JOURNAL OF TROPICAL LIFE SCIENCE
2024, Vol. 14, No. 3, 651 – 662
http://dx.doi.org/10.11594/jtls.14.03.20

Research Article

Morphological Characteristics of Porang *(Amorphophallus muelleri* Blume*)* in Timor-Leste and Their Correlation with Climatic Conditions

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Article history:
Submission April 2023
Revised August 2024
Accepted August 2024

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ABSTRACT

Porang (*Amorphophallus muelleri* Blume) is native to the forests of Timor-Leste, with cultivation starting in 2017. This study examined the morphological characteristics and nutrient content of porang from six gardens across Timor-Leste, assessing relationships with climatic factors. Various morphological traits and climate variables, including elevation, were measured. Nutrient analysis of porang tubers utilized chromatographic and mass spectrometric techniques, while principal component analysis helped identify links between morphology, nutrient content, and abiotic factors. Despite some qualitative similarities, such as colour and leaf patterns, significant differences were noted in measurable traits. Findings indicated that environmental conditions significantly influenced porang growth. For instance, higher air humidity in the Bobonaro District positively affected plant height and canopy width. In contrast, elevated temperatures and soil conductivity in the Liquiça District influenced leaf venation. The Aileu District exhibited the highest bulbil abundance, while larger tubers were found in the Ermera District, which is at a higher elevation. The Manufahi District had rich organic carbon content, and porang in Manatuto, with higher soil pH, produced more bulbils. However, drought conditions in Manatuto led to moisture loss and partial tuber decay. The highest glucomannan concentration was found in tubers from Bobonaro (10.25%), followed by Liquiça (9.87%) and Ermera (9.81%). Overall, environmental factors like elevation, soil temperature, and humidity significantly impacted porang characteristics and yield.

Keywords: Climatic factors, Glucomannan, Morphology, Nutrition, Yellow konjac

Introduction

Timor-Leste, located in the western Pacific region [1], has extraordinary biodiversity. One of the plants that grow there is the porang plant (*Amorphophallus muelleri* Blume). The *porang* plant (*A. muelleri* Blume) is naturally abundant in Timor-Leste, but it also has become a promising crop with a substantial economic impact that has improved the welfare of farmers[2]. This is particularly relevant because approximately half of the Timor-Leste population resides in rural regions, and ~85% of those residents depend on agriculture as their main livelihood. Consequently, the advancement of *porang* plant cultivation is particularly important not only for local economies but also for the welfare of rural communities throughout the country [3].

Local narratives indicate that Indigenous inhabitants of Timor-Leste have utilized the tender leaves of young *porang* plants as a source of sustenance and the stems as animal fodder. Nonetheless, residents in some communities do fully understand the potential for *porang* tubers to enhance their livelihood. The cultivation of *porang* in Timor-Leste has contributed substantially to the spectrum of available food sources and fostered industrial prospects. It increased commodity

How to cite:
da Cruz N de D, Azrianingsih R, da Costa HR (2024) Morphological Characteristics of Porang *(Amorphophallus muelleri* Blume*)* in Timor-Leste and Their Correlation with Climatic Conditions. Journal of Tropical Life Science 14 (3): 651 – 662. doi: 10.11594/jtls.14.03.20.

exports in 2017, when the export of *porang* chips reached '~568 tons' [2], and export was '~395 tons' in 2018 [4], according to data from the Ministry of Agriculture and Fisheries. Thus, the export of *porang* chips has propelled the growth of the agricultural sector and local industries, creating new opportunities for regional economies and supporting efforts toward economic diversification.

Porang is a member of the Araceae family [5] and is a tuber-producing plant [6] with leaf stalks ranging in color from green to dark green. The *porang* stalk is round with a prismatic white pattern [7]. Each plant has a single leaf [8]. In the early growth stages, the edges of the *porang* leaf are pink, transitioning to white as the plant matures. Each leaf has a smooth, undulating surface devoid of any indumentum. The fine undulations on the leaf edges are influenced by light intensity [7]. *Porang* features aerial corms or bulbils, symmetrically round and brown, functioning as regenerative organs. The bulbils are positioned at the central junction of each stalk and branch of the leaflet [9]. Each plant bears a solitary spadix inflorescence comprising female flowers at the lower portion and male flowers above. Variations have been observed in other organs, such as the peduncle, spathe, stigma, carpel, and appendix [10]. The shape of the flower resembles a blunt-tipped spear and is unisexual. The fruit is an oval-shaped berry arranged in clusters, consisting of 100–450 (average 300) fruits, each of which contains 1–4 seeds that vary in size [11]. *Porang* typically grows in secondary vegetation and thrives in shade at elevations ranging from 0 to 900 m above sea level (masl). *Porang* grows optimally in well-drained soil of high humus content, although it also grows well in sandy clay soil with a pH range of 6 to 7.5. Moreover, optimal growth occurs within an air-temperature range of 25–35°C and soil temperature of 22–30°C [12].

Porang tubers are modified leaf stalks that serve as storage organs for reserve nutrients. Tubers contain carbohydrates with high fiber content in the form of glucomannan, making them highly sought after in various industries such as food, cosmetics, and pharmaceuticals, among others [13]. Conventional processing of *porang* tubers generally involves washing and repeated boiling to eliminate potential toxins and irritants [12]. Tubers contain oxalic acid, and therefore consuming large numbers of tubers can reduce the whole-body bioavailability of calcium and may lead to the development of kidney stones [14]. For instance, the oxalate content in tubers is influenced by environmental factors such as temperature, rainfall, weed coverage percentage, calcium availability in the soil, cation exchange capacity, and soil pH. Given the potential benefits and risks of *porang* for the Timor-Leste population, here we report new aspects of its morphological characteristics, the nutrient content of tubers, and environmental factors that affect growth.

Material and Methods

Description of research location

The morphological characteristics of porang plants and weather-related factors at porang plantations were observed from August 2021 to September 2022 in six districts of Timor-Leste. The plantations in the Bobonaro District are situated in the western part of Timor-Leste, whereas those in the Liquiça District are in the northern coastal area. The plantations in the Ermera District are in the north, and those in the Aileu District are in the southwest. The Manufahi District is positioned in the southern part of Timor-Leste, and the Manatuto District is situated in the central region (Figure 1).

