



Morphological Diversity of *Amorphophallus gigas* (Araceae) in North Sumatra, Indonesia

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Abstract

Amorphophallus gigas is an endemic species in Sumatra with significant ecological and economic value; however, information regarding its morphological variation remains limited. This study aimed to analyze the morphological diversity of *A. gigas* in several locations in North Sumatra as a basis for conservation strategies. Observations were conducted on 20 individuals per location, focusing on vegetative and generative characters, and analyzed using the UPGMA clustering method with NTSYS software. The results showed that *A. gigas* populations were divided into two major groups: the South Labuhanbatu, North Padang Lawas, Mandailing Natal group and the North–South Tapanuli Group. The main differences were found in floral organs, particularly the color of the appendix, spathe, and staminate flowers. Cluster analysis produced a similarity coefficient of 0.33, indicating high morphological diversity among populations. This variation reflects the influence of environmental factors on morphological expression and highlights the importance of maintaining distinct populations to support genetic conservation. These findings emphasize that morphological studies can serve as an essential foundation for sustainable management and conservation of *A. gigas* in North Sumatra.

Key words: Conservation, Indonesian Flora, Morphological Diversity

Introduction

Amorphophallus gigas Teijsmann & Binnendijk (1862: 329) is one of the protected species of *Amorphophallus* Blume ex. Decaisne (1834: 366) under the Regulation of the Minister of Environment and Forestry No. 20 of 2018, and is an endemic species in Sumatra, including in North Sumatra (Rambey *et al.* 2022). This species is comparable to *Amorphophallus decussilvae* Backer & Alderwerelt van Rosenburgh (1920: 369), an endemic species of West Java. It is evident that both vegetative and generative forms exhibit a high degree of similarity, including in terms of their substantial dimensions. However, both species can be distinguished from the flowers, in which *A. decussilvae* has smaller stigmas, longer and more slender styles, stamens shorter and very obtuse anthers (Yuzammi *et al.* 2017).

Amorphophallus gigas is characterized by long peduncle, can reach 4.50 m high, campanulate, erect spathes, with dark-olive green with some paler spots at the base and the margin dark red-brown; dark green with numerous large

and small, rounded or elongate-oval, pale green spots petioles and smooth or slightly rugose near the base of petiole; spadix longer than spathe; appendix pale brownish to yellowish, and white tubers. Its flowers emit a strong foul odor that functions to attract insects as pollinators (Wulandari *et al.* 2022). This species is found growing wild under rubber stands, along riverbanks, and beneath oil palm plantations (Rambey *et al.* 2023). Although it is native to Sumatra, information on its distribution and habitat characteristics remains limited (Rambey *et al.* 2024a).

The genus *Amorphophallus* has high economic value when managed sustainably (Rambey *et al.* 2024a). The tubers of *A. gigas* have potential as food and traditional medicine due to their glucomannan content (Nababan *et al.* 2024), which provides health benefits including supporting diabetes treatment and maintaining blood sugar levels (Lizawati *et al.* 2023). The numerous advantages associated with certain species within this genus have resulted in heightened demand, thereby endangering their survival in their natural habitats. (Rambey *et al.*, 2024a). In India, some species have even been cultivated as commercial crops with high production potential and significant economic returns (Yadav & Singh 2016).

Scientific studies on *Amorphophallus* have been conducted through chloroplast genome analysis, providing insights into genetic diversity and phylogenetic relationships (Li *et al.* 2024). The distribution and habitat suitability of *A. gigas* in North Sumatra can be predicted using MaxEnt modeling, which is crucial for conservation strategies (Rambey *et al.* 2025). Morphological and habitat studies of *A. paeoniifolius* (Dennstedt 1818: 13, 21, 38) Nicolson (1977: 338) on Mount Ciremai revealed a close relationship between environmental conditions and morphological characters (Mutaqin *et al.* 2021). Populations of *Amorphophallus* in West Kalimantan also exhibited variation based on elevation (Wulandari *et al.* 2022), while the exploration of *A. titanum* (Beccari 1878: 290) Beccari (1879: 46) in West Sumatra highlighted its distinctive morphological features important for conservation (Yusniwati *et al.* 2024). These findings reinforce the need for morphology- and ecology-based research on endemic species such as *A. gigas*.

