem, which facilitates the transportation of water and nutrients necessary for the processes of photosynthesis and transpiration (Saputri et al., 2022; Defaveri et al., 2011). The adaptation of a particular plant to its local settings can be inferred from the combined analysis of leaf vein features and functional attributes (Viacrucis & Buot, 2021).

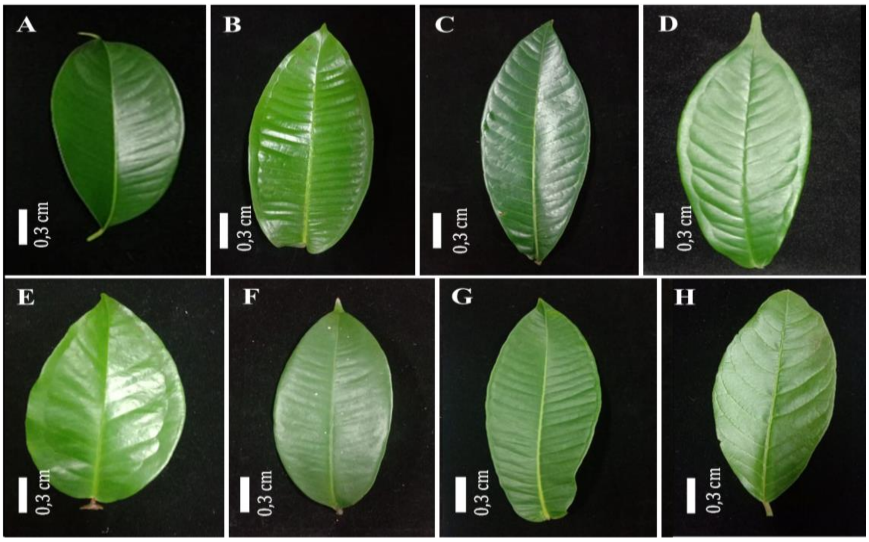

Figure 1. Leaf samples of *Syzygium urceolatum* subsp*. palembanicum* (Miq.) P.S.Ashton (A), *Syzygium tinombalum* Sunarti (B), *Syzygium sexangulatum* (Miq.) Amshoff (C), *Syzygium hirtum* (Korth.) Merr. & L.M. Perry (D), *Syzygium boerlagei* (Merr.) Govaerts (E), *Syzygium racemosum* (Bl) DC. (F), *Syzygium claviflorum* (Roxb.) Wall ex Steud (G), and *Psidium guineense* Sw. (H)

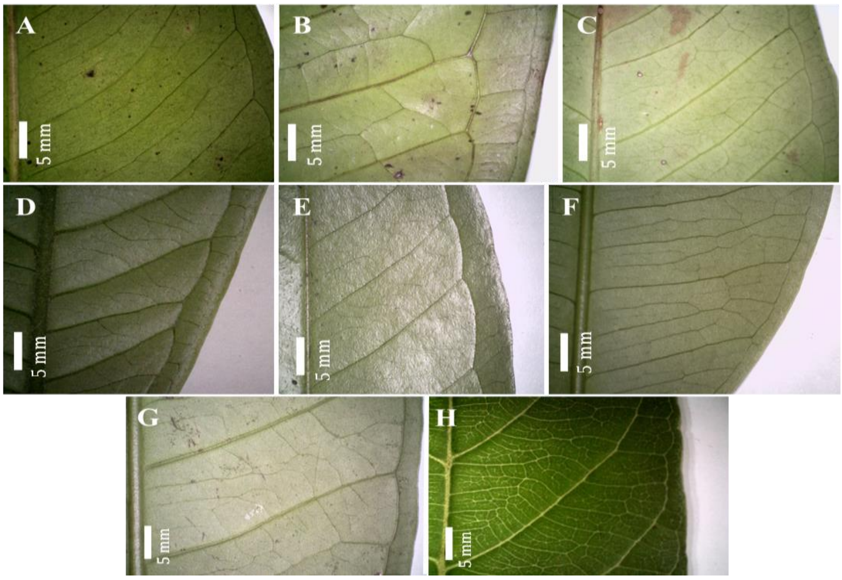

Figure 2. Venation characters of the leaves *Syzygium urceolatum* subsp*. palembanicum* (Miq.) P.S.Ashton (A), *Syzygium tinombalum* Sunarti (B), *Syzygium sexangulatum* (Miq.) Amshoff (C), *Syzygium hirtum* (Korth.) Merr. & L.M. Perry (D), *Syzygium boerlagei* (Merr. Govaerts) (E), *Syzygium racemosum* (Bl) DC. (F), *Syzygium claviflorum* (Roxb.) Wall ex Steud (G), and *Psidium guineense* Sw. (H)

