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EFFECTS OF WATERLOGGING ON THE GROWTH OF TARO (*Colocasia esculenta* (L.) Schott) ACCESSIONS IN COASTAL AREA OF BENGKULU

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ABSTRACT

Taro (*Colocasia esculenta* (L.) Schott) is a vital tropical root crop with considerable potential for food diversification due to its nutritional and carbohydrate content. In Bengkulu Province, Indonesia—a region with rich taro genetic diversity in coastal agroecosystems—systematic evaluation of local accessions under waterlogging stress remains limited. This study assessed the effects of waterlogging depth and accession variability on taro growth using a Randomized Complete Block Design with three replications, evaluating ten local accessions under three waterlogging levels: 0 cm (control), 15 cm, and 30 cm. Results revealed significant ($p < 0.01$) differences among accessions for plant height, leaf width, leaf length, and stem diameter, indicating substantial genetic variation. Waterlogging significantly affected leaf width and length ($p < 0.01$) and plant height ($p < 0.05$), but not leaf number or stem diameter. No significant accession × waterlogging interaction was observed, suggesting consistent accession performance across treatments. Karang Tinggi (AK10) showed the greatest plant height (134.69 cm) and stem diameter (6.39 cm), while Bentiring 2 (AK4) exhibited the largest leaves. Moderate waterlogging (15 cm) did not impair growth relative to the control, but 30 cm waterlogging reduced leaf dimensions. These findings support the selection of resilient accessions like Karang Tinggi and Bentiring 2 for cultivation in flood-prone coastal areas and provide a foundation for breeding waterlogging-tolerant taro varieties.

Keyword: *accession variability, Colocasia esculenta, genetic diversity, waterlogging stress*

ABSTRAK

[PENGARUH GENANGAN AIR TERHADAP PERTUMBUHAN AKSESI TALAS (*Colocasia esculenta* (L.) Schott) DI KAWASAN PESISIR BENGKULU]. Talas (*Colocasia esculenta* (L.) Schott) merupakan tanaman umbi tropis yang penting dan memiliki potensi signifikan dalam diversifikasi pangan berkat kandungan nutrisi dan karbohidratnya. Di Provinsi Bengkulu, Indonesia—suatu wilayah yang kaya akan keanekaragaman genetik talas dalam agroekosistem pesisir—evaluasi sistematis terhadap aksesi lokal di bawah stres genangan air masih terbatas. Penelitian ini bertujuan mengevaluasi pengaruh kedalaman genangan air dan keragaman aksesi terhadap pertumbuhan talas menggunakan Rancangan Acak Kelompok Lengkap dengan tiga ulangan, melibatkan sepuluh aksesi lokal yang diuji pada tiga taraf genangan air: 0 cm (kontrol), 15 cm, dan 30 cm. Hasil menunjukkan adanya perbedaan nyata ($p < 0,01$) antar aksesi dalam parameter tinggi tanaman, lebar daun, panjang daun, dan diameter batang, mengindikasikan variasi genetik yang substansial. Genangan air secara signifikan memengaruhi lebar dan panjang daun ($p < 0,01$) serta tinggi tanaman ($p < 0,05$), namun tidak berpengaruh nyata terhadap jumlah daun maupun diameter batang. Tidak ditemukan interaksi signifikan antara aksesi dan perlakuan genangan air, yang mengisyaratkan konsistensi performa aksesi di berbagai kondisi genangan. Aksesi Karang Tinggi (AK10) menunjukkan tinggi tanaman tertinggi (134,69 cm) dan diameter batang terbesar (6,39 cm), sedangkan Bentiring 2 (AK4) menghasilkan daun terluas. Genangan air moderat (15 cm) tidak menghambat pertumbuhan dibandingkan kontrol, namun genangan 30 cm menyebabkan penurunan dimensi daun. Temuan ini mendukung seleksi aksesi toleran seperti Karang Tinggi dan Bentiring 2 untuk budidaya di kawasan pesisir rawan banjir serta memberikan dasar bagi pemuliaan varietas talas yang toleran terhadap genangan air.

Kata kunci: *Colocasia esculenta (talas), keanekaragaman genetik, keragaman aksesi, stres genangan air*

INTRODUCTION

Taro (*Colocasia esculenta* (L.) Schott) is one of the staple food crops with significant potential as a source of carbohydrates and nutrients, making it highly valuable for food diversification programs. This crop is widely cultivated and consumed across many parts of the world, including Indonesia, where approximately 10% of the global population uses taro as an alternative food source. In support of the Indonesian government's food diversification program, promoting taro cultivation is considered an appropriate strategy, as the crop requires relatively low cultivation inputs and offers a highly nutritious alternative to rice, primarily due to its carbohydrate-rich corms (Aditika *et al*., 2022). In Indonesia, taro-based products have been widely known for generations, with high production centers found particularly in Java, including Bogor, Malang, and Sumedang, which serve as major taro production hubs (Andarini & Risliawati, 2018).