Morphological characteristics of porang plants

The point-intercept method was employed for selecting porang samples using 10×10 m^2 transects. Two samples were chosen from each of the five sections (west, north, east, south, and center) within each transect (ten replicates). Morphological characteristics were observed using a descriptive approach [15], encompassing both the vegetative and regenerative aspects of the porang plant.

Measurement of abiotic factors

Abiotic factors were measured in each transect. Air temperature (°C) and air humidity (%) were measured with a hygrometer, soil temperature (°C), soil humidity, and light intensity were measured using a 4-in-1 soil survey instrument, and soil organic carbon (%) and soil organic compounds (%) were quantified using gravimetric methods. Soil organic carbon was calculated using the following formula:

$$\%C\ organic = \frac{w1 - w0 - w2}{w1} x\ 100\% \quad (1)$$

W0 = Weight of tins
W1 = Weight of tins and soil
W2 = Weight of tins and soil after burning

Soil organic matter content was calculated by multiplying the organic carbon (%) by a factor of 1.274. Soil pH was measured by pH meter, Electrical conductivity values were obtained with an electrical conductivity meter and were converted using a unit conversion calculator to micro siemens per meter (μS/m) [16].

Nutrition analysis of porang tubers

Three porang tubers were utilized for the analysis, representing ten porang plants from each of the six locations. Nutrition analysis of the tubers was carried out with liquid chromatography–coupled mass spectrometry and high-performance liquid chromatography [17].

Data analysis

Morphological descriptions, tuber nutrient content, and climate factor analyses were conducted using Microsoft Excel. Additionally, the correlations between morphological characteristics, tuber nutrient content, and climate factors were analyzed through the principal component analysis programs Biplot and Cluster using Statistic (PAST 4.0) software [18].

Results and Discussion

Morphological characters

The morphological characteristics varied significantly among research locations, particularly in terms of quantitative aspects. However, certain aspects were consistent between and within locations, such as color, surface texture, and shape across tubers, leaf stalks, leaves, and bulbils. Differences were observed for other characteristics of

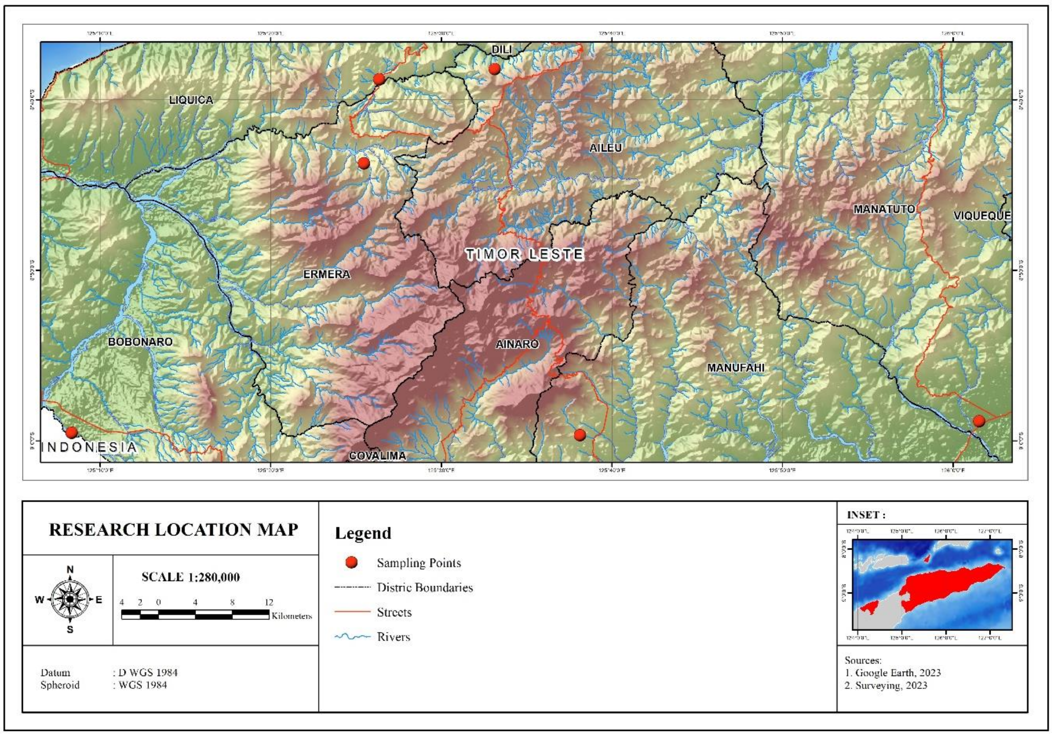


Figure 1. Map of Study sites in six districts of Timor-Leste

Table 1. lists data acquired for all these morphological characteristics

Morphological characters	
Plant height (cm)	
Canopy width (cm)	
Tuber	Shape, surface, diameter (cm), circumference (cm), weight (kg)
Pedicel	Colour, Surface, Shape of the steam pattern, Height (cm), diameter of base, middle and tip of pedicel (cm)
Leaf	Colour, Surface, Shape, Width (cm), Length (cm), Number of venations
Bulbil	Colour, Shape, Surface, Amount, Wild (cm), Diameter (cm), Weight (g)

the 60 individual *porang* plant samples, including plant height and leaf canopy width, with an average canopy width ranging from 99.3 cm to 173.5 cm (Table 2). Differences were also found in leaf color, length, width, and the number of leaf veins. Despite being diverse in other aspects, the observed types of *porang* leaves were consistent in that their leaves were compound palmate and lobed, having elliptical shapes and pointed tips. Leaflets were consistent in terms of shape, tips, and edges. However, the number of leaf lobes varied, averaging between 11 and 17 depending on the width of the leaf canopy. The leaf surface varied in color from bright green to dark green. The leaf stalk varied in length, base diameter, mid-section diameter, tip base diameter, and color. Leaf stalks were round, with white prismatic or diamond-shaped patches on the surface and a smooth texture. Leaf-stalk color could be divided into two categories: green and dark green. Morphologically, bulbils also displayed variation in weight and diameter and were symmetrical and round, brown in color, and had a rough surface with numerous protrusions. The number of bulbils per