Studies on morphological variation of *Amorphophallus muelleri* Blume (1837: 143) in Sulawesi demonstrated the importance of phenotypic characters for conservation and germplasm utilization (Ashan *et al.* 2023). The latest taxonomic guide also provides a global dichotomous key that facilitates species identification within the genus *Amorphophallus* (Scholten 2023). Exploration in the Sibolangit Nature Tourism Park revealed the presence of diverse *Amorphophallus* species along tourist trails (Ulfa *et al.* 2025). Morphological variation in *A. muelleri* flowers has even been shown to be influenced by agamospermy and gibberellin treatment (Santosa *et al.* 2018). Vegetation studies in the habitat of *A. gigas* in North Sumatra revealed associated flora that play an important role in ecosystem structure (Rambey *et al.* 2024b). These facts emphasize the relevance of morphological and ecological studies in supporting conservation strategies for endemic species.

The distribution of *Amorphophallus beccarii* Engler (1881: 182) in the Singgalang Nature Reserve area is influenced by local ecological conditions (Hayati & Vauzia 2024). The phenology of *A. gigas* in North Sumatra shows a distinctive flowering and fruiting pattern aligned with seasonal cycles (Rambey *et al.* 2021). Environmental factors such as humidity and canopy cover have been proven important for the optimal growth of this species, while autecological studies confirm its association with riverine ecosystems (Rambey *et al.* 2024c). Therefore, an understanding of the morphology, distribution, and ecology of *A. gigas* is an essential foundation for conservation efforts. Based on these considerations, this study aims to analyze the morphological diversity of *Amorphophallus gigas* in North Sumatra as a basis for conservation strategies and the sustainable management of this endemic species.

Methods

This research was conducted from May 2022 to February 2024 in several natural populations of *Amorphophallus gigas* in North Sumatra Province, namely South Labuhanbatu, North Padang Lawas, South Tapanuli, North Tapanuli and Mandailing Natal districts. The study sites were determined purposively based on the presence of *A. gigas* individuals in their natural habitats. At each site, 20 individuals were observed, and from each individual, 10 samples of petioles and leaves were collected. The morphological characters observed included vegetative traits such as petiole length (PL), total length (TL), petiole diameter (PD), number of leaves (NL), average leaf area (LA), canopy width (CW), leaf color, and petiole color. For reproductive organs, the observed characters included peduncle height, peduncle diameter, appendix height, appendix diameter, staminate flower height, staminate flower diameter, pistillate flower height, pistillate flower diameter, total flower height, and the colour of each floral part. The morphological data obtained were then analyzed using the UPGMA clustering method with the aid of NTSYS software version 2.02 to determine grouping patterns based on morphological similarities.

Results and discussion

Morphology of *Amorphophallus gigas* in North Sumatra

The morphology of *A. gigas* in North Sumatra is divided into two major groups: Group 1 (South Labuhanbatu, North Padang Lawas, and Mandailing Natal) and Group 2 (North and South Tapanuli). Detailed differences between the groups of *A. gigas* in North Sumatra are presented in Table 1, Figures 2 and 3, while the floral organs are shown in Figure 1. The morphological differences among *A. gigas* populations are presented in Table 1, which highlights the main variations in floral organs, seeds, stems, leaves, and tubers.



FIGURE 1. Characteristics of the inflorescence of *Amorphophallus gigas*: (A) general habit, showing the inflorescence (a) and peduncle (b); (B) upper part of the inflorescence, showing the appendix (c) and spathe (d); (C) longitudinal view of the opened spathe, showing the appendix (c), male flower zone (e), and female flower zone (f).

TABLE 1. Morphology of *A. gigas* in North Sumatra.

