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Morphology of *porang* (*Amorphophallus muelleri*) in the Citarum Watershed, West Java, Indonesia

ASEP ZAINAL MUTAQIN♥, MARZHAVIRA AZLIKA KHRISNAN, JOKO KUSMORO, JOHAN ISKANDAR, RULY BUDIONO, MADIHAH, MOHAMAD NURZAMAN, TIA SETIAWATI, RUSDI
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran. Jl. Raya Bandung-Sumedang Km 21, Sumedang 45363, West Java, Indonesia. Tel./fax.: +62-22-7796412, ♥email: asep.zainal.mutaqin@unpad.ac.id

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Abstract. *Mutaqin AZ, Khrisnan MA, Kusmoro J, Iskandar J, Budiono R, Madihah, Nurzaman M, Setiawati T, Rusdi. 2024. Morphology of porang (*Amorphophallus muelleri*) in the Citarum Watershed, West Java, Indonesia. Biodiversitas 25: 2656-2662.* The *porang* plant (*Amorphophallus muelleri* Blume) is a plant from the Araceae family that grows widely in various regions in Indonesia, including West Java Province, Indonesia. The *porang* plant contains various compounds, especially glucomannan, which can be used as food, cosmetics, medicines, etc., making it a prospective agricultural commodity widely cultivated by farmers. Like other plants, the characteristics of the *porang* plant are dependent on the environmental growing conditions. This research aims to determine the morphological characteristics of *porang* plants in several locations under various growing environments in the Citarum watershed, West Java Province. This research makes use of qualitative and quantitative approaches. The sampling technique was exploratory, with observation and interviews as additional data sources. Exploration was carried out to find the growing *porang* locations. Observations were carried out to observe or record the morphological characteristics and growing environment of *porang*. Interviews were conducted with competent community groups regarding the *porang* plant, such as farmers, to enrich information, especially regarding morphology and the growing environment. The research shows that *porang* are found in several locations, including the Citarum watershed. Unfortunately, this research observed intensively *porang* grown in Soreang Sub-district, Bandung District; Cipatat Sub-district, West Bandung District; and East Cikalong Sub-district, West Bandung District. Furthermore, specific observations of *porang* showed morphological differences in different growing environments in several locations, such as differences in light intensity, temperature, and soil pH.

Keywords: *Amorphophallus muelleri*, Citarum Watershed, morphology, *porang*

INTRODUCTION

Morphology is the study of the form and structure of organisms, especially their external form (Hine 2019). Another definition informs that morphology is concerned with the study of the form and structure of organisms and their specific structural features, which includes the analysis of both external and internal structures and explores the relationships between structure and function in living organisms (Campbell and Reece 2020). In addition, plant morphology studies the structure of plants, which includes the study of the morphological diversity of plants in nature, structural laws, interactions of organs and organ systems, changes in the general structure of plants, and the development of individual organs, and plant organ formation evolutionary development worldwide. In biology, studying plant morphology is important to distinguish the structure of one plant from another (Maftuna et al. 2020). Furthermore, plant morphology serves as a key to biomimetic applications, which are applications that mimic natural processes or structures to solve human problems. This study is based on a combination of knowledge of morphology, anatomy, and plant mechanics; therefore, the form-structure-function relationship can be studied (Speck and Speck 2021). Morphological descriptions are critical to understanding biological systems because the appearance of a structure often determines its function. Morphological analysis is important for understanding how an entire community responds, functions, and interacts in a particular environment (Balduzzi et al. 2017).