Table 2. Morphological characteristics of porang from six plantations in Timor-Leste

Morphological characteristics		Location					
		BB	LQ	ER	AI	MF	MT
Growing Period		3th	3th	2nd	2nd	1st	1st
Plant Height (cm)		**153.2**	138	151.5	130.3	125.5	127.4
Canopy Width (cm)		**173.5**	117.4	133.3	117.2	113	99.3
Tuber	Shape	Round					
	Surface	Rough Race					
	Diameter (cm)	27.2	27.6	25.4	**28.2**	19.8	15.3
	Circumference (cm)	61.2	62.3	60.2	**63.4**	47.9	37.5
	Weight (kg)	2.54	**2.93**	**2.93**	2.77	1.36	0.5247
Leaf Stalk	Colour	Green and dark green					
	Surface	Smooth and Slick					
	Shape of the stem pattern	Prismatic white					
	Height (cm)	**132.2**	112.5	114.1	106.2	113.6	91.2
	Stem base width (cm)	**19.9**	16.9	17.8	15.5	11.3	13
	Stem center width (cm)	**13.5**	11	11.1	10.3	8.5	8.45
	Stem end width (cm)	**10.3**	8.4	8.2	7.7	6.5	7
Leaf Lamina	Adaxial colour	Green					
	Adaxial surface	Smooth and slippery					
	Shape	Round and incised inwards					
	Abaxial	Light green					
	Width (cm)	**11.6**	9.3	9.8	9.2	6.1	9.9
	Length (cm)	**29.1**	25.2	25.7	23.7	23	22.6
	The number of venations	**12.5**	17.7	13.2	12.5	13.8	11.2
Bulbil	Colour	Chocolate					
	Shape	Ovals					
	Surface	Rough					
	Amount	9.7	9.2	5.1	7.4	6.6	**11.3**
	Wild (cm)	11.9	11.8	10.7	**13.1**	8.8	11.3
	Diameters (cm)	6	6.6	5.9	**6.9**	4.5	5.7
	Weight (g)	15.27	21.4	12.28	**23.4**	8.41	12.96

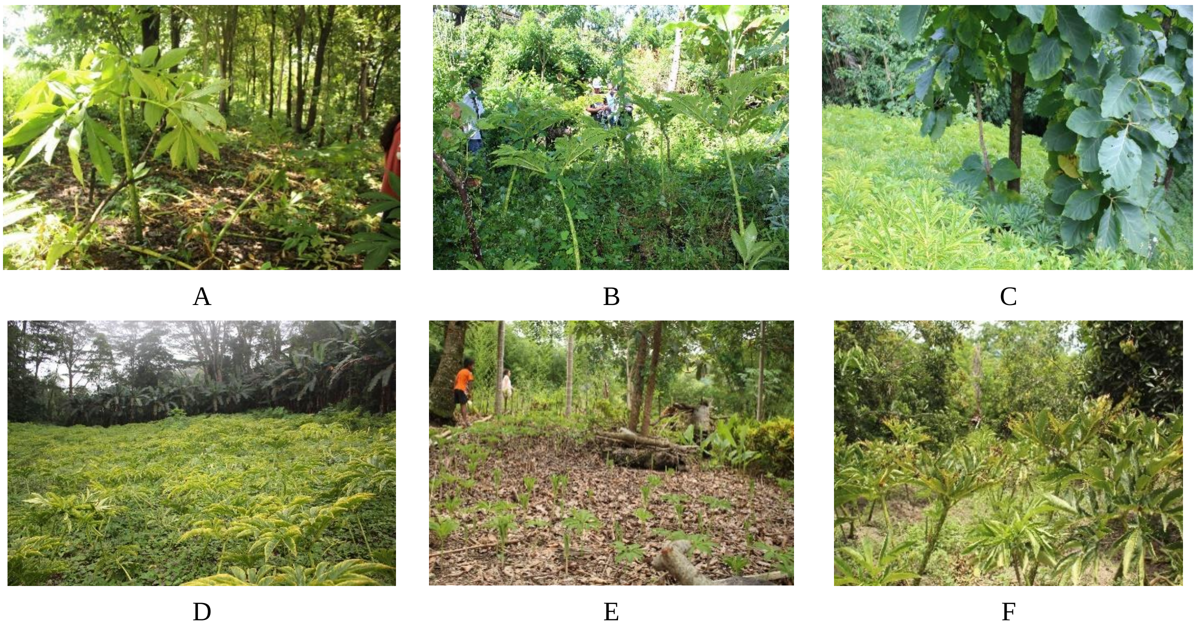
Locations: BB (Bobonaro), LQ (Liquiça), ER (Ermera), AI (Aileu), MF (Manufahi), MM (Manatuto).

sample varied from 8.41 to 21.04. Meanwhile, tubers varied in diameter and weight, the latter ranging from 0.5247 kg to 2.93 kg. Tubers were round and brown, and their surface had a smooth wave texture.

Morphological characteristics were mainly consistent across all samples of *porang* plants, particularly in terms of plant height, canopy width, and production of high-quality tubers and bulbils with substantial weight. During the early growth phase, however, plants had distinct characteristics, especially plants originating from the Manatuto and Manufahi Districts, which were relatively shorter, had a narrower canopy width, and produced smaller tubers and bulbils. In the Bobonaro District, plants exhibited high average values for several parameters such as plant height, canopy width, leaf stalk height, base and mid-section diameter of the stalk, tip base diameter, and leaf width and length, as well as the number of leaf veins. On the other hand, plants from the Aileu District had the highest average diameter and circumference of tubers. Tuber weight was highest in the Liquiça and Ermera Districts, the average number of bulbils per *porang* plant was highest in Manatuto District, and the average bulbil circumference, diameter, and weight were highest in the Aileu District. The morphological characteristics of *porang* plants also varied with the growth period, i.e., first, second, and third, which was a consequence of differences in climate and/or local environment among the six cultivation sites. It has been established that soil nutrient availability can significantly impact the productivity of *porang* plants [19]. Moreover, genetic aspects inherited by each individual plant underpin the observable phenotypes, although phenotypes can be influenced by climate as well as other abiotic factors, including the soil type of the local habitat [20].