Statistical analysis of leaf architectural characteristics of *Syzygium* and *Psidium*

Leaves are organs of plants that can be easily observed. Throught the naked eye, the leaf of some members are difficult to distungish (Octariyanti et al., 2022). This study highlights the importance of leaf characteristics in the identification of the majority of the taxa being examined. Leaf forms and venation patterns are important characteristics that are commonly used to distinguish between members of the *Syzygium* and *Psidium* genera, either at the subgeneric or sectional levels. The Principal Component Analysis (PCA) is supplying the quantitative values that are associated with the morphological characteristics utilized in this taxonomic examination. Principal Component Analysis (PCA) is widely recognized as a conventional multivariate statistical technique utilized for the analysis of numerical data (Mardia et al., 1979). The findings of this study indicate a moderate level of agreement between the results obtained by Principal Component Analysis (PCA) and the most recent taxonomic studies that have utilized leaf morphology as the primary determinant for the classification of angiosperms (Fayed et al., 2020).

Similarities and dissimilarities of the leaf architercure and venation characters were visually shown in output patterns using multivariate analysis. Dendograms using unweighted pair-group average (UPGMA) and single linkage (nearest neighbor) algorithm evidently illustrate the distinction between seven species of *Syzygium* and *Psidium*. The relationship between *Syzygium* spp. based on morphometric studies showed that the seven of them are closely related, but *P. guineense* is distant to them (Figure 3). The close kinship is due to the many similarities in the morphological studies (Gusmiaty et al., 2017).

PCA data ordination (Figure 4) showed variation among characters of the leaf samples studied. As observed, the species clustered distinctly in groups indicating relevant variabilities between laminal and venation characters of *S. urceolatum* subsp*. palembanicum*, *S. tinombalum*, *S. sexangulatum*, *S. hirtum*, *S. boerlagei*, *S. racemosum*, *S. claviflorum*, and *P. guineense*, has the most distinct cluster between the two indicating strong variability among the seven *Syzygium* species.

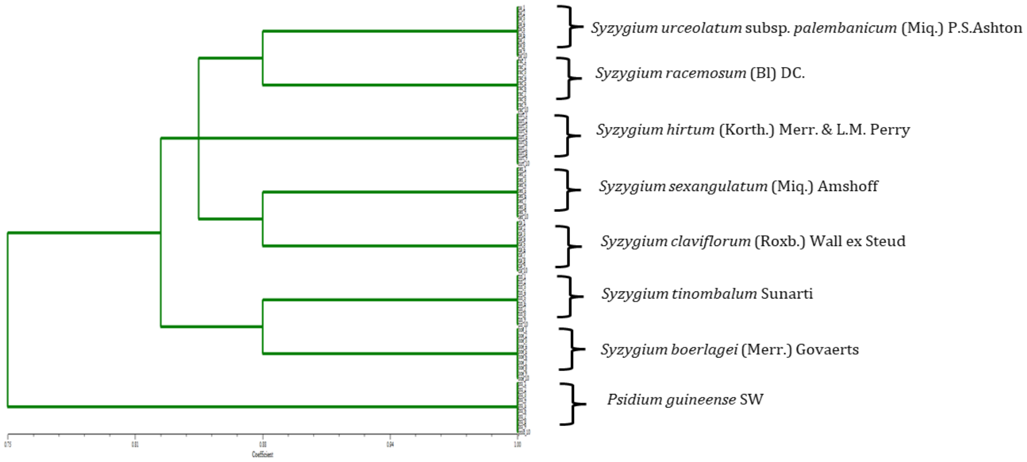

Figure 3. Dendrogram generated using unweighted pair-group average (UPGMA) clustering approach for *Syzygium urceolatum* subsp*. palembanicum* (Miq.) P.S.Ashton, *Syzygium tinombalum* Sunarti, *Syzygium sexangulatum* (Miq.) Amshoff, *Syzygium hirtum* (Korth.) Merr. & L.M. Perry, *Syzygium boerlagei* (Merr.) Govaerts, *Syzygium racemosum* (Bl) DC., *Syzygium claviflorum* (Roxb.) Wall ex Steud, and *Psidium guineense* Sw.