Indonesia is located on the equator and has approximately 17,000 islands. Hence, this situation allows various organisms to live, grow, and develop very well, which makes Indonesia rich in biodiversity. Indonesia's biological richness combines the biological richness of Asia and Australia (Darajati et al. 2016). Every region in Indonesia has its biodiversity, including plants, with their characteristics and habitats. Biodiversity includes genetic, species, and ecosystem diversity (Verma 2016). Specifically, genetic diversity occurs due to two factors: adapting living creatures to their environment and mating (Esquinas-Alcázar 2005). Genetic diversity between individuals reflects the presence of different alleles in the gene pool, giving rise to differences in genotypes in the population. Genetic diversity is very important at the individual and population levels. All phenotypic plasticity depends on the genetic variability of any organism, which also helps it adapt and evolve under different environmental pressures (Mukhopadhyay and Bhattacharjee 2016). Plants will respond to the conditions of their growing environment as a form of biological adaptation, which may lead to evolution. Organisms will change themselves at the morphological, physiological, behavioral, and molecular levels to survive the changing environment (Luo and Zhang 2014). For example, plants respond differently to adapting and surviving in drought conditions, such as morphological, biochemical, physiological, and molecular mechanisms, through drought escape, avoidance, and drought tolerance strategies (Abobatta 2019).

Amorphophallus is a group of plants widely distributed in Indonesia with various species and growing environments. Those species found in this country include *A. paeoniifolius*, *A. muelleri*, and *A. variabilis* (Asih et al. 2015; Yuzammi et al. 2017). Mutaqin et al. (2022) concluded that *A. paeoniifolius* is a species of *Amorphophallus* genus with a wide habitat spectrum. Mutaqin et al. (2021) stated that *A. paeoniifolius* has different morphological characteristics from other species of the *Amorphophallus* and is found in locations with diverse climatic and edaphic conditions. *A. muelleri*, which has the local name *porang*, is a widely cultivated species, especially in Central Java Province, Indonesia (Wahidah et al. 2021a). This species also has certain morphological characteristics influenced by environmental factors such as light intensity (Nugrahaeni et al. 2021). Aditionally, *A. muelleri* is found in several locations with different soil pH conditions and altitudes (Lizawati et al. 2023).

Amorphophallus muelleri is widely used for various purposes, including food, cosmetics, medicines, and industrial raw materials (Endang et al. 2022). This use is related to the tuber's composition, which includes protein, fat, crude fiber, glucomannan, and starch (Nur'aini et al. 2020; Nurlela et al. (2022). Meanwhile, Pulungan et al. (2022) stated that *A. muelleri* leaves contain alkaloids, flavonoids, tannins, saponins, and steroids. Aditionally, Putri et al. (2022) stated that *A. muelleri* bulbil contains carbohydrates, proteins, antioxidants, saponin, and polyphenols.

Based on the above, a study of the morphology of *A. muelleri* is important, considering that this species grows widely in various environmental conditions, resulting in more specific variations. Variations in other characteristics, such as metabolite or phytochemical content, may also occur.

MATERIALS AND METHODS

Study area

This research was conducted from October 2022 to November 2023. Data collection and field observations were carried out in Sukajadi Village, Soreang Sub-district, Bandung District, Cipatat Sub-district, West Bandung District, Indonesia and Sumur Bandung Village, East Cikalong Sub-district, West Bandung District, Indonesia (Figure 1). In addition, observations were made at the Biosystematics and Molecular Laboratory of the Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran.

Data collection procedures

This research was conducted through several stages: surveys, morphological observations, habitat conditions in certain locations, and morphological observations in the laboratory. The survey was carried out exploratively in the Citarum watershed area to observe the existing or actual conditions of the *A. muelleri* to be studied. Field observations were carried out in purposively determined locations with certain considerations, such as the presence of studied objects (*A. muelleri*). There were 10 samples observed at each location. Observations were also conducted in the laboratory for several morphological aspects requiring certain tools. The morphological parameters observed were leaf morphology (shape, size, surface texture, leaf blade margin, shape, diameter/circumference, color, petiole surface properties), tubers (diameter and weight), and bulbils (diameter and weight). In addition, environmental conditions for *porang* (*A. muelleri*) growth were also observed using certain tools, such as air temperature, air humidity, location altitude, soil pH, type of soil, and light intensity.

