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Research Article

Study of Morphology and Growth of *Alocasia* spp. from Papua, Indonesia

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ABSTRACT

Alocasia is a genus of perennial, flowering plants from Araceae, native to tropical and subtropical Asia and eastern Australia. The corms of some *Alocasia* species are edible, but many *Alocasia* species are cultivated as ornamentals. Despite the rich biodiversity of *Alocasia*, there have been limited studies on the morphology and anatomy of these genera. Our study aimed to describe the morphology and growth patterns of two *Alocasia* species found in Papua, one of the remote regions in Indonesia, *A. brancifolia* and *A. lauterbachiana*. The existence of *A. lauterbachiana* in Papua has never been reported before. The two *Alocasia* species can be distinguished by their distinct leaf shapes and colors. *Alocasia brancifolia* has pinnatifid leaves, while *A. lauterbachiana* has serrated leaves. The leaf of *A. brancifolia* is thin and predominantly green with faint spots, while the petioles exhibit stripes of brown and green, whereas *A. lauterbachiana* leaves are thicker and have darker green and reddish color. Due to their attractive leaf shape and colors, both species have the potential to be developed as ornamental potted plants. In terms of growth, *A. lauterbachiana* exhibited faster growth than *A. brancifolia*. However, *A. brancifolia* demonstrated a 50% increase in multiplication over the 16-week study period, while *A. lauterbachiana* primarily grew taller and larger. This information could prove valuable for future studies to optimize the growth and cultivation techniques of the two *Alocasia* species for commercial purposes, particularly ornamental foliage plants.

1. Introduction

Papuasia, located in the Southwest Pacific Ocean in the Melanesia Eco-Region of Oceania and tropical Asia, is one of the richest botanical regions defined in the World Geographical Scheme for Recording Plant Distribution (WGSRPD). Papuasia includes New Guinea, the Bismarck Archipelago, and the Solomon Islands (Brummitt 2001). As the second largest island, New Guinea is divided into two countries, namely Papua New Guinea in the east and Indonesia Papua in the west (before called Irian Jaya) (Brummitt 2001; Takeuchi 2003). As of Presidential Regulation No. 24 of 2023, Indonesia Papua is divided into six provinces: Papua Province, West Papua Province, South Papua Province, Central Papua Province, Highlands Papua Province, and Southwest Papua Province. Infrastructure construction and development in Papua have resulted in ecological threats in some areas due to habitat destruction and species extinction. Eleven

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percent of Papua's 1.3 million hectares of forest had been cleared in 2019 (Jong 2021). Currently, there is limited information on biodiversity in the Papua area and West Papua due to the lower collection in this area, and many herbarium specimens are unidentified (Leret *et al*. 2020).

Araceae is one of the largest monocot families, with 150 genera and 4,599 species distributed worldwide and published (Boyce and Croat 2011). Araceae's most common morphological feature is the spathe-and-spadix-shaped flower (Thompson 2020). Plants from the Araceae family are most diverse in terms of morphology, habitat, growth patterns, and phenology; therefore, many species from Araceae have high values as ornamental plants (particularly foliage plants) (Yuzammi 2018; Reda *et al*. 2020; Asih *et al*. 2022; Irsyam *et al*. 2023). The richest regions for Araceae species are tropical and subtropical South Asia, Southeast Asia, and Papuasia (Croat and Ortiz 2020). Hutasuhut (2020) reported the diversity of Araceae in North Sumatra, Indonesia; however, their potential, particularly for economic purposes, has not been fully explored (Yuzammi 2018).

One of the largest genera in the Araceae family is *Alocasia*, which currently consists of 92 described species out of an estimated 141 species worldwide (Boyce and Croat 2011). Out of the total 92 accepted species names of *Alocasia* in the GBIF Backbone Taxonomy (2019), 79 species are reported to originate from tropical and subtropical Asia, ranging from the subtropical eastern Himalayas to India, China, Japan, and across Melanesia, Oceania, eastern Australia to Papua (Hay and Wise 1991; Nauheimer *et al*. 2012). The corms of some *Alocasia* species are edible (Nauheimer *et al*. 2012). Still, many *Alocasia* species are cultivated as ornamentals with high values, e.g., *Alocasia* × *mortfontanensis* André has prominent white veins and dark green leaves, and *Alocasia odora* (G.Lodd.) Spach has large, glossy leaves and sweet-scented flowers.