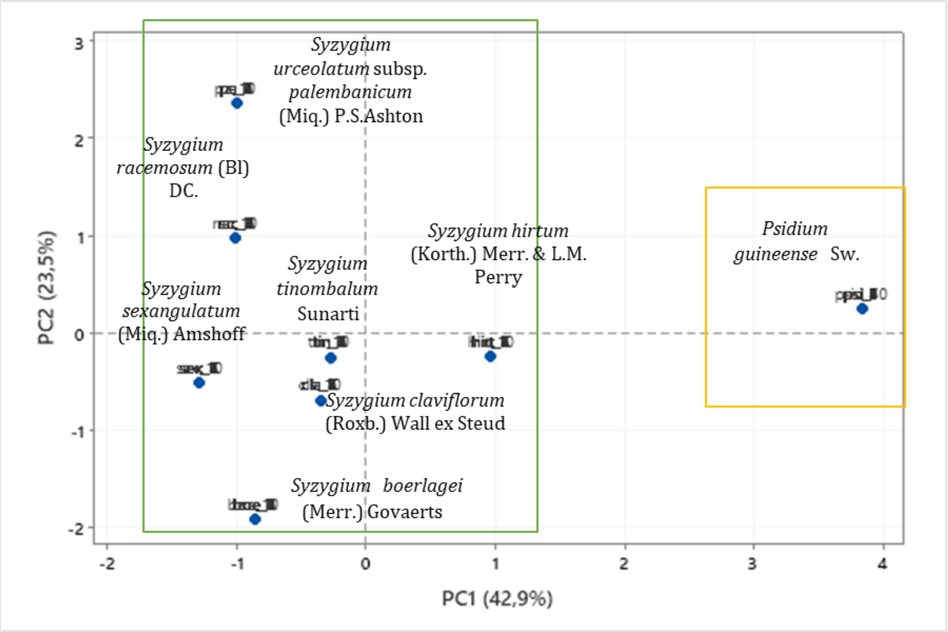

Figure 4. Principal Component Analysis (PCA) for *Syzygium urceolatum* subsp*. palembanicum* (Miq.) P.S.Ashton (c.f), *Syzygium tinombalum* Sunarti, *Syzygium sexangulatum* (Miq.) Amshoff, *Syzygium hirtum* (Korth.) Merr. & L.M. Perry, *Syzygium boerlagei* (Merr.) Govaerts, *Syzygium racemosum* (Bl) DC., *Syzygium claviflorum* (Roxb.) Wall ex Steud, and *Psidium guineense* Sw., showing distinct groups, further validating the distinction of laminar and venation characters.

CONCLUSIONS AND SUGGESTIONS

In conclusion, taxonomically significant leaf features of examined taxa showed great diversity in leaf opposite, primary vein framework pinnate, and major secondary angle smoothly decreasing towards base. Based on the coefficient value of the morphometric study shows that *Syzygium* spp. has a distant relationship to the outgroup *P. guineense* Sw. PCA analysis of leaf architecture and venation characters showed a strong variability among the seven species of *Syzygium*.

ACKNOWLEDGEMENTS

The observation at Bogor Botanic Gardens was made possible given to the consent and help of the Head of the Directorate for Scientific Collection Management. Without the support of Arcadia Millennium Seed Bank Partnerships RBG Kew, represented here by Mrs. Dian Latifah, neither this publication nor the research that went into it would have been possible.

REFERENCES

Andrés-Hernández, A. & Terrazas, T. (2009). Leaf architecture of rhus s.str. (Anacardiaceae). *Feddes Repertorium*, *120* (5–6), 293–306. https://doi.org/10.1002/fedr.200911109

Ash, A., Ellis, B., Hickey, L. J., Johnson, K., Wilf, P., & Wing, S. (1999). Manual of Leaf Architecture, Morphological description and categorization of dicotyledonous and net-veined monocotyledonous angiosperms. *Systematic Botany*. *34*(2), 100-110 https://doi.org/10.13140/2.1.3674.5282