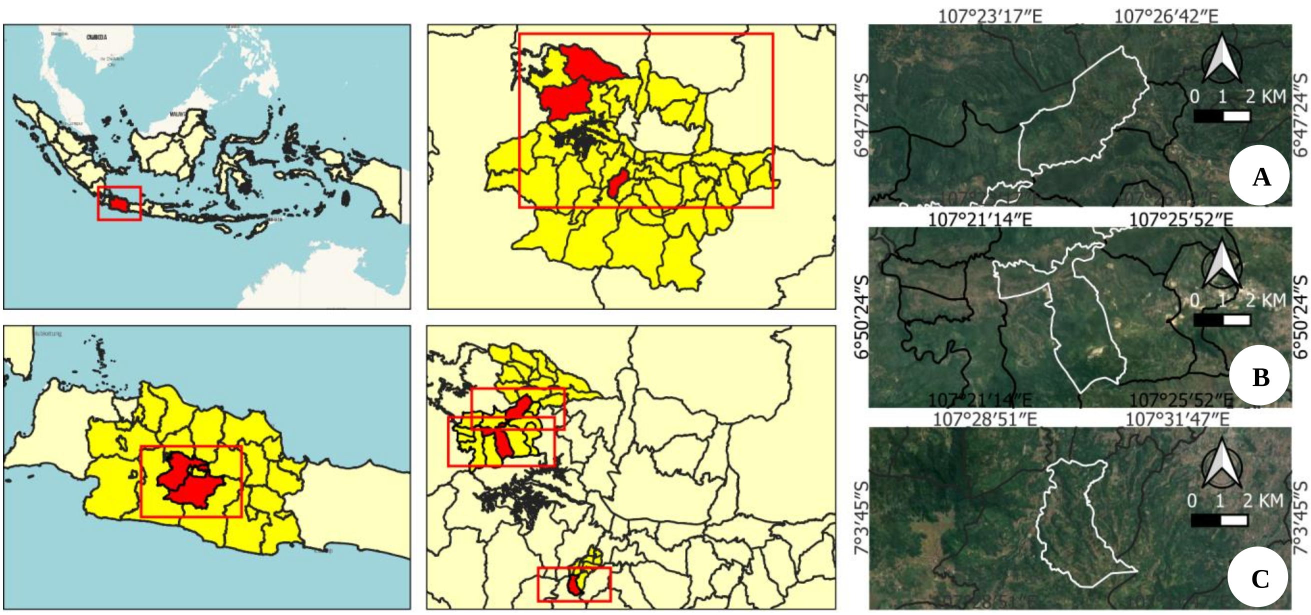

Figure 1. Research locations. A. Sukajadi Village, Soreang Sub-district, Bandung District; B. Cipatat Sub-district, West Bandung District; C. Sumur Bandung Village, East Cikalong Sub-district, West Bandung District, Indonesia

Data analysis

Morphological data were analyzed concerning the terminology developed by Harris and Harris (1994), Mayo et al. (1997), Bendre and Kumar (2009), and Boyce et al. (2010). Furthermore, the existing morphological data is compiled by *porang* plant descriptions from different locations, arranged in a table based on the characteristics obtained from general to specific properties, from bottom to top, and from outside to inside. Environmental parameter data was analyzed descriptively to evaluate the growing environmental conditions of *A. muelleri*, then compared to other studies' findings based on scientific literature searches.

RESULTS AND DISCUSSION

The observation results show that the morphology and growing environment of *Amorphophallus muelleri* Blume at several research locations have certain characteristics, shown more clearly in Tables 1 and 2 and Figures 2-6. This study's detailed results presented in Table 1 of *A. muelleri* at three different locations (Cipatat, Soreang, and East Cikalong) possess similar morphological characteristics of leaf, tuber, and bulbs with slight distinction morphometrically each other. The leaflets of *A. muelleri* have characteristics such as a dark green color on both the adaxial and abaxial sides, an elliptical shape with a pointed tip, a wrinkled and grooved surface, an oblique base, bifid crenate of leaflet edge, and a pinnate vein pattern. Although these characteristics were mostly similar to previous reports, especially in finger leaf shape patterns, certain characteristics were different in some locations. *A. muelleri* in South Sulawesi has light green/dark green/yellowish-green leaves (Ashan et al. 2023); in East Java, it has bright to dark green leaf color blade (Sulistiyo et al. 2015); in Sukabumi, it has flat, notched, and jagged leaf edge (Firdaus et al. 2022), in Madiun, it has elliptical leaflets with pointed tips, wavy leaf surface, pointed leaf tip, wavy leaf edges, leaf length 52 cm, and leaf width of 8.3 cm (Nugrahaeni et al. 2021). The differences in adaxial and abaxial leaf color of *A. muelleri* are caused by the chlorophyll levels on each side of the leaf tissue surface that is controlled genetically. However, the slightly different color of the same surface of the leaf blade due to different chlorophyll content occurred due to the difference in light intensity the plant received under the plant's shade as its habitat.