Organ	Variant: South Labuhanbatu, North Padang Lawas, and Mandailing Natal	Variant: North and South Tapanuli
Flower	<ul style="list-style-type: none"> - Appendix color yellow (2.5Y 8/10) - Appendix surface rough - Inner spathe color purple-red (5 RP 4/8) - Outer spathe upper part red (5R 2/3) - Spathe base yellow (10 Y6/6) - Male flower color yellow (7.5 YR 7/8) - Female flower color purple (10 P 1/6) - Spathe surface wavy 	<ul style="list-style-type: none"> - Appendix color purple-red (7.5RP 2/6) - Appendix surface rough - Inner spathe color purple-red (7.5RP 2/6) - Outer spathe upper part red (5R 2/3) - Spathe base varies (10 R 6/4) - Male flower color purple-red (7.5RP 2/6) - Female flower color purple-red (7.5RP 2/6)—Spathe surface wavy
Seed	<ul style="list-style-type: none"> - Female flower color purple (10 P 1/6) - Immature seed color purple (10 P 1/6) - Mature seed color red 	<ul style="list-style-type: none"> - Female flower color purple-red (7.5RP 2/6)—Mature seed color red
Stem	<ul style="list-style-type: none"> - Green with circular patches resembling spots covering almost the entire stem 	<ul style="list-style-type: none"> - Dark green with circular patches resembling spots covering almost the entire stem
Leaf	<ul style="list-style-type: none"> - Green leaves with smooth surface, arranged above petiole, generally with three leaflets when mature 	<ul style="list-style-type: none"> - Green leaves with smooth surface, arranged above petiole, generally with three leaflets when mature
Tuber	<ul style="list-style-type: none"> - Outer tuber brown, inner tuber white 	<ul style="list-style-type: none"> - Outer tuber brown, inner tuber white



FIGURE 2. Morphological features of *A. gigas* variant from South Labuhanbatu, Padang Lawas Utara, and Mandailing Natal. (A) Inflorescence. (B) Close-up of the spathe and spadix. (C) Young infructescence. (D) Close-up of immature fruits. (E) Infructescence growing under the forest canopy. (F) Close-up of mature fruits. (G) Unopened inflorescence. (H) Vegetative plant with a human for size comparison. (I) Petiole, tuber, and part of the leaf blade.

The morphological variations found among *A. gigas* populations in North Sumatra show clear differentiation in floral organs, particularly in the color of the appendix, spathe, and male flowers. These differences are significant because generative organs are one of the main markers in the taxonomic identification of *Amorphophallus* (Scholten 2023). The variation in color and form across locations also emphasizes the role of environmental factors in shaping morphological expression of this species, as previously reported for *A. paeoniifolius* and *A. muelleri* in other regions (Mutaqin *et al.* 2021, Ashan *et al.* 2023). Figures 2 and 3 illustrate the visual morphological variations of the two main groups of *A. gigas* in North Sumatra. The morphology of *A. gigas* from the South Labuhanbatu, North Padang Lawas, and Mandailing Natal variant is presented in Figure 2. The morphology of *A. gigas* variant from South Tapanuli and North Tapanuli can be seen in Figure 3. The cluster analysis results based on the morphological characters of *A. gigas* are presented in Figure 4. As illustrated in Figure 4, two major groups of *Amorphophallus gigas* populations can be identified: the first group consists of Sipenggeng, Simasom, Suka Maju, Aek Nabara, Luat Lombang, Aek Batang Paya, and Jukkihan villages, while the second group consists of Sabungan, Napalancat, Pangirkiran, Lubuk Bondar, Silaiya, Bangkelang, and Rao-Rao villages. Cluster analysis using the UPGMA method with NTSYS software produced a similarity coefficient of 0.33 (33%), indicating high morphological diversity among populations. The phenetic tree was constructed from a Dice similarity matrix, where coefficients closer to 1 indicate higher similarity among taxa or accessions (Dice 1945, Sokal & Sneath 1963). These results show that *A. gigas* in North Sumatra exhibits broad morphological diversity, reflecting population differentiation due to environmental factors and local selective pressures. This also indicates that each population has specific adaptations to its microhabitat conditions. These findings are consistent with research on *A. muelleri* in Sulawesi, which revealed inter-location morphological variation that can serve as a basis for germplasm conservation and utilization (Ashan *et al.* 2023).

