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Morphology study, leaf anatomy and growth of the Indonesian *Scindapsus*

S.A. Ardiningtyas[1], D.D. Matra[1], R. Poerwanto[1], Krisantini[1] and N.P.S. Asih[2]

*[1]Department of Agronomy and Horticulture, IPB University, Bogor, Indonesia. [2]Research Center for Biosystematics and Evolution, National Research and Innovation Agency (BRIN), Indonesia. *E-mail: krisantini@apps.ipb.ac.id*

Abstract

Scindapsus (Araceae) is commonly found growing wild in Indonesian forests, including West Borneo. *Scindapsus* has been extensively cultivated and marketed, but information about the variability, morphology and growth of the plant is limited. This study aimed to identify five types of Indonesian *Scindapsus* based on their morphology, leaf anatomy, and growth patterns. The morphology study observed the plant's organ structures, including leaves, stems, and roots. The anatomy study examined the tissue structure of the leaf lamina, including epidermal cells and stomata. The growth observations were conducted by propagating the plants through stem cuttings. The research findings showed that, based on their morphology, the five types of *Scindapsus* in this study could be classified into two groups: *Scindapsus pictus* and *Scindapsus treubii.* The differences between the two groups were in the shape and pattern of their leaves. Based on leaf anatomy, structure, shape of the epidermal cells, and stomata types were the same for all five species, but *Scindapsus treubii* 2 has the thickest lamina.

Key word: *Scindapsus pictus, Scindapsus treubii,* West Borneo

Introduction

The Araceae family encompasses numerous food and ornamental plants. With 144 genera and 3,676 species documented (Boyce and Croat, 2012), it is a diverse botanical group. Indonesia, specifically, is home to 44 genera of Araceae. (Asih *et al.*, 2015; Boyce and Wong, 2015; Low *et al.*, 2018; Joling and Wong, 2022). Limited research on Araceae in Indonesia made it difficult to determine the number of species. Most Southeast Asian herbaceous and mesophytic plants are poorly recorded, according to Kurniawan *et al.* (2011).

Scindapsus is one of the genera in the Araceae family, characterized by its climbing habit and woody stems (Saibeh, 2010). The natural distribution of *Scindapsus* is in tropical Asia, ranging from northeastern India to New Guinea and eastern Australia (Boyce and Wong, 2015). The species of *Scindapsus* had attracted attention due to the diverse leaf colors, leaf shapes, and unique patterns, making it a potential candidate for wider development as a commercial ornamental leaf plant. Some species of *Scindapsus* had been utilized for medicinal purposes*, e.g.,* stem extract of *S. pictus* Hassk. was found to contain triterpenoid compounds (Amaliah *et al.,* 2020) that had been proven to have anticancer and anti-inflammatory (Vil *et al.,* 2019). The studies on the inventory had been conducted on several species of *Scindapsus* found in different regions of Indonesia. For example, *Scindapsus* sp. had been discovered in the forests of West Borneo (Widiyanti *et al.,* 2017), *Scindapsus* spp. and *Scindapsus pictus* had been documented in the Kayan Mentarang National Park, SPTN I Long Bawan (Lestari *et al.*, 2017), *Scindapsus sumatranus* (Boyce and Hay, 2000), *Scindapsus hederaceus* in Bali (Erlinawati *et al.,* 2019), and *Scindapsus lucens,* which was possibly found in Sumatra (Bogner and Boyce, 1994; Othman *et al.,* 2010a).

The exploration of *Scindapsus* morphology and growth characteristics has been limited, resulting in a lack of essential information about this genus. Saibeh (2010) conducted morphological and anatomical studies on 17 herbarium specimens from Malaysia, yet no similar investigations were carried out in Indonesia. Saibeh's work formed a basis, but given *Scindapsus*'s significance in plant species inventory and identification (De Almeida *et al.*, 2023), it is crucial to extend these studies to Indonesia (Zulfahmi, 2013). As the identification and classification of *Scindapsus* remain unstable, additional data on morphological, anatomical and physiological aspects is vital.