Table 1. morphology characteristics of *Amorphophallus muelleri*

Morphology	Sites		
	Cipatat	**Soreang**	**East Cikalong**
Leaflet			
Leaflet color	Adaxial: dark green Abaxial: green	Adaxial: dark green Abaxial: green	Adaxial: dark green Abaxial: green
Leaflet blade	Finger	Finger	Finger
Leaflet blade shape	Ellipse with a pointed end	Ellipse with a pointed end	Ellipse with a pointed end
Leaflet surface	Wrinkled, trenched	Wrinkled, trenched	Wrinkled, trenched
Leaflet tip	Aristate	Aristate	Aristate
Leaflet base	Oblique	Oblique	Oblique
Leaflet edge	Bifid crenate	Bifid crenate	Bifid crenate
Leaflet veins	Pinnipalmate	Pinnipalmate	Pinnipalmate
Leaflet length	23-26	24-32 cm	17-20 cm
Leaflet width	5-9 cm	8-9,5 cm	6-9 cm
Petiole color	Green flecked with light green	Green flecked with light green	Green flecked with light green
Petiole shape	Round, herbaceous	Round, herbaceous	Round, herbaceous
Petiole texture	Slippery	Slippery	Slippery
Petiole length	80-117 cm	90-110 cm	64-90 cm
Petiole circumference	8-20 cm	15-20 cm	10-13 cm
Tuber			
Tuber color	Outer (skin): Reddish dark brown Inner (flesh): Light orange	Outer (skin): Reddish dark brown Inner (flesh): Light orange	Outer (skin): Reddish dark brown Inner (flesh): Light orange
Tuber weight	450-810 g	500-1100 g	190-300 g
Tuber diameter	8-12 cm	8.5-15 cm	7-9 cm
Bulbil			
Bulbil color	Outer (skin): dark brown with a few white spots Inner (flesh): White-like bone	Outer (skin): dark brown with a few white spots Inner (flesh): White-like bone	Outer (skin): dark brown with a few white spots Inner (flesh): White-like bone
Number of bulbils	6-10	6-8	4-6
Bulbil diameter	1.5-4 cm	2-3.5 cm	2.5-4 cm

Table 2. Habitat of characteristics of *Amorphophallus muelleri*

Environmental parameters	Sites		
	Cipatat	**Soreang**	**East Cikalong**
Air temperature	19-29°C	20-35°C	18-29°C
Altitude	435 masl	985 masl	661 masl
Light intensity	70%	70%	40%
Soil pH	6.1	6.3	6.8
Type of soil	Humus	Sandy loam	Loam