Profiles of porang gardens at six research locations in Timor-Leste

In the Bobonaro District, *porang* plants were cultivated in the shade of *Piliostigma thonningii* trees. The *porang* plants in this particular district had progressed to the third growth phase, having been planted in November 2019. Morphological analysis was carried out on March 18, 2022, with harvesting occurring on May 5, 2022. In the Liquiça District, *porang* was cultivated alongside cassava (*Manihot esculenta*) under the canopy of teak (*Tectona grandis*) trees and several soursop (*Annona muricata*) trees. Similarly, *porang* in this district had also reached the third growth phase, having been planted in December 2019. Morphological traits were observed on March 12, 2022, with harvesting occurring on May 1, 2022. In the Ermera District, *porang* plants were cultivated on sloped terrain in the shade of teak trees surrounded by bamboo and other medium-to-large trees. The *porang* in this area had entered its second growth phase, with planting taking place in November



A B C D E F

Figure 2. Profile of porang gardens in Timor-Leste. A. Bobonaro, B. Liquiça, C. Ermera, D. Aileu, E. Manufahi, and F. Manatuto.

2021. Morphological examination was conducted on May 29, 2022, with harvesting occurring on May 4, 2022. In the Aileu District, *porang* had progressed to the second growth phase and was cultivated on level ground alongside sweet potatoes, devoid of shade trees. Nonetheless, the presence of tall trees and thick banana plants around the *porang* garden provided ample moisture. *Porang* in the Aileu District was planted in November 2021, morphologically characterized on March 24, 2022, and harvested on April 30, 2022. *Porang* in the Manufahi District was cultivated alongside areca palm (*Areca catechu*) trees, with planting taking place in November 2021. Morphological traits were observed on April 2, 2022, and harvesting occurred on May 7, 2022. In the Manatuto District, *porang* was grown in raised beds shaded by rambutan (*Nephelium lappaceum*) trees, as depicted in Figure 2 (panel 6). The *porang* in this district was planted in November 2021, morphologically characterized on March 13, 2022, and harvested on May 14, 2022. The growth phases of *porang* in both the Manufahi and Manatuto Districts had recently transitioned to the initial stage, resulting in the formation of smaller tubers. Generally, Amorphophallus species flourish in secondary vegetation alongside riverbanks, within forests, village plantations, and shaded environments [21]. Notably, shade is the preferred lighting condition for optimal growth of *porang* [22].

Nutrition characteristics of porang tubers from the six porang gardens

Summarizes data from an analysis conducted using liquid chromatography–coupled mass spectrometry and high-performance liquid chromatography of 18 *porang* tubers sourced from six *porang* gardens in Timor-Leste (Table 3). Samples were analyzed in duplicate. The results revealed the existence of nine primary compound types encompassing proteins, fats, water, ash, carbohydrates, crude fiber, starch, glucomannan, and oxalic acid, along with data for caloric energy. Among the samples of tubers from different plantations, the concentrations of certain compound types varied substantially.

Carbohydrates were the predominant compound type detected in *porang* tubers across the six observation sites. Carbohydrates have a notable impact on the duration of dormancy and emergence of shoots in *porang* plants [23]. Carbohydrate content within tubers is influenced by an array of factors, encompassing environmental

Table 3. Components and caloric energy of porang tubers from the six plantations in Timor-Leste

Compound	**Test**	**Sampel**					
		BB	LQ	ER	AI	MF	MT
Protein (%)	I	0.89	0.90	0.77	0.92	0.93	0.88
	II	0.89	0.89	0.77	0.91	0.92	0.88
Fat (%)	I	0.24	0.28	0.21	0.21	0.33	0.28
	II	0.26	0.26	0.24	0.21	0.31	0.28
Water (%)	I	0.84	9.06	9.28	9.33	9.98	10.08
	II	8.88	9.05	9.30	9.37	9.92	10.26
Ash (%)	I	4.64	4.64	4.85	4.78	4.70	4.66
	II	4.63	4.63	4.85	4.67	4.70	4.66
Carbohydrate (%)	I	85.36	85.10	84.87	84.74	84.04	84.07
	II	85.31	85.15	84.82	84.82	84.13	84.90
Coarse Fiber (%)	I	8.41	8.96	9.23	8.98	8.95	8.48
	II	8.35	8.94	9.23	8.98	8.96	8.44
Caloric Energy (%)	I	3.48	3.47	3.45	3.45	3.43	3.43
	II	3.48	3.47	3.45	3.45	3.44	3.42
Starch (%)	I	46.20	45.64	45.69	45.47	45.02	45.21
	II	46.42	45.62	45.72	45.62	45.14	45.13
Glucomannan (%)		**10.25**	9.87	9.81	9.72	9.61	9.70
Oxalic Acid (%)		0.50	0.51	0.53	0.50	0.51	0.54

Locations: BB (Bobonaro), LQ (Liquiça), ER (Ermera), AI (Aileu), MF (Manufahi), MM (Manatuto).