The genus *Alocasia* is closely related to *Colocasia*, which often leads to confusion between the two genera (Boyce 2008). In Papua, eight species of *Alocasia* are reported, namely *Alocasia aequilobia*. N.E. Brown *Alocasia brancifolia* (Schott) A. Hay, *Alocasia lancifolia* Engl., *Alocasia macrorrhizos* (L.) G.Don, *Alocasia monticola* A. Hay, *Alocasia nicolsonii* A. Hay, *Alocasia pyrospatha* A. Hay and *Alocasia wentii* Engl. & K. Krause (Hay and Wise 1991; Hay 1998). However, there has yet to be a revision of this genus in Papua.

Despite the high biodiversity of *Alocasia* worldwide, limited studies on this genus have been reported, e.g., *A. mycorrhizas* (Garcia *et al*. 2008) and *Alocasia alba* (Asih *et al*. 2022). These studies observed genetic variation based on morphological character and reported that morphological variations in the two species could be found in other *Alocasia* species. Exploration of new species in remote areas is generally challenging, including in Indonesia; some species are yet to be found and named.

Variations in the leaves are one of the desired traits for developing potential ornamental foliage, such as potted plants and cut foliage (Henny and Chen 2003). *Alocasia brancifolia* and *A. lauterbachiana* have the potential to be further developed into commercial foliage plants. Morphological characteristics are a valuable indicator for assessing genetic variation, which is required for taxonomy, breeding, formulating conservation strategies, and managing and sustainably utilizing genetic resources (Henny and Chen 2003). Leaf anatomical traits are additionally beneficial for species identification, systematic analysis, and resolving taxonomic issues (Farr *et al*. 2024).

Our exploration in Papua and West Papua regions conducted in 2018-2019 and early 2024 reported the findings of several *Alocasia* species in these two provinces. This study aimed to describe the morphology and growth of two *Alocasia* species found in Papua, Indonesia, *A. brancifolia* and *A. lauterbachiana*. The leaf greenness value, pigment content, and specific leaf weight were determined to supplement the morphological information of the two Papua *Alocasia*. Information on morphological characters is important for future systematic molecular studies, whereas information on plant growth and multiplication is required to commercialize *Alocasia brancifolia* and *A. lauterbachiana* as foliage plants.

2. Materials and Methods

Alocasia brancifolia and *A. lauterbachiana* plants for the experiment were grown at The Papua Nature Education Nursery in Arso 2, Keerom Regency, Papua Province. Each plant consists of two leaves planted on 5-L pots containing a mix of topsoil and manures (1:1 by volume) and maintained under a 50% shade house. The temperature in Keerom ranges from 22 to 33 °C with

relative humidity > 80%. The average yearly rainfall is 2200 mm, with 8 to 18 rainy days per month.

2.1. Morphology

The morphology was described quantitatively and quantitatively. Qualitative leaf morphology was described based on leaf type, lobing, margin, leaf margin types, apex, base, phyllotaxy, leaf color (adaxial and abaxial), leaf and petiole patterns as described in Hay and Wise (1991) and Schmid *et al*. (2002). Adaxial and abaxial leaf color was recorded using the Royal Society of Horticulture (RHS) color chart and supplemented with color information from UPOV (2008). The number of leaves and basal shoots per plant was measured on ten plants for each species. Quantitative measurement was conducted on a fully expanding leaf plant from five plants per species. Leaf length, leaf width, leaf-specific weight, leaf greenness values, leaf chlorophyll a, chlorophyll b, and carotene content were determined. Plant height and leaf traits were measured once at 12 weeks after planting. Leaf size was determined by measuring each plant's most extended and the widest mature, fully expanding leaf. Specific leaf weight is the weight per unit area when the plants are in the state of field capacity, i.e., the plants were watered until the excess water drained from the drainage holes. Specific leaf weight was measured in triplicates. Leaf greenness value was measured using an AtLeaf® handheld Chlorophyll meter (LT Green, USA) on a mature leaf of 12-week-old plants.