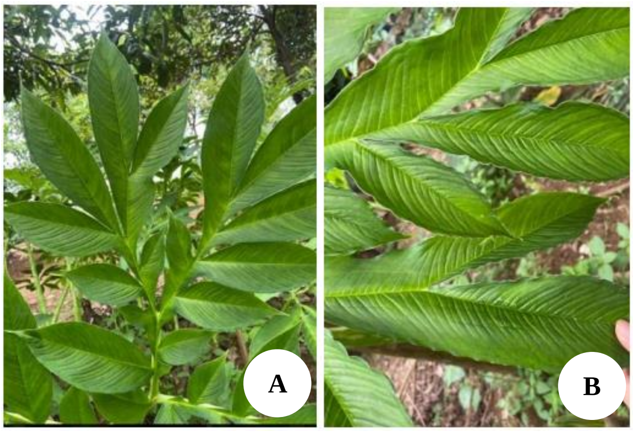

Figure 2. A. Leaflet shape; B. Leaflet color of *Amorphophallus muelleri*

Figure 3. Morphology of the petiole of *Amorphophallus muelleri*

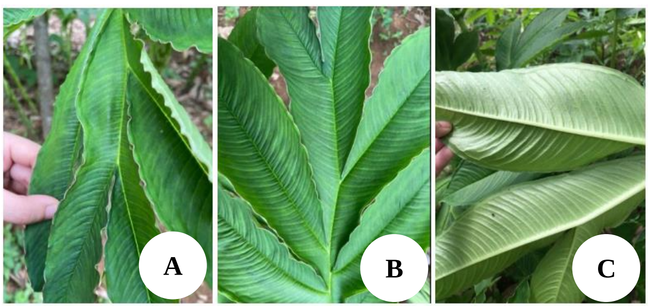

Figure 4. A. Edge color; D. Leaflet texture; C. Back color of *Amorphophallus muelleri*

The study revealed that morphometrical leaflet length and width differences were recorded among *A. muelleri's* three sites due to different ecological factors. The leaflet length of *A. muelleri* at Soreang (24-32 cm) was higher than at Cipatat (23-26 cm) or East Cikalong (17-20 cm), a similar case to the leaf width. The leaflet width of *A. muelleri* at Soreang (8-9.5 cm) was slightly wider than that located both at Cipatat (5-9 cm) and East Cikalong (6-9 cm). These leaflet length and width differences correlate with ecological factor differences among those sites. Warmer temperatures at Soreang (20-35°C) compared to Cipatat (19-29°C) and East Cikalong (18-29°C) are more suitable for *A. muelleri* growth, supported by its leaflet morphology size. In addition, higher latitude at Soreang (985 masl) than either Cipatat (435 masl) or East Cikalong (661 masl), along with sufficient light intensity (70%), soil pH (6.3), and sandy loam soil play an important role in optimum growth of *A. muelleri* at Soreang. At East Cikalong, the light intensity was low (40%); this condition contributed to the plants' lower photosynthesis activity, causing relatively smaller leaflet length and width. The leaflet width parameter of *A. muelleri* in this study is relatively wider compared to a previous study in Kepuh Ulu, Muaro Jambi District, which recorded the leaflet's average width of 6.79 cm (Lizawati et al. 2023). Aditionally, Aisah et al. (2017) reported that three-year-old *A. muelleri* in Nganjuk, Madiun, and Bojonegoro has a length of 16.3-20.1 cm and a leaflet width of 8.5-11.1 cm.

The petiole of *A. muelleri* in the study sites has the same color of green, flecked with light green, rounded shape, and slippery texture; however, there were slight differences in its morphometric, petiole length, and circumference. Furthermore, based on the review of several references, the characteristics of the petiole of *A. muelleri* include being round and patterned with a green color with white spots resembling a diamond shape (Nugrahaeni et al. 2021), having a surface with vertical/irregular lines (Firdaus et al. 2022); a surface that is smooth, somewhat rough, with diamond-shaped linear stripes (Sulistiyo et al. 2015); with a length of 58.61 cm and a diameter of 1.9 cm (Lizawati et al. 2023); and a smooth surface, colored green/olive green/ brownish green/almost black with many large elongated elliptical/diamond-shaped spots or pale green lines, sometimes with a large number of small pale green dots, and a length of 40-180 cm, diameter 1-8 cm (at the base) (Yuzammi et al. 2017). Based on age, *porang* has several branching patterns; namely, the branching pattern in *porang* one-year-old was 1-0 (not produced branching yet); Petiole directly supported lamina or leaflet. *Porang* two-, three, and four-year-olds had patterns 1-3, 1-3-2, and 1-3-3-2, respectively (Harijati and Mastuti 2014); those stalk characteristics in many studies above showed the study's location variation. Quantitative character variability is generally controlled by many genes (polygenic), each of which influences the expression of a trait and is strongly influenced by the environment (Syukur et al. 2012). The variability observed in a trait can be differentiated based on genetic or environmental factors. Those traits emerge as the result of differences in genes carried by one individual to another or by differences in the environment of each individual where the plant grows (Acquaah 2012).