Morphological identification relies on recording plant phenotypes, emphasizing traits linked to environmental influences (Zulfahmi, 2013). The study of leaf anatomy is crucial not just for photosynthesis but also for exploring relationships among plant species (Hafiz and Rahayu, 2013).

Our research aimed to investigate visual and cellular morphological characteristics in order to distinguish Scindapsus species found in various regions of Indonesia, with the goal of addressing these existing gaps in knowledge. Growth patterns of diverse *Scindapsus* species in Indonesia are examined in the study. We hope this comprehensive approach will help us identify and classify *Scindapsus* by improving our understanding of its morphology and growth.

Materials and methods

The research was conducted in the screen house of the Leuwikopo experimental station, Department of Agronomy and Horticulture, Faculty of Agriculture, Bogor Agricultural University (IPB) from September 2022 to July 2023. The average temperature at the research site ranged from site ranged 22 to 36 ºC, with relative humidity (RH) between 24 and 65 %. A light intensity of 2568 lux with a photosynthetic photon flux density (PPFD) of 50.79.

The plant materials were five types of Scindapsus from nurseries in West Borneo and Ciapus, Bogor. The species names of the *Scindapsus* were assigned based on morphological characteristics information from the book Araceae (Mansor *et al.*, 2012), Plant Story (https://plantstory.com/), and the Global Biodiversity Information Facility (https://www.gbif.org/). The trade names of the five *Scindapsus* are *Scindapsus pictus* 1, 2 and 3, *Scindapsus treubii* 1, and 2 (Table 1).

Table 1. Five Indonesian *Scindapsus* used for the study.

Scientific names	Trade names	Sources
Scindapsus pictus 1	*Scindapsus* 'Silver Hero'	West Borneo
Scindapsus pictus 2	*Scindapsus* 'Argyraeus'	West Borneo
Scindapsus pictus 3	*Scindapsus* 'Silver Lady'	West Borneo
Scindapsus treubii 1	*Scindapsus* 'Dark Form'	West Borneo
Scindapsus treubii 2	*Scindapsus* 'Sterling Silver', 'Moonlight'	West Java

Scindapsus were planted in 15 cm diameter pots using a planting medium composed of husk charcoal: bamboo cocopeat: and bamboo compost with a volume ratio of 60 : 30: 10. The growing medium had a pH of 6.27 with a carbon (C) content of 37.31% and nitrogen (N) content of 1.27 %. Vegetative propagation of *Scindapsus* was carried out through tip cuttings and stem cuttings using the same medium. Cuttings consisted of 2-3 plant nodes with 1-2 leaves per cutting. Growth observations were conducted to assess the rooting ability of the cuttings, the time required for rooting and adventitious shoot formation, the number of shoots, the number of leaves and plant height, which were measured for 16 weeks.

Morphological observations were qualitatively conducted on the shape, colour, pattern, venation, and surface characteristics of the leaves. Leaf anatomy studies were carried out by thinly sectioning fresh leaves transversely on a glass slide, covering them with a cover glass, and observing them under an Olympus CX23 microscope at a magnification of 100 X. Measurements were taken on the upper and lower epidermis thickness, mesophyll thickness, and overall leaf thickness on two leaves, with measurements taken at three different locations and averaged. Stomata observations were performed on the abaxial epidermis by thinly sectioning the leaf lamina and then placing it on a glass slide. Stomata measurements include stomatal density, stomatal type, stomatal length, and stomatal width. Stomatal density was calculated by dividing the number of stomata by the field of view area of 3.461 mm^2 at a magnification of 100 X. The stomatal density calculation was based on two replicates, and the results were averaged. Stomatal length and width measurements were taken on three randomly selected stomata at a magnification of 400 X.