Based on corm morphology, taro is classified into two major morphotypes: eddoe (*Colocasia esculenta* var. *antiquorum*), which produces multiple small corms, and dasheen (*Colocasia esculenta* var. *esculenta*), which produces a single large corm. In Indonesia, the dasheen type is more commonly cultivated, whereas eddoe represents a relatively recent introduction (Maretta *et al*., 2020). Taro is a highly versatile crop containing essential vitamins and minerals, and it can be processed into various high-value food products, making it a promising candidate for supporting food diversification efforts (Pitoyo *et al*., 2018). In Bengkulu Province, taro holds particular cultural significance; local communities, especially those living on Enggano Island, frequently use taro as an alternative staple food and prepare it as part of traditional culinary dishes, often in combination with fish and spices (Yulian *et al*., 2016).

Bengkulu Province is located on the southwest coast of Sumatra, directly facing the Indian Ocean, with a total area of 19,919.33 km², comprising nine regencies and one municipality. Approximately 525 km of its territory lies along the western coastline of Sumatra, creating diverse coastal agroecosystems suitable for cultivating various crops, including taro. The province possesses abundant genetic resources that remain largely unexplored, particularly in coastal areas where taro naturally grows wild. However, the utilization and management of these coastal resources are still suboptimal, with limited systematic inventories and sustainable conservation practices. Land-use decisions in these regions are often economically driven, with less consideration given to land suitability and environmental sustainability (Sayer *et al*., 2013).

In Bengkulu, wild taro populations are believed to possess a high level of genetic diversity, making them valuable for developing superior varieties. However, scientific information regarding taro exploration, genetic characterization, and phylogenetic relationships in this region remains limited. Characterization studies are essential as they serve as the foundation for plant breeding programs aimed at improving yield, quality, and adaptability (Miyasaka *et al*., 2019). Through comprehensive morphological and genetic characterization of taro accessions, researchers can identify key agronomic traits relevant for breeding superior genotypes (Lebot *et al*., 2004 ; Trimanto & Sugiyarto, 2010)). Previous studies have revealed significant variations among taro accessions in plant height, leaf greenness, pseudostem diameter, and the number of suckers (Simamora *et al*., 2018). Such information is crucial for classifying germplasm accessions and determining genetic relationships, ultimately guiding breeding strategies and conservation planning (Zhang *et al*., 2017 ; Maxted & Kell, 2009).

Despite its potential, taro genetic resources in Bengkulu's coastal areas remain underutilized and insufficiently studied. Sustainable conservation of taro genetic diversity requires detailed identification and characterization of accessions, particularly in coastal regions where environmental conditions such as water availability strongly influence growth performance. Furthermore, little is known about taro's adaptability and tolerance to waterlogging stress, a critical factor in coastal ecosystems prone to fluctuating soil moisture levels. Investigating taro's response to varying waterlogging conditions is therefore essential for identifying promising genotypes with superior growth performance and adaptability.

Given the limited understanding of taro's growth response and genetic variability under water-logging conditions, this study aims to evaluate the effects of different waterlogging levels and accession variations on the growth performance of taro (*Colocasia esculenta* (L.) Schott) in the coastal areas of Bengkulu. The findings are expected to provide valuable insights for breeding programs, conservation strategies, and the sustainable development of superior taro genotypes adapted to coastal environments.

MATERIALS AND METHODS

Research time and location

The cultivation experiment was carried out to evaluate the growth performance of the collected taro accessions. The study was conducted from March to June 2024 at the Experimental Farm in Sukamerindu Village, Sungai Serut District, Bengkulu City, situated at an altitude of approximately 10 meters above sea level (m a.s.l.).

Experimental design for Taro cultivation

The experiment was arranged using a Randomized Complete Block Design (RCBD) with two treatment factors and three replications, resulting in a total of 90 experimental units. Each experimental unit consisted of one taro seedling propagated from the crown section (huli).

First factor: Taro accessions (AK)

The first factor was taro accessions (AK) collected from different locations based on a morphological survey. A total of 10 accessions were evaluated: AK1: Padang Genting, AK2: Semarang, AK3: Bentiring 1, AK4: Bentiring 2, AK5: Kandang Limun, AK6: Bentiring 3, AK7: Pematang Gubernur, AK8: Urai, AK9: Marga Mulia, and AK10: Karang Tinggi.

Second factor: Waterlogging levels (T)

The second factor was the waterlogging level from the soil surface (T), which consisted of three levels: T_1: Control (no waterlogging), T_2: Waterlogging depth of 15 cm, and T_3: Waterlogging depth of 30 cm

Experimental setup

The combination of 10 taro accessions (AK) and 3 waterlogging levels (T) produced a total of 30 treatment combinations, each replicated three times, resulting in 90 experimental units overall. Each experimental unit consisted of one seedling transplanted into a polybag and subjected to the assigned waterlogging treatment.