Table 1 shows the tuber morphology of *A. muelleri* from three locations: Cipatat, Soreang, and East Cikalong. As is the case with the morphology of leaves and petioles, the tuber of *A. muelleri* possesses similar morphological characteristics with slightly different morphometrics. The tuber of *A. muelleri* at Soreang has the highest diameter (8.5-15 cm) and weight (500-1,100 g) compared to those of Cipatat and East Cikalong. This difference is suggested due to the influence of the ecological condition of their habitat that supports optimum growth rather than the genetic factor differences. Furthermore, the literature search revealed the outer (skin) tuber color of *A. muelleri* is brown, the inner (flesh) tuber is yellowish orange (Sulistiyo et al. 2015), chips color is yellow with glucomannan crystals, the tuber shape is bulbous/oval, tuber surface is smooth-coarse, tuber tissue (flesh) is smooth-coarse (Ashan et al. 2023); the tuber weight is 1.6 kg, and the tuber diameter is 23.7 cm (Nugrahaeni et al. 2021); globose or depressed-globose, dark brown, yellow or orange inside, to 28 cm in diameter, weighting to c. 3 kg (Yuzammi et al. 2017; Erlinawati et al. 2019).

The bulbil of *A. muelleri* in study sites possesses the same color morphological characteristic: dark brown with a few white spots at the outer part and white bone in the inner part of the bulbil. *A. muelleri* of East Cikalong has the fewest number of bulbils related to the leaf size, length, or width of the leaves (Table 1). On the other hand, the size of bulbil, both minimum and maximum diameter, showed comparable size among them, 1.5-4 cm at Cipatan, 2-3.5 cm at Soreang, and 2.5-4 cm at Ciklalong Wetan. Bulbil is not the main storage in *A. muelleri*; therefore, the plant size, including stalk and leaves, does not significantly affect the size of the bulbis. In contrast, the size of the tuber that acts as the main storage for glucomannan in *A. muelleri* differs among the three locations in this study. Furthermore, based on the results of a literature search, the characteristics of *A. muelleri* bulbil include a greyish-brown color (Erlinawati et al. 2019). Ashan et al. (2023) report that the bulbil shape is round/ oval symmetric/ symmetric, with a smooth-to-rough surface, and located at the leaf branches. Harijati and Mastuti (2014) report that the number of bulbils is 30. Nugrahaeni et al. (2021) state that the diameter of the bulbils is 2.17 cm.

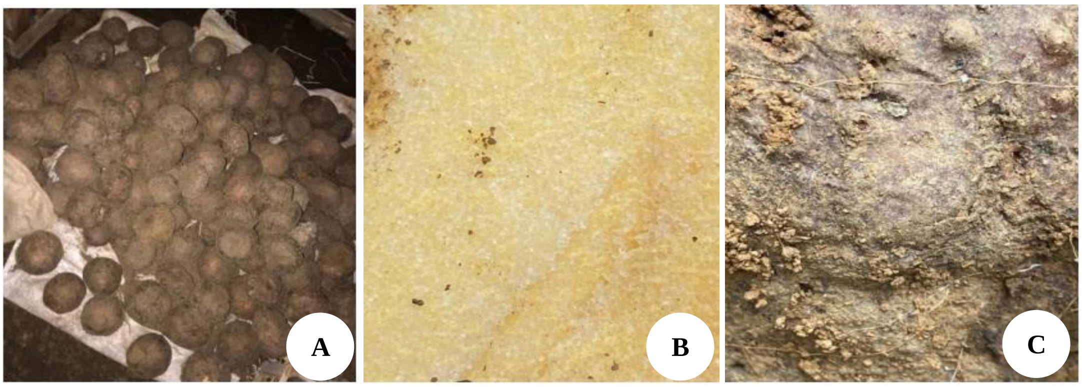

Figure 5. Morphology of *Amorphophallus muelleri* tubers: A. Shape; B. Flesh color; C. skin texture