Result and discussion

Morphological identification: The results of morphological identification in this study for the five species of *Scindapsus* can be viewed in Table 2. The five *Scindapsus* are characterized based on the presence or absence of leaf patterns. *S. pictus* 2 and 3 have leaves with patterns with different distributions and intensities of colours (Figs. 1B and 1C). On the other hand, *S. treubii* Engl. 1, 2, and *S. pictus* 1 have no leaf patterns (Figs. 1D, 1E and 1A). *S. pictus* differed from *S. treubii* in leaf shape; *S. pictus* has oval-shaped leaves with less dense primary leaf patterns (Figs. 1A, 1B and 1C), while *S. treubii* has elongated leaves without patterns and denser primary vein structure (Figs. 1D and 1E). The leaf colours varied significantly among species; the lamina of *S. treubii* has a shiny dark green colour with a smooth leaf surface, whereas *S. pictus* is a light green to white leaf colour because it is dominated by its patterns and a shimmering appearance on the leaf surface. The leaf lamina and petiole shapes observed in this study were consistent with previous findings, which reported heart-shaped, oval, elongated oval, elliptical, and lanceolate leaf forms for *Scindapsus* species (Othman *et al.,* 2010; Saibeh, 2010). The petioles of *Scindapsus* were slender and typically ended in a pulvinate shape (Boyce and Yeng, 2012). The stems of five *Scindapsus* species were cylindrical and untextured.

***Scindapsus pictus* 1:** *S. pictus* sp. 1 is known in the plant market as *S. pictus* 'Silver Hero' (Fig. 1A). Based on morphological

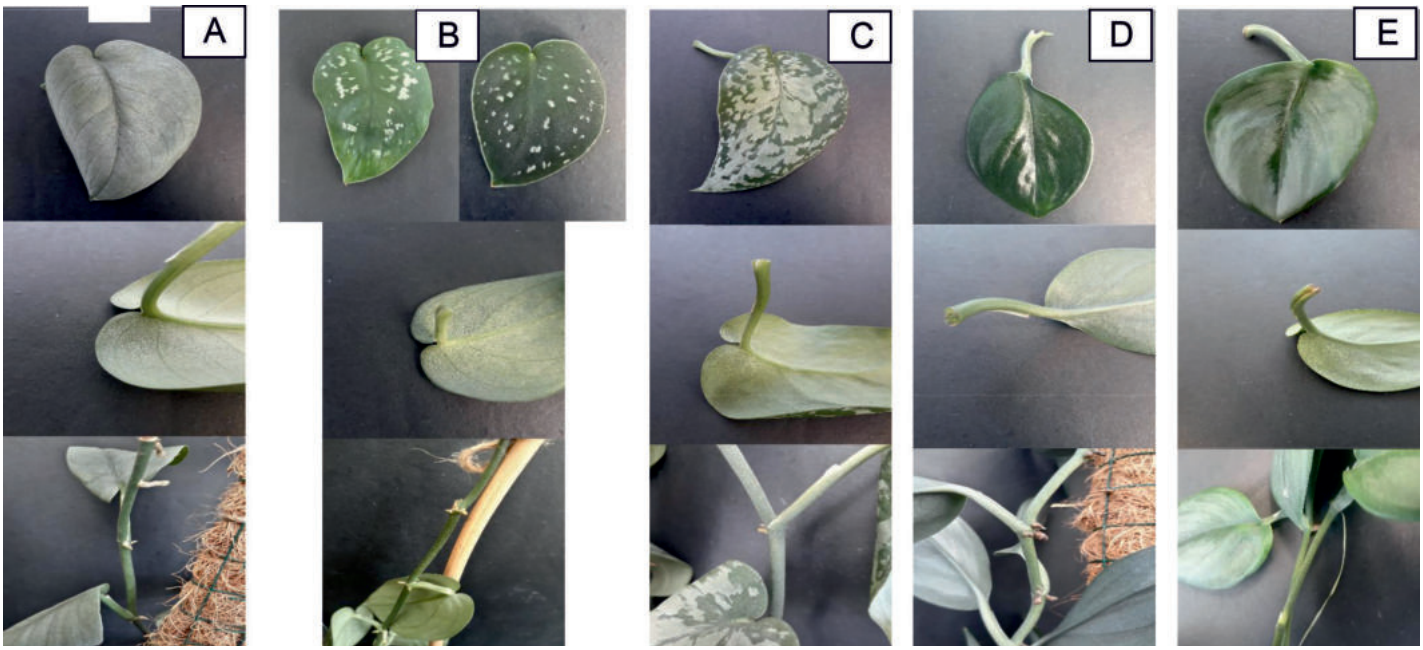

Fig. 1. Morphological variations of lamina, petiole, and steam of (A)*Scindapsus pictus* 1; (B)*Scindapsus pictus 2;* (C)*Scindapsus pictus 3;* (D) *Scindapsus treubii* 1 and (E)*Scindapsus treubii 2*