Leaf pigment content was measured using the method of Costache *et al*. (2012). Leaf samples were cut into fine pieces of about 25mm^2 following extraction using 100% acetone. Solutions were stored for 48 h in a - 20 ºC fridge until the leaves turned white, which indicates that the pigments had been fully dissolved. The analytical determination was performed with a spectrophotometer Genesys 10s UV-Vis at the 662 and 645 wavelengths for chlorophyll a and b and 470 nm for carotene and quantified according to Costache *et al*. (2012)

2.2. Growth Measurement

The number of leaves and basal shoots was measured weekly for 16 weeks. The propagation rate was calculated based on the number of new shoots formed after 16 weeks. Each species consists of 10 individual plants.

3. Results

The descriptions of *Alocasia brancifolia* and *A. lauterbachiana* are in Table 1. Variations were recorded in *Alocasia brancifolia* petiole pattern color, i.e., brown and green (Figure 1). *A. lauterbachiana* has variations in the leaf color, i.e., green and red-brown (Figure 2).

3.1. Morphological Description of *Alocasia brancifolia* and *Alocasia lauterbachiana*

The plants, leaves, and petioles of *A. brancifolia* are in Figure 1 A-F, whereas those of *A. lauterbachiana* are in Figure 2 A-D. The leaf of *A. brancifolia* is green with slight faded spots (Figures 1A and B). The petioles have stripes with brown color (Figure 1D) and green color (Figure 1E), but they have similar leaf shape and color. Another striking difference between the *Alocasia* species is leaf lobing; *A. brancifolia* leaves are pinnatifid (Figure 1B), whereas *A. lauterbachiana* leaves are serrated (Figure 2C).

Table 1. Description of *Alocasia brancifolia* and *A. lauterbachiana* species found in Papua

Species	Location	Distinc features and morphological variation
Alocasia brancifolia	Kaimerah village, Teluk Etna District, West Papua Province	Leaf lobing is pinnatifid; variations in the color of petiole (brown and green stripes) were recorded
Alocasia lauterbachiana	Suskun village, Keerom District, Papua Province	Leaf lobing is serrate; variations in the color of the leaf (green and dark red) were recorded

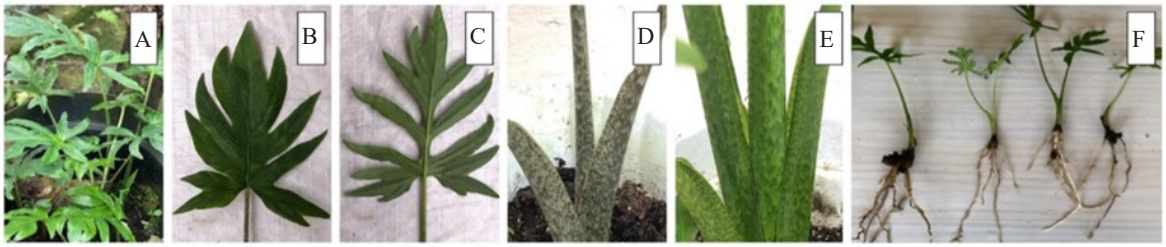

Figure 1. (A) *Alocasia brancifolia* plants, (B) adaxial of a fully expanding leaf, (C) abaxial of a fully expanding leaf, (D) brown patterns and (E) green patterns of the petioles, and (F) the basal shoots

Alocasia lauterbachiana is generally taller and has longer petioles than *A. brancifolia* (Table 3). Leaf chlorophyll and carotene levels in *A. lauterbachiana* leaves were thicker and contained >2x more chlorophyll and carotene than in *A. brancifolia* leaves. The larger leaf-specific weight (31.9 mg/cm^2) in *A. lauterbachiana* indicated a thicker leaf than in *A. brancifolia* (19.5 mg/cm^2, Table 3).

3.2. *Alocasia brancifolia* and *Alocasia lauterbachiana* Growth and Development

Leaf growth of the two *Alocasia* is similar up to week 10; afterward, *A. brancifolia* started having the old leaves dropped, whereas all the *A. lauterbachiana* leaves were intact after 10 weeks and kept growing (Figure 3A). Therefore, it appears that *A. brancifolia* leaves lived shorter than *A. lauterbachiana*. In terms of plant multiplication, 20% (2 out of 10) of *A. brancifolia* plants formed new shoots 12 weeks after planting, whereas *A. lauterbachiana* had none (Figure 3B).