Preparation of growing media

The growing media used in this experiment consisted of topsoil, farmyard manure, and rice husk charcoal mixed at a ratio of 2:1:1 (v/v). The prepared mixture was placed into 20 L plastic buckets that had been perforated at specific heights to regulate waterlogging levels according to the treatments: 0 cm (control), 15 cm, and 30 cm above the soil surface.

Preparation of planting materials

Taro accessions used in this study were obtained from a morphological survey conducted in coastal areas of Bengkulu. The planting materials were propagated from crown sections (huli) of selected taro plants, ensuring uniformity in plant size and initial growth stage.

Planting procedure

Taro seedlings from the prepared accessions were directly transplanted into the designated growing media. A single planting hole was made in the center of each bucket, and one seedling was placed per experimental unit to ensure uniform spacing and consistent growth conditions.

Fertilization

Fertilization was performed once**,** 14 days after planting (DAP)**,** using a balanced NPK compound fertilizer to provide additional nutrients and support early plant growth and development. The dosage and application were adjusted based on standard agronomic recommendations for taro cultivation.

Crop maintenance

Weeds were manually removed by hand-pulling to minimize competition for nutrients, water, and light. Pests and diseases were monitored regularly throughout the experiment. When necessary, appropriate fungicides and insecticides were applied following recommended dosages to manage specific pest and disease outbreaks effectively.

Observation variables for Taro cultivation

In this study, several morphological growth parameters were measured to evaluate the growth performance of taro (*Colocasia esculenta* (L.) Schott). Observations were conducted five times at 3, 5, 7, 9, and 11 weeks after transplanting (WAT) for all variables.

Plant height (cm)

Plant height was measured from the soil surface to the tip of the tallest leaf using a measuring tape. Measurements were performed five times at 3, 5, 7, 9, and 11 WAT to monitor growth dynamics.

Leaf width (cm)

Leaf width was determined by measuring the widest section of the middle part of a fully expanded leaf using a measuring tape. Observations were conducted five times at 3, 5, 7, 9, and 11 WAT.

Leaf length (cm)

Leaf length was measured from the base of the petiole to the tip of the longest leaf using a measuring tape. Measurements were carried out at the same observation intervals as other variables.

Number of leaves (leaves per plant)

The number of leaves was counted manually by recording only the fully expanded leaves for each plant. Observations were performed five times at 3, 5, 7, 9, and 11 WAT.

Stem diameter (cm)

The stem diameter was measured 1–5 cm above the soil surface using a digital caliper for accuracy. Measurements were conducted five times at 3, 5, 7, 9, and 11 WAT to evaluate stem development over time.

Data analysis

The observational data were analyzed using Analysis of Variance (ANOVA) at a 5% significance level. When significant differences among treatments were found, the means were further compared using Duncan's Multiple Range Test (DMRT) at the 5% level.

RESULTS AND DISCUSSION

A survey was conducted to identify local taro (*Colocasia esculenta*) accessions. Based on morphological characterization, ten accessions exhibited distinct morphological differences. These accessions were subsequently cultivated under different waterlogging levels. Vegetative propagation was carried out using the plant's crown portion (huli).

During field cultivation, the plants were infested by the tobacco hornworm (*Manduca sexta*), indicated by leaf tearing and perforation. The pests were controlled manually by handpicking. Leaf blight (*Phytophthora colocasiae*), characterized by yellow spots leading to leaf margin necrosis, was managed through a combination of manual pruning of infected leaves and chemical control using foliar application of fungicides containing 25% Trifloxystrobin and 50% Tebuconazole.

The ten taro accessions were analyzed using an analysis of variance (ANOVA) at the 5% significance level (Table 1). Treatments that showed significant differences were further analyzed using Duncan's Multiple Range Test (DMRT) at the 5% level.

The taro accession had a highly significant effect on plant height, leaf width, leaf length, and stem diameter, but no significant effect on the number of leaves. Waterlogging depth exerted a highly significant effect on leaf width and leaf length, a significant effect on plant height, and no significant effect on the number of leaves or stem diameter. No significant interaction was observed between the 10 taro accessions and waterlogging depth for any of the measured variables (Table 1).