characteristics, the leaf lamina of this species is light greenish-grey in colour with a slight shimmer and is covered in fine hairs on its surface. The leaf lamina is not patterned and has an ovate shape, with the widest part of the leaf near the base, referred to as the midrib. Both the primary and secondary leaf veins are clearly visible and green in colour. New leaves typically emerge very close to the leaf below. The mature stem forms climbing roots when it reaches a certain age. These climbing roots are light brown, short, and firm, attaching to the support. In this study, the parent plant used for propagation developed up to four branches below the pruned surface and near the ground, resulting in a denser appearance.

***Scindapsus pictus* 2:** *S. pictus* sp. 2 in this study exhibited two different leaf colours, namely green and dark greenish black. The *S. pictus* 2 with the light green colour is known as 'Argyraeus' in the market (Fig. 1B), while the dark greenish-black leaf colour is known as 'Black Exotica' (Fig. 1B). The leaf pattern of *S. pictus* 2 consists of white to greyish patches. The pattern spreads from the inner part of the leaf surface to the edges. The pattern is irregular and non-uniform, not located on the midrib but on the primary and secondary leaf veins (Fig. 1B). There is a white line along the leaf edges (Fig. 1B). One of the *S. pictus* varieties with dark leaf surfaces is commercially known as 'Black Exotica' (Figs. 1B). According to Munawaroh *et al.* (2017) and the Royal Botanic Kew (https://powo.science.kew.org/taxon/urn:lsid:ipni.org: names:88853-1), *S. pictus* sp. 2 is considered synonymous with *S. pictus.*

***Scindapsus pictus* 3:** It is, known commercially as 'Silver Lady', is characterized by its delicate leaflets and slightly dull to moderately shimmering leaf colour. This species has bright green leaves with serrated patterns in white to silver, with most patterns merging into larger areas. The leaves are oval-shaped with visible midribs, primary leaf veins, and secondary leaf veins that are gray to light green in colour. The stems of the *S. pictus* 3 have more white spots compared to other *Scindapsus* varieties (Fig. 1C). The leaf petioles have prominent sheaths when they are still in the juvenile stage, but they become less visible when mature. The leaf petioles and leaf nodes are the longest, measuring 25-65 mm and 30-55 mm, respectively (Table 2). According to Indrajati *et al.* (2022), 'Silver Lady' is also marketed with the name 'Silver Exotica' and still falls within the species group of *S. pictus.*

***Scindapsus treubii* 1:** *S. treubii* sp. 1 exhibits an elliptical to lanceolate leaf shape with a dark green colour. The leaves are glossy, smooth, and not wavy. In the market, it is referred to as *Scindapsus* 'Dark Form' (Fig. 1D). The midrib and primary leaf veins are visible. The leaf petioles have slightly visible sheaths, and the leaf stalks are straight without bending towards the apex. The leaf base has an asymmetrical type known as oblique. The stem nodes are long. The stem is dark green, similar to the leaf colour, without white spots, and has a smooth surface. The leaf blades of *S. treubii* are sub-succulent or thick and do not have any patterns. This is consistent with the report by Othman *et al.* (2010) that *Scindapsus* plants, including some species, are considered sub-succulent. According to Boyce and Yeng (2009), *S. treubii* is a hemi epiphytic commonly found in Borneo. This species is also found in Malaysia, specifically in flat or slope areas and dry forests, climbing to medium-sized trees (Zulhazman *et al.*, 2021).

***Scindapsus treubii* 2:** *S. treubii* sp. 2 has leaves that are significantly different from *S. treubii* sp. 1. In the plant market, *S. treubii* sp. 2 is known as 'Moonlight' or 'Sterling Silver' (Fig. 1E). The leaf colour of *S. treubii* sp. 2 is brighter compared to *S. treubii* sp. 1. The leaves of *S. treubii* sp. 2 have a pearly colour with light green edges and no spreading patterns. They have an oval shape with even tips and balanced leaf bases. The midrib and primary leaf veins have a dark green colour. The stem is light green and smooth, without white spots like other plants. The climbing roots of this variety are different from the *S. treubii* 1; they are smaller and longer in size.