4. Discussion

This study focuses on *A. brancifolia* and A. *lauterbachiana*. *Alocasia brancifolia* was found in Kaimerah village, Teluk Etna District, West Papua Province, whereas *A. lauterbachiana* was found in Suskun village, Keerom District, Papua Province. *A. macrorrhizos* can be found in many other Indonesian islands, and morphological studies and variations in *A. macrorrhizos* have been reported (Garcia *et al*. 2008). To the best of our knowledge, this is the first study reporting the existence of A. lauterbachiana in Papua.

From the limited survey that we conducted, morphological variations in the petiole pattern (brown and green) of *A. brancifolia* and leaf color in *A. lauterbachiana* (dark green in the adaxial and brown in the abaxial) were recorded (Figure 1B and 2C). Plant size, leaf shape, and leaf color are important characteristics of indoor potted plants. Therefore, *A. lauterbachiana,* which has brown adaxial leaves, could

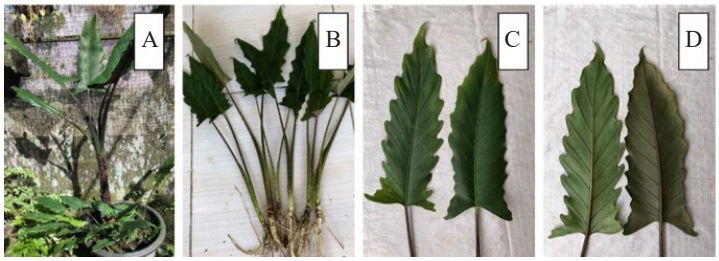

Figure 2. (A) *Alocasia lauterbachiana* plants, (B) the basal shoots, (C) adaxial of a fully expanding leaf of variant 1 and variant 2, (D) abaxial of a fully expanding leaf of variant 1 and variant 2

Table 2. Qualitative leaf morphological features of *Alocasia brancifolia* and *Alocasia lauterbachiana*

Qualitative leaf morphological feature	*Alocasia brancifolia*	*Alocasia lauterbachiana*
Leaf type	Simple	Simple
Leaf lobing	Pinnatifid	Serrated
Leaf margin	Lobed	Lobed
Leaf shape	Sagittate	Narrowly hastate
Leaf apex	Acute	Acute-rounded
Leaf base	Sagittate	Hastate
Phyllotaxy	Basal	Basal
Adaxial leaf color	Green (136B)*	Dark green (131C)*
Abaxial leaf color	Pale green (134D)*	Brown (166A)*
Leaf leaf	Erect - apex up	Erect - apex up
Leaf pattern	Absent	Absent
Petiole pattern	Present	Absent

Table 3. Quantitative morphological features of *Alocasia brancifolia and Alocasia lauterbachiana*

Quantitative morphological feature	*Alocasia brancifolia*	*Alocasia lauterbachiana*
Plant height (cm)	35-60	80-130
Petiole length (cm)	17-30	38-40
Leaf length (cm)	16-27	45-50
Leaf width (cm)	13-25	16
Number of primary leaf vein	10	16
Leaf chlorophyll a (µg/g fresh weight)	53.6	143.3
Leaf chlorophyll b (µg/g fresh weight)	67.1	157.6
Leaf carotene (µg/g fresh weight)	24.2	66.2
Leaf greenness value	62.9	62.6
Specific leaf weight (mg/cm^2)	19.5	31.9