conditions, the maturation stage during harvest, and storage time. These combined factors can alter the metabolic functioning of tubers [24]. Carbohydrates tend to amass predominantly within cell walls, playing a pivotal role in steering plant growth and developmental processes [25]. The highest concentration of glucomannan is found in *porang* tubers from Bobonaro Regency with an average value of ~10.25%, followed by *porang* tubers from Liquiça district with an average of ~9.87%, then followed by *porang* tubers from Ermera district with an average value -average ~9.81%, followed by tubers from Aileu district with an average value of ~9.72%, tubers from Manatuto Regency have an average glucomannan content in tubers of 9.70% and *porang* tubers from Manufahi district with an average value of average 9.61%. The concentration of oxalate compounds in *porang* tubers from six (6) districts is, on average, low, ranging from 0.50-0.54%. This low level of glucomannan in tubers from the Liquiça District is likely attributable to the extended post-harvest storage period, potentially resulting in shoot growth within the tubers. As reported by [26], glucomannan content typically wanes with heightened shoot growth subsequent to the tuber's initiation. Soil-based environmental circumstances (comprising total nitrogen, cation exchange capacity, organic carbon, organic matter, pH, C/N ratio), the microclimate, cultivation techniques [27], and plant maturity [28] also collectively influence glucomannan content within *porang* tubers. The amount of glucomannan in *porang* tubers is contingent upon the timing of harvest, as tubers tend to have higher glucomannan content during plant growth (i.e., mainly oriented horizontally) compared to before or after the plant's demise. Growth in shade also influences *porang* growth by moderating the local temperature and the intensity of light exposure [28]. Glucomannan content can also be affected by plant age at harvest, processing method, whether tubers are ground into powder, the types of tools used during tuber processing [29], and the origin of bulbils [30]. Glucomannan concentration also tends to decrease as shoots progress [26], due to its breakdown into simpler sugars that serve as an energy source for vegetative development [24]. Finally, both biotic and abiotic factors play roles in determining the content of oxalate crystals in *porang* tubers [31]. Beyond glucomannan, other factors such as the content of proteins, fats, water, ash, carbohydrates, crude fiber, starch, oxalic acid, and caloric energy content confer health benefits to plants and have industrial utility. Water concentration diminishes as tubers age post-harvest [32].

Climate factors

Climate factors significantly impacted the growth of *porang* in the six *porang* plantations in Timor-Leste. Several factors included light intensity, soil and air temperatures, air and soil humidity, soil pH, organic carbon content, soil organic matter, soil electrical conductivity, rainfall, and elevation. These climate factors had varying effects on *porang* growth across the research sites (as depicted in Figure 3), and these differences provided a deeper understanding of *porang*'s habitat preferences within each plantation.

Air humidity (Figure 3a) differed significantly among the *porang* plantations in Liquiça, Ermera, Manatuto, and Bobonaro, whereas air humidity did not differ between the Aileu and Manufahi plantations. Air temperature did not differ between the Manufahi and Bobonaro plantations, although it differed significantly among the Aileu, Ermera, and Liquiça plantations (Figure 3b). Soil elevation and electrical conductivity varied substantially among the six plantations (Figure 3c, d). Soil organic matter and soil organic carbon did not differ significantly between the Aileu and Manatuto plantations. In contrast, these parameters differed significantly among the Ermera, Bobonaro, Liquiça, and Manufahi plantations (Figure 3e, f). Soil temperature (Figure 3g) did not differ significantly among the Ermera, Liquiça, Aileu, and Manufahi plantations, whereas it differed significantly between the Manatuto and Bobonaro plantations. Soil pH did not differ significantly between the Aileu and Ermera plantations, although it differed significantly among the Bobonaro, Aileu, Manatuto, and Manufahi plantations (Figure 3h). Light intensity across the six plantations was low to very low. Soil moisture in the Bobonaro plantation was categorized as very wet, the Liquiça plantation had neutral soil moisture, the Ermera and Manufahi plantations had [little OR dry] soil moisture, and the Manatuto plantation had very little soil moisture. The Aileu District is at the highest elevation of ~794 masl, whereas Manatuto District is situated in a lowland area with 94 masl. Amorphophallus species can thrive in lowland areas up to an elevation of 1000 masl [33]. However, *porang* grows best at elevations of 100–600 masl. Soil temperature in the Manatuto District was higher than in other districts, at approximately 28°C. Air temperature is a climate factor that can influence the growth and yield of *porang* plants [22]. Air temperature in the Liquiça and Manatuto Districts was higher than in other districts due to their proximity to urban and coastal areas. The *A. muelleri* plants thrive optimally at temperatures between 22 and 30°C. If the temperature exceeds 35°C, the leaves experience dehydration, whereas low [temperatures of ≤12°C lead to plant dormancy [33]. Additionally, excessively high temperatures can hinder plant growth and even lead to plant death. Furthermore, the highest air humidity was in the Bobonaro District. The soil pH at all six research locations ranged from 6.5 to 7. *Porang* thrives in soils with a pH of 6.0–7.5, a light-texture soil like sandy loam, good nutrient content, and high humus content [34]. The highest soil electrical conductivity was found in the Liquiça District, whereas the highest soil organic carbon and soil organic compound content was in the Manufahi District.