Growth of *Scindapsus* cuttings: The growth and development of *Scindapsus* cuttings from planting to readiness for sale took approximately 4 months, and adventitious roots were primarily initiated from the older nodes.

Scindapsus roots grew from nearly every node, which can be referred to as climbing roots, as exhibited in Fig. 1. According to Mansor *et al.* (2012), these climbing roots serve as anchors and feeders, and the roots emerging from stem nodes can develop into lateral roots. In their natural habitat, *Scindapsus* roots grow along the ground surface, and the roots that do not touch the ground can serve as nutrient gatherers or attachments to support the plant's climbing habit (Boyce *et al.,* 2010). In this study, the climbing roots were twined around supports to provide a place for the plant's roots to attach and support its growth.

The growth of shoots begins with the emergence of buds on the axil. A new axillary shoot grew approximately every two weeks. Newly emerged shoots of *Scindapsus* have the characteristic of initially being covered by leaves. For example, in *Scindapsus*

Table 2. Leaf morphological characteristics of *Scindapsus* species

Species	Petiole length (mm)	Stem diameter (mm)	Intersection length (mm)	Leaf area (mm^2)	Leaf shape	Leaf color	Leaf pattern	Bone leaves	Leaf surface
Scindapsus pictus 1	14-27	2-41	22-45	553-1144	Ovate,Pointed tip, cordate base	Light green/ silver	no patterns	Primary veins curved, secondary and tertiary veins reticulate	Smooth and shiny
Scindapsus pictus 2	10-18	1.2-4.0	13-39	281-449	*Lanceolate,* pointed tip, tapered base	Dark green	Spread, not dense, different sizes	Primary veins curved, secondary and tertiary veins reticulate	Smooth, slightly dull in color
Scindapsus pictus 3	25-65	2.0-2.8	30-55	483-1180	Elongated oval ovate,Pointed tip, cordate base	The pattern dominates light green	Unified pattern	Primary veins curved, secondary and tertiary veins reticulate	Wavy and shiny
Scindapsus treubii Engl. 1	12-17	2.5-5.8	21-38	221-861	ellipses and lancets, ointed tip,oblique base	Dark green	no patterns	Primary veins curved, secondary and tertiary veins reticulate	Smooth and shiny
Scindapsus treubii 2	26-55	2.2-3.3	25-50	806-848	Ovate/ovate, tapered mucronate tip, rounded base	Ash/silver	no patterns	Primary veins curved, secondary and tertiary veins reticulate	Smooth andshiny

pictus 3 the new shoots are covered by partially opened leaves (Fig. 2A). The new shoots of *S. pictus* 1 and *S. pictus* 2 are enveloped by small leaves called cataphylls (Figs. 2B and 2C), while in both types of *S. treubii*, the new shoots are not covered by anything (Figs. 2D and 2E).

The development of leaves from the emergence of buds until they fully opened took approximately 14 days, and all *Scindapsus* had similar growth rates (Table 3). *S. treubii* 2 experienced a decrease in the number of leaves 16 days after emergence (Table 3) due to a whitefly infestation, which caused the leaves to turn yellow and fall off.

***Scindapsus* leaf anatomy:** Anatomical observations of the leaves were examined, indicating that all five *Scindapsus* had similar epidermal shapes (Fig. 4). Observations at 100x magnification revealed that the epidermal cells were square, pentagonal, and hexagonal in shape and were arranged irregularly (Fig. 3).

Table 3. Leaf and node number of Indonesian *Scindapsus* on different days after planting

Species	Leaf number (DAP)				Node number (DAP)			
	4	8	12	16	4	8	12	16
S. pictus 1	2.33	2.67	3.67	5.00	2.33	3.00	4.00	5.00
S. pictus 2	2.50	3.25	4.00	4.50	3.00	3.50	4.25	4.75
S. pictus 3	2.00	2.00	3.33	4.00	2.33	2.33	3.00	4.00
S. treubii 1	1.80	1.80	3.60	5.00	2.00	2.20	3.20	5.00
S. treubii 2	2.00	2.00	3.50	4.50	2.00	2.50	3.50	4.50
	ns	ns	ns	ns	ns	ns	ns	ns

Note: ns = not significant according to the DMRT at α=0.05.