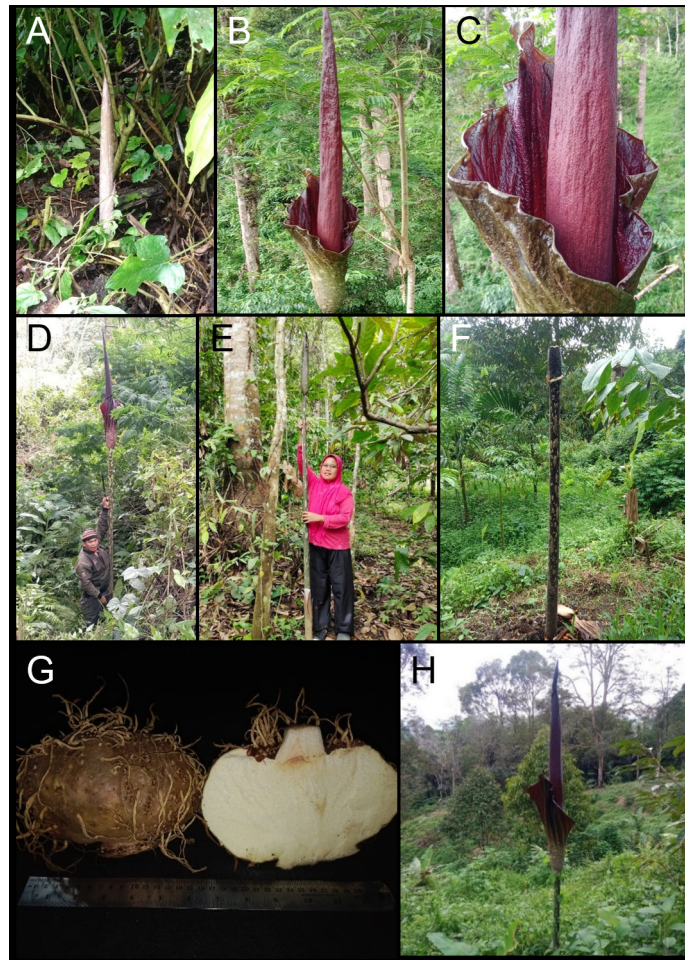


FIGURE 3. Morphological features of *A. gigas* variant from South Tapanuli and North Tapanuli. (A) Emerging inflorescence bud. (B) Spathe and spadix. (C) Close-up of the appendix. (D) Inflorescence shown with an adult human for size comparison. (E) Developing inflorescence bud. (F) Post-anthesis stage with developing infructescence. (G) Tubers, one shown in longitudinal section. (H) Plant in the generative phase.

In addition to natural adaptation, the issue of morphological diversity within the genus *Amorphophallus* can be approached from a genetic perspective. Supporting evidence comes from DNA content analysis, where studies of three *Amorphophallus* species revealed significant genetic variation as the basis for species diversification (Zhao *et al.* 2020). This reinforces the idea that morphological diversity in *A. gigas* may reflect deep genetic variation. On the other hand, morphological differences between groups are thought to be influenced by habitat conditions. Factors such as light intensity, humidity, and type of stand have been shown to affect *Amorphophallus* growth (Wulandari *et al.* 2022). In populations from South Tapanuli and North Tapanuli, variations in appendix and spathe coloration are likely linked to adaptations to microhabitat conditions that differ from those in South Labuhanbatu, North Padang Lawas, and Mandailing Natal populations.

This high phenotypic diversity has important implications for conservation, as each population contributes to maintaining genetic diversity. This is supported by studies on *A. titanum* in West Sumatra, which emphasized the importance of morphological documentation in the conservation of large endemic species (Yusniwati *et al.* 2024). These results are also consistent with research on *A. paeoniifolius* from South Kalimantan, where genetic analysis revealed high inter-species diversity but low intra-species variation (Mursyidin *et al.* 2022). Thus, morphological studies serve not only as a basis for taxonomic identification but also as a strategic foundation for the sustainable conservation of *A. gigas* in North Sumatra. The phenetic analysis separated the *A. gigas* populations of North Sumatra into two principal groups: South Labuhanbatu, North Padang Lawas, and Mandailing Natal, and South Tapanuli together with North Tapanuli. Morphological differences were most evident in the floral characters, especially the coloration of the appendix, spathe, and staminate flowers. The similarity coefficient of 0.33 suggests considerable morphological differentiation among populations. Such variation may reflect the influence of contrasting environmental conditions

and local adaptation across the study sites. From a conservation perspective, the maintenance of these morphologically variable populations is important, as they may represent valuable biological diversity relevant to the conservation and sustainable management of *A. gigas* in North Sumatra.