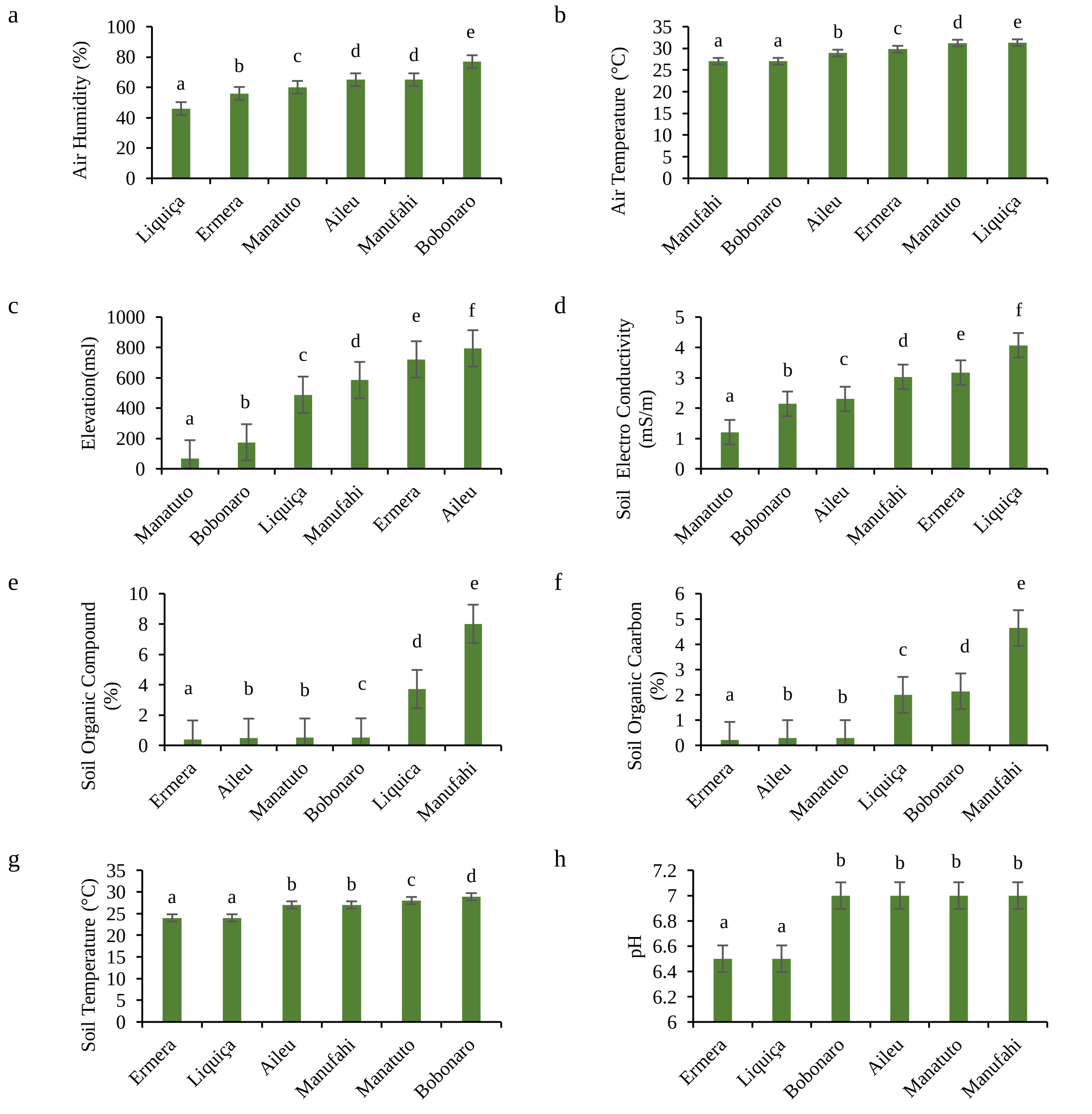


Figure 3. Elevation and climatics factors for six porang gardens in Timor-Leste. (a.) Air Humidity (%), (b.) Air Temperature (°C), (c.) Elevation(msl), (d.) Soil Electro Conductivity (mS/m), (e.) Soil Organic Compound (%), (f.) Soil Organic Caarbon (%), (g.) Soil Temperature (°C) and (h.) pH.

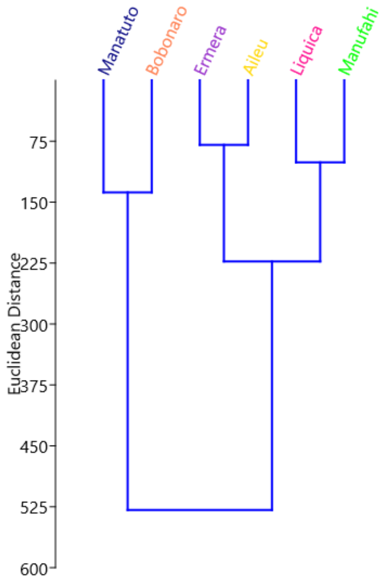


Figure 4. Cluster of six porang gardens in Timor-Leste

Dendrogram of the six porang gardens in Timor-Leste

The results of the cluster analysis were based on the average morphological characteristics of *porang* plants from the six *porang* plantations, including parameters such as plant height, canopy width, stalk height, leaf base width, tuber weight, main bulbil weight, leaf venation, and bulbil count. An overview of these cluster analysis findings is depicted in Figure 4.

The dendrogram had three primary clusters. The first cluster comprised *porang* gardens of Bobonaro and Manatuto Districts, which had similar soil pH, soil organic carbon, and soil organic carbon. The second cluster included *porang* gardens of Aileu and Ermera Districts, which had similar soil pH and elevation. Finally, the third cluster encompassed the pouring gardens of Liquiça and Manufahi Districts, equipped by their high soil electrical conductivity and soil organic matter content.

Correlations between morphological characteristics of porang, nutrition composition of tubers, and climatic factors based on principal component analysis

Based on data from the principal component analysis reported in Figure 5, the high air humidity in the *porang* garden of the Bobonaro District correlated positively with plant height, canopy width, stem height, stem diameter, and glucomannan content. Plants that grow in shaded areas tend to have slower respiration rates [27]. High air temperature and soil electrical conductivity in the Liquiça District correlated positively with the number of leaf veins in *porang* plants. The