Epidermal cell positioning differed between *S. pictus* and *S. treubii*. *S. pictus* epidermal cells were tightly packed, while S. treubii had spaces between them. 400x magnification showed this difference (Fig. 3).

The five *Scindapsus* had similar stomatal density, size, mesophyll, and epidermal thickness (Table 4). Stomatal density varied with species and was affected by light intensity, water availability, temperature, and CO_2 concentration (Meriko, 2018). Stomatal size and density usually correlate. High-density leaves had smaller stomata, and vice versa, which can affect stomatal function (Drake *et al.*, 2013). Lawson and Blatt (2014) found that water and light affect stomatal size and number. The five *Scindapsus* species have anomocytic stomata (Fig. 4), which has neighboring cells that are similar in shape and size to the epidermal cells.

All the five species of *Scindapsus* had leaf thicknesses > 400 µm. *S. treubii* 1 and 2 had the thickest lamina, followed by *S. treubii* 1 and *S. pictus* 1 and 2 (Table 4). *S. pictus* 1 and 2 had similar leaf thickness. The upper epidermis is a single layer of cells on the upper surface of the leaf, aiding in water conservation and typically forming a glossy coat of wax.

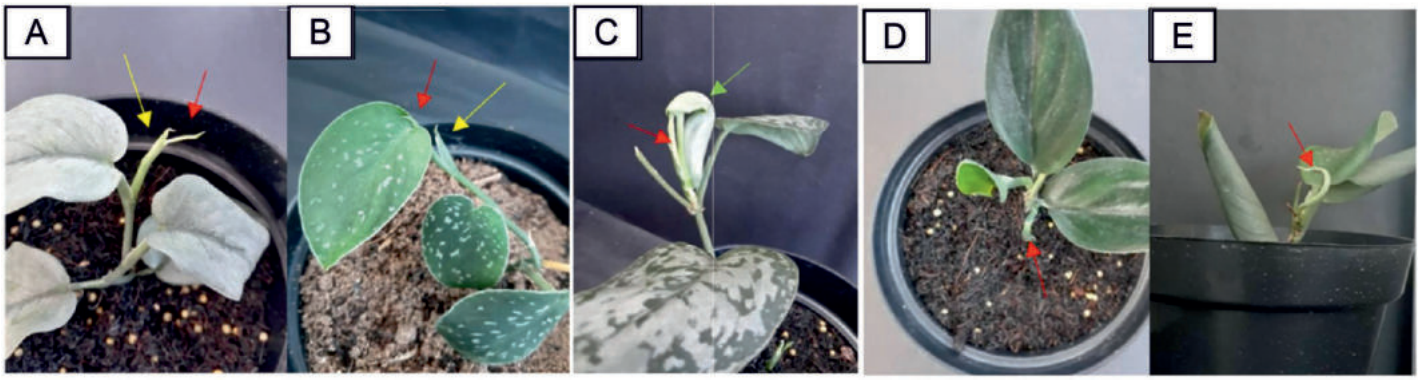

Fig. 2. Variations in the growth of *Scindapsus pictus* shoots: (a) *Scindapsus pictus* 1, (b) *Scindapsus pictus* 2, (c) *Scindapsus pictus* 3, (d) *Scindapsus treubii* 1 and (e) *Scindapsus treubii* 2. (Red arrows indicate new shoots, green arrows indicate partially opened leaves and yellow arrows indicate cataphylls)