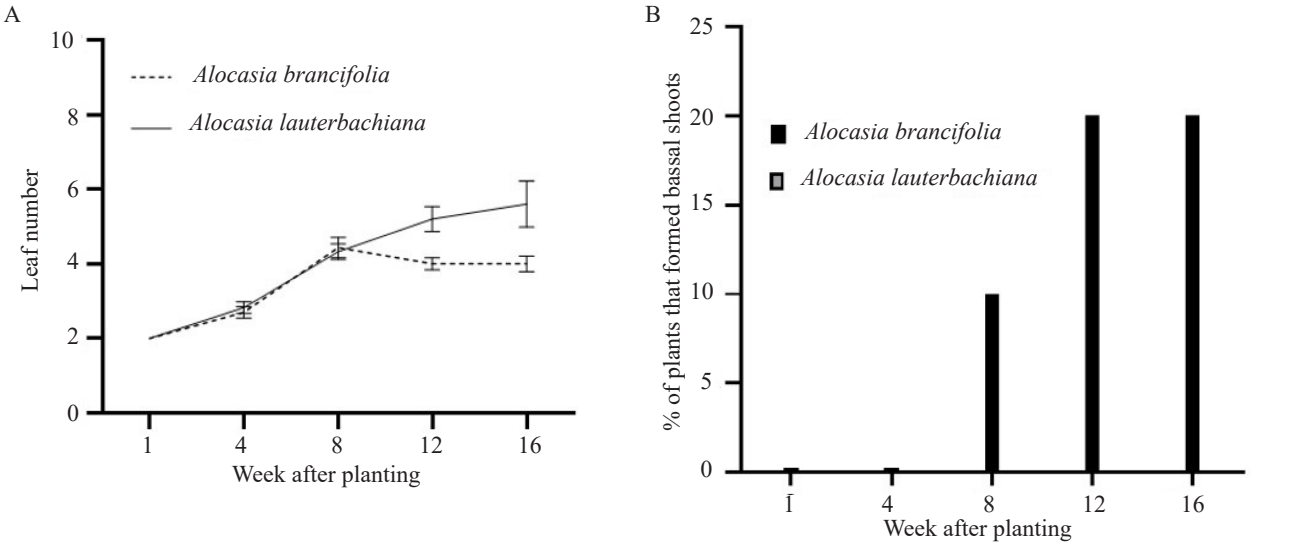

Figure 3. (A) Leaf number and (B) percentage of plants that formed basal shoot growth of *Alocasia brancifolia* and *Alocasia lauterbachiana* at weeks 1-16 after planting

be attractive as an indoor plant. The long petioles of *A. lauterbachiana* (38-40 cm, Table 3) also make them a potential cut foliage for floral arrangements. Leaves of attractive color, long-lasting, and petioles of >30 cm could potentially be marketed as cut foliage in floral decorations. Thick leaves are potentially long-lasting than thinner leaves; however, this character was not included in this study.

The leaf chlorophyll content is one of the indicators of the leaf's physiological condition as affected by various biotic and abiotic factors. In terms of leaf greenness that was measured by the Atleaf®, the values of the two species showed only slight differences (62.9 and 62.6, respectively, Table 3). However, when the quantity of chlorophyll a and b and carotene's level were measured by spectrophotometer, the values were quite different; *A. lauterbachiana* leaves contained chlorophyll and carotene 2.5 times higher than those of *A. brancifolia* (Figure 2). It is possible that the Atleaf device, which measured greenness based on light transmission, is not sensitive enough to detect the different shades of green. Carotenes also have an essential role in photosynthesis; they absorb the blue-green region of the solar spectrum and transfer the energy to chlorophylls, hence driving photosynthesis (Hashimoto *et al*. 2016).

Leaf growth of the two *Alocasia* is initially similar up to week 10; however, *A. brancifolia* started having the old leaves drop, whereas all the *A. lauterbachiana* leaves were intact after growing (Figure 3A). Leaf longevity is an essential feature for plants used for indoor decoration and cut foliage in flower decorations. In terms of multiplication, 20% (2 out of 10) of *A. brancifolia* plants formed new shoots 12 weeks after planting, whereas *A. lauterbachiana* had none (Figure 3b). After 16 weeks, five new shoots were produced, which means that the parent plants (originally 10) have multiplied into 15 (50%) in four months. Therefore, in terms of multiplication, *A. brancifolia* can be propagated earlier than *A. lauterbachiana* as the basal shoots are a complete individual new plant, whereas A. *lauterbachiana* can only be propagated by cuttings 16 weeks after planting.

In terms of generative growth, none of the plants of the two *Alocasia* species formed flowers during this study. However, the three-year-old mother plants flowered for the first time in March 2024, whereas none of *A. brancifolia* flowered.

In conclusion, Our study described the distinct morphology and growth rate of the two *Alocasia* species found in Papua, Indonesia, *Alocasia brancifolia* and *Alocasia lauterbachiana*. The two *Alocasia* species can be easily differentiated by their distinct leaf shapes and colors. *Alocasia lauterbachiana* grew faster than *A. brancifolia*, but *A. brancifolia* had multiplied by 50% during the 16 weeks of study, whereas *A. lauterbachiana* only grew taller and larger. This information would be useful for further studies on optimizing the growth and culture of the two *Alocasia* species for commercialization as foliage plants.

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