Cardoso, C. M. V., Proeņa, S. L., & Sajo, M. G. (2009). Foliar anatomy of the subfamily Myrtoideae (Myrtaceae). *Australian Journal of Botany*, *57*(2), 148–161. https://doi.org/10.1071/BT07176

Cardoso, C. M. V., & Sajo, M. das G. (2004). Vascularização foliar e a identificação de espécies de Eugenia L. (Myrtaceae) da bacia hidrográfica do Rio Tibagi, PR. *Revista Brasileira de Botânica*, *27*(1), 47–54. https://doi.org/10.1590/s0100-84042004000100006

Defaveri, A. C. A., Arruda, R. C. O., & Sato, A. (2011). Leaf anatomy and morphology of eugenia rotundifolia applied to the authentication of the “abajurú” commercially sold. *Revista Brasileira de Farmacognosia*, *21*(3), 373–381. https://doi.org/10.1590/S0102-695X2011005000029

Fayed, A. A. A., Ahamed, M. S., Faried, A. M., & Mohamed, M. H. (2020). Leaf Morphology and Venation Patterns of Euphorbia L. (Euphorbiaceae) in Egypt with Special Notes on Their Taxonomic Implications. *Jordan Journal of Biological Sciences*, *13*(2), 165–176.

Gomes, S. M., Somavilla, N. S. D. N., Gomes-Bezerra, K. M., de Miranda, S. do C., de-Carvalho, P. S., & Graciano-Ribeiro, D. (2009). Anatomia foliar de espécies de Myrtaceae: Contribuições à taxonomia e filogenia. *Acta Botanica Brasilica*, *23*(1), 223–238. https://doi.org/10.1590/s0102-33062009000100024

Guddad, M., Singh, A., Shah, H. P., Chaudhari, P., & Ahlawat, T. R. (2022). Effect of Foliar Application of Chemicals on Plant Architecture in Potted Ixora chinensis var. ‘Mini Double.’ *Current Journal of Applied Science and Technology*, *41*(32), 9–15. https://doi.org/10.9734/cjast/2022/v41i3231814

Gusmiaty, G., Restu, M., Asrianny, A., & Larekeng, S. H. (2017). Polimorfisme Penanda RAPD untuk Analisis Keragaman Genetik Pinusmerkusii di Hutan PendidikanUnhas. *Jurnal Natur Indonesia*, *16*(2), 47. https://doi.org/10.31258/jnat.16.2.47-53

Hadijah, H. (2013). Peramalan Operasional Reservasi dengan Program Minitab menggunakan Pendekatan Arima PT Surindo Andalan. *The Winners*, *14*(1), 13. https://doi.org/10.21512/tw.v14i1.640

Hickey, L. J. (1973). Classification of the Architecture of Dicotyledonous Leaves. *American Journal of Botany*, *60*(1), 17–33. https://doi.org/10.1002/j.1537-2197.1973.tb10192.x

Hussin, K. H., Cutler, D. F., & Moore, D. M. (1992). Leaf anatomical studies of Eugenia L. (Myrtaceae) species from the Malay Peninsula. *Botanical Journal of the Linnean Society*, *110*(2), 137–156. https://doi.org/10.1111/j.1095-8339.1992.tb00287.x

Ismail, A., Amir, W., Wan, N., Ismail, A., & Amir, W. (2019). Syzygium Polyanthum (Wight) Walp : A Potential Phytomedicine Common Names And Plant. *Pharmacognosy Journal*, *11*(2), 429–438.

Kremer, A., Dupouey, J. L., Deans, J. D., Cottrell, J., Csaikl, U., Finkeldey, R., … Badeau, V. (2002). Leaf morphological differentiation between Quercus robur and Quercus petraea is stable across western European mixed oak stands. *Annals of Forest Science*, *59*(7), 777–787. https://doi.org/10.1051/forest:2002065

Mahmoud, M. F., Nabil, M., Abdo, W., Abdelfattah, M. A. O., El-Shazly, A. M., El Kharrassi, Y., & Sobeh, M. (2021). Syzygium samarangense leaf extract mitigates indomethacin-induced gastropathy via the NF-κB signaling pathway in rats. *Biomedicine and Pharmacotherapy*, *139*(March), 111675. https://doi.org/10.1016/j.biopha.2021.111675