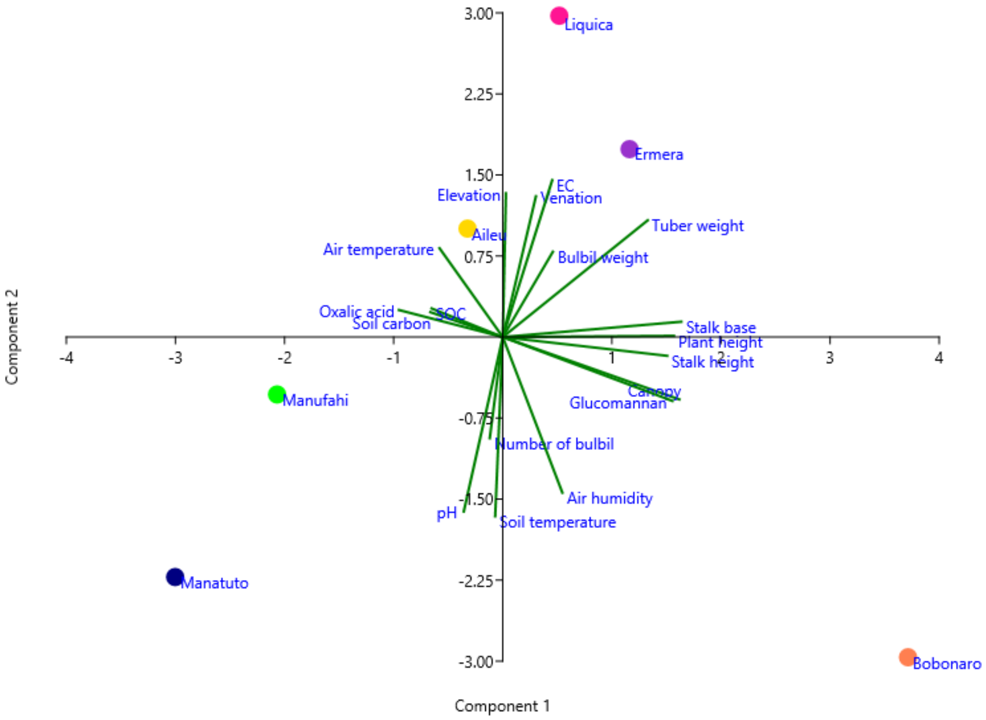


Figure 3. Correlation between morphological characteristics, Nutrition composition of tubers, and climatic factors. SOC (Soil Organic Compounds), Ec (Soil Electro conductivity meter).

elevation of the Aileu region correlated positively with the weight of bulbils and tubers, whereas the elevation of the *porang* gardens in the Ermera District correlated positively with the weight of tubers. *Porang* gardens in the Manufahi District were characterized by a distinct content of each of glucomannan, soil organic carbon, and organic soil compounds. It has been reported that glucomannan content in *porang* plants is linked to higher soil organic carbon content, which in turn improves soil structure and supports plant growth. Furthermore, soil pH in the *porang* garden of the Manatuto District correlated positively with glucomannan content and the number of bulbils. However, factors such as high air and soil temperatures were associated with a decrease in plant height, canopy width, tuber weight, and bulbil weight.

Conclusion

The morphological characteristics and nutrient content of *porang* (*Amorphophallus muelleri*) in Timor-Leste are significantly influenced by various environmental factors, including elevation and soil conditions. The study highlights the variability in growth and nutrient profiles across different districts, particularly noting the highest glucomannan concentration in the Bobonaro District. These findings underscore the importance of understanding local climatic influences on *porang* cultivation to optimize its agricultural potential.

Acknowledgment

This research was financially supported by a grant from the Center of Science Technology Excellence from the Porang Research Center of Brawijaya University.

References

1. Tornabene L, Valdez S, Erdmann M, Pezold F (2015) Support for a 'Center of Origin' in the Coral Triangle: Cryptic diversity, recent speciation, and local endemism in a diverse lineage of reef fishes (Gobiidae: Eviota). *Molecular Phylogenetics Evolution* 82 (Suppl PA): 200–210. doi: 10.1016/j.ympev.2014.09.012.
2. Market Development Facility (2021) https://marketdevelopmentfacility.org/wp-content/uploads/2021/03/Konjac-Farming-Guide-Web.pdf. Accessed date: August 2022.
3. Convention on Biological Diversity (2011) Timor-Leste's Fourth National Report to the UN Convention on Biological Diversity. https://www.cbd.int/doc/world/tl/tl-nr-04-en.pdf. Accessed date: January 2023.
4. Hornai EML, Vicente EF (2018) Kalendariu Ai-Horis Principal iha Timor-Leste. https://www.maf.gov.tl/tl/dokumentu. Accessed date: August 2022.
5. Wahidah BF, Afiati N, Jumari (2021) Community knowledge of *Amorphophallus muelleri* blume: Cultivation and utilization in central java, indonesia. Biodiversitas 22 (7): 2731–2738. doi: 10.13057/biodiv/d220722.
6. Nurlela, Ariesta N, Santosa E, Muhandri T (2019) Effect of harvest timing and length of storage time on glucomannan content in porang tubers. IOP Conf. Series: Earth and Environmental Science 299. In The 5th International Seminar on Science; October 2018, Bogor, Indonesia. doi: 10.1088/1755-1315/299/1/012012.
7. Nugrahaeni N, Hapsari RT, Trustinah et al. (2021) Morphological characteristics of Madiun 1, the First Porang (*Amorphophallus muelleri* Blume) released cultivar in Indonesia. In the Second International Conference on Sustainable Cereal and Crops Production System in the Tropics. 23-25 september 2021, Makasar, Indonesia. doi: 10.1088/1755-1315/911/1/012011.
8. Sookchaloem D, Sunkajanttranon O, Petchsri S et al. (2016) Leaf blade anatomy characteristics of the genus Amorphophallus Blume ex Decne. in Thailand. Agriculture Natural Resources. 50 (6): 437–444. doi: 10.1016/j.anres.2016.09.002.
9. A'yun Q, Harijati N, Mastuti R (2019) The selection technique of bulbil porang (*Amorphophallus muelleri* Blume) based on growth response. Jurnal of Environmental Engineering & Sustainable Technology. 06 (1): 30–35. doi: http: 10.21776/ub.jeest.2019.006.01.5.
10. Santosa E, Sugiyama N, Kurniawati A, Lontoh AP, Sari M, Krisantini (2018) Variation in floral morphology of agamosporous (*Amorphophallus muelleri* Blume) in natural and gibberellin induced flowering. Journal of Applied Horticulture. 20 (1): 15–23. doi: 10.37855/jah.2018.v20i01.03.
11. Dewi DFK, Azrianingsih R, Indriyani S (Eds) (2015) Struktur Embrio Porang (*Amorphophallus muelleri* Blume) Dari Berbagai Variasi Ukuran Biji. Jurnal Biotropika. 3 (3): 146–150.
12. Jansen PCM, van der Wilk C, Hetterscheid WLA (1996) Amorphophallus Blume ex Decaisne. In M. Flach, & F. Rumawas (Eds.), Plant Resources of South-East Asia 9. Plants yielding non-seed carbohydrates (pp. 45-50). Backhuys Publishers.
13. Gusmalawati D, Arumingtyas EL, Azrianingsih R, Mastuti R (2019) LC-MS analysis of carbohydrate components in Porang tubers (*Amorphophallus muelleri* Blume) from the second and the third growth period. Annual conference on Environmental Science, Society: 5-7 August 2019; Purwokerto, Indonesia. doi: 10.1088/1755-1315/391/1/012022.
14. Yanuriati A, Marseno DW, Rochmadi, Harmayani E (2017) Characteristics of glucomannan isolated from fresh tuber of Porang (*Amorphophallus muelleri* Blume). Carbohydrate Polymers. 20 (156): 56–63. doi: 10.1016/j.carbpol.2016.08.080.
15. Suryabrata S, eds. (2012) Metodologi Penelitian,1st Edition. RajaGrafin, Jakarta.
16. Rayment GE, Lyons DJ, eds. (2010) Soil Chemical Methods Australasia. 1st Edition. Australia, CSIRO.
17. Parasuraman S, Rao A, Balamurugan S, Muralidharan S, Kumar KJ, VijayanV (2015) An Overview of Liquid Chromatography-Mass Spectroscopy Instrumentation. Pharmaceutical Methods. 5 (2): 47–55. doi:

10.5530/phm.2014.2.2.

18. Hammer Ø, Harper DAT, Ryan PD (2001) PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontol Electron 4 (Supp 1): 1–9.
19. Rustiana R, Suwardji S, Suriadi A (2021) Pengelolaan Unsur Hara Terpadu Dalam Budidaya Tanaman Porang (Review). Jurnal Agrotek Ummat. 8 (2): 99-109. doi: 10.31764/jau. v8i2.5229.
20. Apu IR, Jawang UP, Nganji MU (2022) Analysis of Land Suitability for the Development of Porang (*Amarphopallus ancophillus*) Plants in Lewa Sub-Regency, East Sumba Regency. Jurnal Tanah dan Sumberdaya Lahan. 9 (1): 49–55, 2022. doi: 10.21776/ub.jtsl.2022.009.1.6.
21. Rahman FA, Kuswara RD, Nurmiati, Gazali Z, Ekaningtias M, Agustin D (2022) Analysis of Suitable Growth of Porang to Environmental Parameters in Selelos Village, Gangga District, Norht Lombok Regency. Braz Dent Journal. 33 (1): 1–12. doi: https://doi.org/10.51673/jips.v3i2.995.
22. Siswanto B, Karamina H (2016) Persyaratan lahan tanaman porang (*Amarphopallus ancophillus*). Jurnal Buana Sains. 16 (1): 57–70. doi: https://doi.org/10.33366/bs.v16i1.411.
23. Sonnewald S, Sonnewald U (2014) Regulation of potato tuber sprouting. Planta. 239 (1): 27–38. doi: 10.1007/s00425-013-1968-z.
24. Gusmalawati D (2021) Evaluasi Kualitas Umbi Porang (*Amorphophallus muelleri* Blume) Selama Periode Dormansi Hingga Muncul Tunas Berdasarkan Karakter Morfologi, Anatomi, Fisiologi Dan Biokimia. PhD thesis. Brawijaya University, Biology Science Department.
25. Butchbaker AF, Promersberger WJ, Nelson DC (1973) Respiration and Weight Losses of Potatoes During Storage. Farm Research. 30 (3): 33-40.
26. Gille S, Cheng K, Skinner ME et al. (2011) Deep sequencing of voodoo lily (*Amorphophallus konjac*): An approach to identify relevant genes involved in the synthesis of the hemicellulose glucomannan. Planta. 234 (3): 515–526. doi: 10.1007/s00425-011-1422-z.
27. Qur'ani N, Yuliani Y, Dewi SK (2021) Morphological Response and glucomannan Content in Porang Plant (*Amorphophallus muelleri* Blume) in Different Environments. Jurnal Lentera Bio. 9 (1): 74–81. doi: https: 10.26740/lenterabio.v9n1.p74-81.
28. Wijayanto N, Pratiwi E (2016) Pengaruh Naungan dari Tegakan Sengon (*Paraserianthes falcataria* (L) Nielsen) terhadap Pertumbuhan Tanaman Porang (*Amorphophallus onchophyllus*). Jurnal Silvikultur Tropika. 2 (1): 46–51. doi: 10.29244/j-siltrop.2.1.%25p.
29. Astuti ES, Suryati S, Bahri S, Masrullita M, Meriatna M (2022) Pengaruh waktu dan suhu perebusan pada umbi porang (*Amorphophallus muelleri* blume) menggunakan larutan NAHCO3 terhadap penurunan kadar kalsium oksalat. Jurnal Teknoli Kimia Unimal. 11 (1): 1-10. doi: 10.29103/jtku. v11i1.7243.
30. Azizi I, Kurniawan F (2021) Pengaruh Bibit Asal, Umur, dan Ukuran terhadap Kadar Glukomanan dan Kadar Oksalat dalam Umbi Porang. Jurnal Sains dan Seni ITS. 9 (2): 2337-3520. doi: 10.12962/j23373520.v9i2.58571.
31. Chairiyah N, Harijati N, Mastuti R (2023) The Relationship of glucomannan, Oxalate, and Crystal Development in Porang Tuber (*Amorphophallus muelleri* Blume). The Journal of Experimental Life Science. 13 (1): 1–11. doi: 10.21776/ub.jels.2023.013.01.01.
32. Kafiya M, Sutrisno N, Syarief R (2018) Perubahan kadar air dan pati ubi jalar (*Ipoema batats* L.) segar pada sistem penympanan sederhana. Jurnal Penelitian Pascapanen Pertanian. 13 (3): 136-145. doi: 10.21082/jpasca.v13n3.
33. Hafsah (2019) Keragaman Dan Peta Distribusi Edible Araceae Di Kabupaten Gowa, Sulawesi Selatan Serta Hubungannya Dengan Faktor Abiotik. Magister Thesis. Brawijaya University, Biology Science Department.
34. Sumarwoto, Puspitaningrum DA, Padmini OS (2020) Pengembangan Porang di Masyarakat Sekitar Hutan. 1st Edition. YOGYAKARTA.

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