Figure 6. Bulbil morphology of *Amorphophallus muelleri*

A previous study reported that *A. muelleri* was observed in the habitat of many locations with various ecological conditions. Related to the habitat in this study, the three research locations have somewhat varied characteristics. Furthermore, based on the results of a literature search, the characteristics of the growing environment for *A. muelleri* include air temperature 26.4-33°C (Nurrahmah et al. 2022); average air humidity 52.14% (without the shade), 53.33% (40% shade), 64.80% (80% shade) (Nurshanti et al. 2023); altitude 265-530 masl (Indriyani et al. 2011) or 100-700 masl (Endang et al. 2022); 13-38 masl (Lizawati et al. 2023); 40-60% under tree shade (Dermoredjo et al. 2021); radiation 2.98-59.99% (Budiman and Arisoesilaningsih 2012); soil pH 6.20 (Soedarjo et al. 2020), sandy loam soil type (Jansen et al. 1996) or sand/topsoil (Nurjannah et al. 2021); spread in thickets, disturbed areas, forest edges, village forests (Yuzammi et al. 2017); and ruderal and open secondary seasonal forest (Erlinawati et al. 2019).

Amorphophallus muelleri, in this study, exhibits differences in morphometrical characters of leaves, tubers, and bulbils but not in morphological characters. This variation is due to various factors, including environmental conditions and developmental stages, but is unlikely due to genetic variations. The role of environmental conditions such as light intensity, temperature, humidity, soil composition, and water availability can greatly influence leaf morphology. For instance, leaves may vary in size, shape, texture, and color in response to changes in environmental conditions. Developmental stages, such as leaf morphology, change as the plant progresses through different developmental stages. Young leaves may exhibit different characteristics than mature leaves. Factors such as leaf expansion and senescence can also affect leaf morphology. In its adaptation to habitat, *A. muelleri* can adjust its leaf morphology to suit its habitat and optimize its performance. Variations in leaf morphology may reflect adaptations to specific ecological niches or environmental challenges the plant possesses. Interactions with other organisms, such as herbivores, pathogens, and symbiotic organisms, can influence leaf morphology. For example, herbivory may lead to changes in leaf shape or size as a defense mechanism against herbivores. Cultural practices, such as cultivation practices, breeding programs, and selection for specific traits, also contribute to variations in morphology within cultivated populations of *A. muelleri*. In another case, the differences in morphological characteristics in *A. muelleri* are likely to be multifactorial, resulting from the interplay of genetic, environmental, developmental, and ecological factors.

Furthermore, Wahidah et al. (2021b) stated that these abiotic and biotic environmental factors influence the diversity and growth of *A. variabilis*, a plant in the same genus as *A. muelleri*. The abiotic environmental factors include temperature, light intensity, nutrients, soil conditions, soil pH, and the abundance of water. The biotic environmental factors observed include human activity, animals, vegetation structure, and microorganisms. Specifically, Wijaya et al. (2023) concluded that the light spectrum (white and blue) influences the growth of *A. muelleri* adventitious shoots. Zahra et al. (2023) also state that light influences vegetative growth, such as dry weight, root length, crown diameter, and leaf green index. Indriyani and Widoretno (2016) stated that lighting affects tuber growth (weight, diameter), plant height, and leaf petiole diameter. Triharyanto et al. (2022) stated that the type of growing media influences the growth of *A. muelleri*. Soedarjo et al. (2020) informs that salinity affects the growth or development of A. muelleri tubers and leaves to become abnormal such as folded leaves, brown color, and drooping shoots.

In conclusion, this study of *A. muelleri* at three locations, Cipatat, Soreang, and East Cikalong Sub-districts, West Java, revealed the morphological characteristics and ecological condition in the location of its growing environment. The same morphological characters of *A. muelleri* most likely share the same genotype. These morphometric differences in quantitative morphological characters are caused by the ecological conditions of the three growing locations of *A. muelleri*. These findings underscore the urgent need for further research to quantitatively analyze the relationship between these two morphological and ecological characteristics, as this will significantly advance our understanding of *A. muelleri*. In addition, the parameters of these two characteristics need to be considered in more detail, highlighting the importance of comprehensive research in this field.

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