Marques, C. A., Barros, C. F., & Costa, C. G. (2004). Beilschmiedia rigida (Mez) Kosterm. (Lauraceae): Diferenciação e desenvolvimento da lâmina foliar. *Rodriguesia*, *55*(84), 89–100. https://doi.org/10.1590/2175-78602004558406

Masungsong, L. A., Alcala, A. A., Buot, I. E., & Belarmino, M. M. (2022). Classifying fifty-seven Cucumis (Cucurbitaceae) accessions into six species using leaf architectural traits. *Biodiversitas*, *23*(8), 4006–4017. https://doi.org/10.13057/biodiv/d230819

Maulia, Z., & Susandarin, R. (2019). Role of Leaf Architecture for the Identification of agarwood-producing Species Aquilaria malaccensis Lam. and Gyrinops versteegii (Gilg.) Domke at Vegetative Stage. *Journal of Biological Sciences*, *19*(6), 396–406. https://doi.org/10.3923/jbs.2019.396.406

Medina, A. L., Haas, L. I. R., Chaves, F. C., Salvador, M., Zambiazi, R. C., Da Silva, W. P., Rombaldi, C. V. (2011). Araçá (Psidium cattleianum Sabine) fruit extracts with antioxidant and antimicrobial activities and antiproliferative effect on human cancer cells. *Food Chemistry*, *128*(4), 916–922. https://doi.org/10.1016/j.foodchem.2011.03.119

Meinata, A., Na'iem, M., Adriyanti, D. T., & Syahbudin, A. (2021). Leaf architecture of 35 species of dipterocarpaceae cultivated in forest area with special purposes in carita, banten, indonesia. *Biodiversitas*, *22*(7), 2952–2960. https://doi.org/10.13057/biodiv/d220748

Mohamed, A., Abd Allah, S., Hamed, karima, & Hosney, N. (2023). Taxonomic treatment of Myrtaceae based on leaf morphology, architecture, foliar oil glands and molecular characteristics. *Taeckholmia*, *43*(1), 88–119. https://doi.org/10.21608/taec.2023.212293.1050

Montojo, J. X. (2020). Pittsburg State University Digital Commons A Survey Of Leaf Venation In New Caledonian Syzygium (Myrtaceae). *Thesis.* Pittburg State University

Mukaromah, A. S. (2020). Wax Apple (Syzygium samarangense (Blume) Merr. & L.M. Perry): A Comprehensive Review in Phytochemical and Physiological Perspectives. *Al-Hayat: Journal of Biology and Applied Biology*, *3*(1), 40. https://doi.org/10.21580/ah.v3i1.6070

Octariyanti, D. A. P., Yulianty, Y., Lande, M. L., & Suratman, S. (2022). Potential Exploration and The Morphology of Zingiberaceae Leaves as Medicinal Plants in Bandar Lampung. *Biosfer: Jurnal Tadris Biologi*, *13*(1), 109–115. https://doi.org/10.24042/biosfer.v13i1.10587

Oliveira, E. F., Bezerra, D. G., Santos, M. L., Rezende, M. H., & Paula, J. A. M. (2017). Leaf morphology and venation of psidium species from the Brazilian savanna. *Revista Brasileira de Farmacognosia*, *27*(4), 407–413. https://doi.org/10.1016/j.bjp.2017.03.005

Patel, S. (2012). Exotic tropical plant Psidium cattleianum: A review on prospects and threats. *Reviews in Environmental Science and Biotechnology*, *11*(3), 243–248. https://doi.org/10.1007/s11157-012-9269-8

Riaz, S., & Abid, R. (2021). Foliar characteristics as an aid for the specific delimitation of the genus cleome l. (cleomaceae) from pakistan. *Pakistan Journal of Botany*, *53*(4), 1325–1330. https://doi.org/10.30848/PJB2021-4(17)

Ribeiro, A. R. C., da Silva Cordeiro, M. L., Silva, L. M. P., Cadavid, C. O. M., de Oliveira Caland, R. B., Fernandes-Negreiros, M. M., &Scortecci, K. C. (2019). Myrciaria tenella (DC.) O. Berg (myrtaceae) leaves as a source of antioxidant compounds. *Antioxidants*, *8*(8), 1–14. https://doi.org/10.3390/antiox8080310