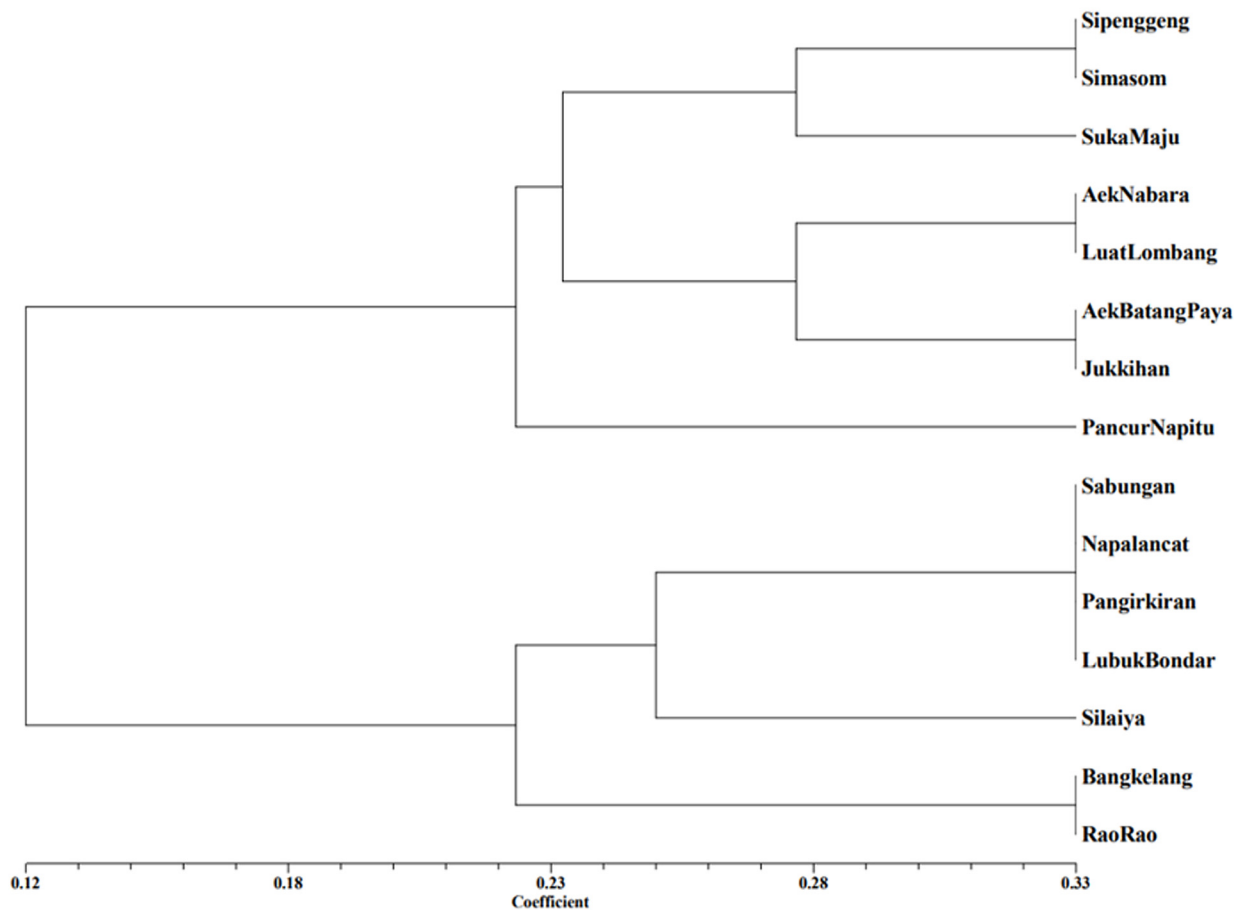


FIGURE 4. Dendrogram showing morphological relationships among subpopulations of *A. gigas* based on Dice's similarity coefficients.

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