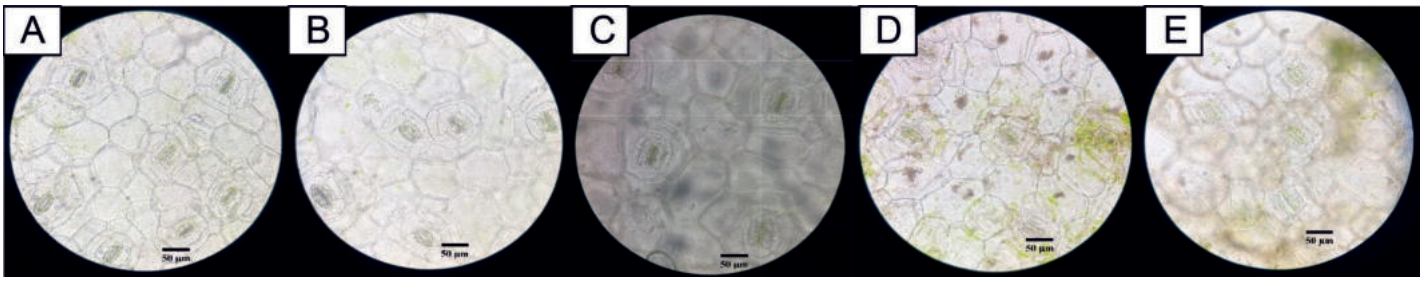

Fig. 3. Epidermal cell shape and stomatal type of the five *Scindapsus* species; A) *S. pictus* 1; B) *S. pictus* 2; C) *S. pictus* 3; D) *S. treubii* 1; E) *S. treubii*

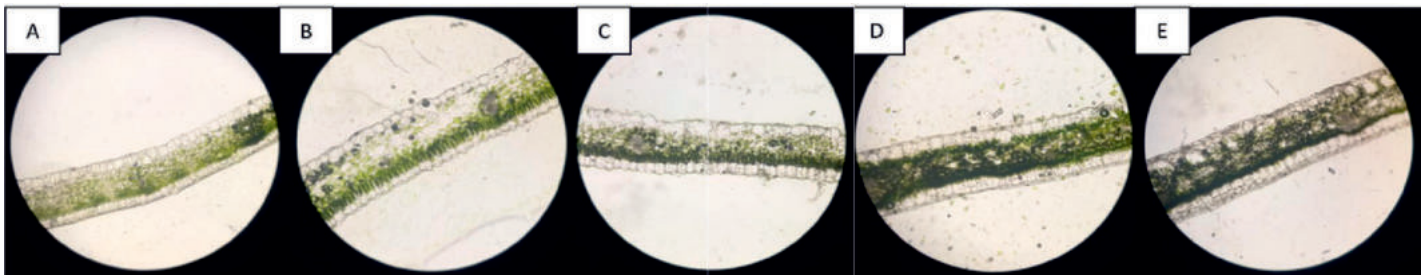

Fig. 4. Leaf cross-section of *Scindapsus* magnification 100 x; A) *S. pictus* 1; B) *S. pictus* 2; C) *S. pictus* 3; D) *S. treubii* 1; E) *S. treubi*i 2. Bar is 100 µm

Table 4. Leaf anatomical characteristics of the Indonesian *Scindapsus*

Species	Stomatal density (per mm^2)	Stomatal length (µm)	Stomatal width (µm)	Mesophyll thickness (µm)	Epidermal thickness (µm)		Leaf thickness (µm)
					Adaxial	Abaxial	
S. pictus 1	24.12	43.23	23.21	245.20	70.11	89.06	422.66 c
S. pictus 2	21.95	45.63	22.74	285.30	87.37	81.83	439.06 c
S. pictus 3	12.57	40.73	19.75	262.56	98.22	93.79	502.12 b
S. treubii 1	13.58	51.01	25.90	265.55	74.72	83.56	536.46 a
S. treubii 2	20.36	49.46	31.25	298.67	116.72	80.43	525.20 a
	ns	ns	ns	ns	ns	ns	*

Note: Values followed by the different letters in the same column were significantly different according to DMRT at 5%. * = significant; ns= not significant

Based on the morphological characteristics of leaves and mature plants, the five species of *Scindapsus* can be distinguished into two groups: *S. pictus* and *S. treubii*. The differences between the two groups were in the shape and pattern of their leaves. All *Scindapsus* had the same type of stomata, which is the anomocytic. *S. treubii* had thicker lamina than *S. pictus.*

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