Romalasari, A., Susanto, S., Melati, M., & Junaedi, A. (2017). Perbaikan Kualitas Buah Jambu Biji (Psidium guajava L.) Kultivar Kristal dengan Berbagai Warna dan Bahan Pemberongsong. *Jurnal Hortikultura Indonesia*, *8*(3), 155. https://doi.org/10.29244/jhi.8.3.155-161

Sani, D. P., Handayani, T. T., Zulkifli, Z., & Lande, M. L. (2020). The Allelopathic Effects Characteristics of Fresh Jatropha (Jatropha curcas L.) Leaves Extract on the Germination and Growth of Bok Choy (Brassica rapa L.) Sprouts. *Biosfer: Jurnal Tadris Biologi*, *11*(1), 26–34. https://doi.org/10.24042/biosfer.v1i1.4205

Saputri, D. A., Kamelia, M., Almayra, S., & Fatayati, S. (2019). Perubahan Anatomi Dan Morfologi Daun Kedelai (Glysin Max L. (Merril), Dan Alang-Alang (Imperata cylindrica L.) Yang Tumbuh Di Tempat Terbuka Dan Ternaungi. *Bioedukasi (Jurnal Pendidikan Biologi)*, *10*(1), 75. https://doi.org/10.24127/bioedukasi.v10i1.2012

Saputri, D. A., Ulmillah, A., Winandari, O. P., & Nova, L. M. (2022). Peningkatan Pertumbuhan dan Perkembangan Cabai Merah (Capsicum annuim L) Melalui Sambung Pucuk (Grafting) Dengan Cabai Rawit (Capsicum frutescens L). *Klorofil*, *6*(2), 46–53.

Seixas, F. de C., Monteiro, S. H. N., Silva, L. B. da, & Leite, K. R. B. (2012). Leaf Anatomy of Castro (Orchidaceae) as an Approach to Taxonomy of Species Occurring in Biomes Cerrado and Atlantic Forest of the Bahia. *American Journal of Plant Sciences*, *03*(12), 1752–1758. https://doi.org/10.4236/ajps.2012.312214

Soh, W. K., & Parnell, J. (2011). Comparative leaf anatomy and phylogeny of Syzygium Gaertn. *Plant Systematics and Evolution*, *297*(1–2), 1–32. https://doi.org/10.1007/s00606-011-0495-2

Sosnovsky, Y., Nachychko, V., Prokopiv, A., & Honcharenko, V. (2017). Leaf architecture in Rhododendron subsection Rhododendron (Ericaceae) from the Alps and Carpathian Mountains: Taxonomic and evolutionary implications. *Flora: Morphology,* *Distribution, Functional Ecology of Plants*, *230*, 26–38. https://doi.org/10.1016/j.flora.2017.03.003

Talwara, S., Grout, B. W. W., & Toldam-Andersen, T. B. (2013). Modification of leaf morphology and anatomy as a consequence of columnar architecture in domestic apple (Malus×domestica Borkh.) trees. *Scientia Horticulturae*, *164*, 310–315. https://doi.org/10.1016/j.scienta.2013.08.025

Viacrucis, J. D. L., & Buot, I. E. (2021). Short communication: Leaf architectural analysis of confusing syzygium species: Syzygium aqueum (burm.f.) alston and syzygium samarangense (blume) merr. & l.m.perry (myrtaceae). *Biodiversitas*, *22*(6), 3341–3348. https://doi.org/10.13057/biodiv/d220640

Vieira, F. C. S. (2020). A new species of Myrceugenia (Myrtaceae) from Southern Brazil. *Phytotaxa*, *435*(2), 208–212. https://doi.org/10.11646/phytotaxa.435.2.8

Widodo, P. (2011). Plant Sociology and Ecology. *Reinwardtia*, *13*(3), 235–240.

Wilson, P. G., O'Brien, M. M., Gadek, P. A., & Quinn, C. J. (2001). Myrtaceae revisited: A reassessment of infrafamilial groups. *American Journal of Botany*, *88*(11), 2013–2025. https://doi.org/10.2307/3558428

Zulkarnain, Rukmana, R., Hasyimuddin, Masriany, Wahidah, B. F., Nurman, & Alir, R. F. (2019). Karakteristik Morfologi Daun di Kawasan Hutan Bulu' Ballea, Tinggi Moncong Kabupaten Gowa sebagai Referensi dalam Pembelajaran Morfologi Tumbuhan. *Prosiding Seminar Nasional Biodiversitas Indonesia*, 48–53.