Table 1. Summary of the results of the analysis of variance of the influence of waterlogging on taro growth in the coastal area of Bengkulu

Variable	Accession (AK)	Waterlogging level (T)	Interaction (AK x T)	CV (%)
Plant height	23.24 **	4.09 *	1.10 ns	7.98
Number of leaves	2.03 ns	1.54 ns	1.09 ns	15.63
Leaf width	13.09 **	16.54 **	1.45 ns	8.61
Leaf length	7.49 **	20.09 **	1.75 ns	9.76
Stem diameter	11.12 **	1.14 ns	1.18 ns	9.2

Note: ns = not statistically significant, * = statistically significant, ** = highly statistically significant

The growth and productivity of taro (*Colocasia esculenta* L. Schott), a staple tropical root crop, are significantly influenced when cultivated in coastal areas. Coastal environments present a unique set of abiotic stressors—including elevated soil and water salinity, fluctuating soil moisture regimes, poor natural drainage, persistent sea winds, and salt spray deposition—that can collectively constrain plant development and physiological function. Although taro is naturally adapted to humid, fertile, and moist lowland tropical soils, it exhibits considerable sensitivity to prolonged waterlogging and high salinity two environmental constraints commonly prevalent in coastal zones.

High concentrations of soluble salts in coastal soils and irrigation water impair root water and nutrient uptake through osmotic and ionic stress mechanisms. This leads to reduced turgor pressure, disrupted ion homeostasis, and ultimately manifests as stunted growth, leaf chlorosis, necrosis, and in severe cases, plant mortality (Tester & Davenport, 2003). Sodium (Na^+) and chloride (Cl^-) ions, in particular, can accumulate to toxic levels in plant tissues, interfering with enzymatic activity and photosynthetic efficiency.

While taro demonstrates moderate tolerance to high soil moisture, prolonged waterlogging frequently observed in low-lying coastal plains induces root hypoxia. Oxygen deficiency in the rhizosphere suppresses aerobic respiration, limits ATP production, and restricts root elongation and nutrient absorption. Consequently, above-ground biomass accumulation and corm development are significantly reduced (Setter & Waters, 2003).

Coastal winds laden with saline aerosols deposit salt crystals directly onto leaf surfaces. This foliar salt deposition causes physical damage to epidermal and mesophyll tissues, reduces stomatal conductance, impairs photosynthetic capacity, and accelerates water loss via transpiration even under adequate soil moisture conditions (Munns & Tester, 2008). These effects are particularly detrimental during early vegetative growth stages.

Certain taro landraces or accessions may exhibit enhanced tolerance to coastal stressors, especially those originating from or traditionally cultivated in marginal coastal ecosystems. Natural and farmer-led phenotypic selection over generations may have favored genotypes with improved salinity exclusion, aerenchyma development for hypoxia tolerance, or cuticular wax layers that mitigate salt spray damage. As noted by Onwueme (1999), taro possesses a broad ecological plasticity and can be cultivated across diverse agroecosystems including marginal lands provided that salinity is minimized and adequate drainage is ensured.

Successful taro cultivation in coastal regions requires integrated management strategies, including the selection of stress-tolerant genotypes, implementation of raised-bed or mound planting systems to improve drainage, pre-planting leaching to reduce soil salinity, and the use of organic mulches to buffer soil microclimate and reduce salt accumulation at the surface. Future research should focus on phenotyping diverse taro germplasm under controlled and field-based coastal stress conditions to identify and deploy resilient cultivars for sustainable production in vulnerable coastal agroecosystems.

The following section presents a summary of the post-hoc mean separation analysis conducted using Duncan's Multiple Range Test (DMRT) at the 5% significance level. This analysis compares the growth performance of the 10 taro accessions cultivated in a coastal agroecosystem, allowing for the identification of statistically distinct groups for each measured trait (Table 2). Accessions sharing the same letter within a trait column are not significantly different, while those assigned different letters exhibit significant divergence in phenotypic expression.

Plant height exhibited significant variation among the 10 evaluated taro (*Colocasia esculenta*) accessions, with Accession 10 (originating from Karang Tinggi village) recording the tallest mean height (134.69 cm), while Accession 6 (from Bentiring subdistrict) displayed the shortest (88.69 cm). These differences in plant stature are attributable to inherent genetic variability among accessions, as well as genotype-by-environment interactions that modulate developmental plasticity under coastal stress conditions. Plant height expression is strongly influenced by genetic potential and pre-stress developmental status particularly under waterlogging or salinity exposure, which are common in coastal agroecosystems.

Table 2. Mean comparison of growth traits among 10 taro (Colocasia esculenta) accessions using Duncan's Multiple Range Test

Accession (AK)	Plant height (cm)	Number of leaves (leaves per plant)	Leaf width (cm)	Leaf length (cm)	Stem diameter (cm)
(AK 1) Padang Genting	103.91 cd	4.44 a	27.07 de	37.70 cd	5.18 cd
(AK 2) Semarang	118.83 b	4.31 ab	30.81 b	44.45 ab	5.76 b
(AK 3) Bentiring 1	107.93 c	3.51 c	29.96 bc	41.08 bc	5.36 bcd
(AK 4) Bentiring 2	97.38 de	3.75 bc	35.80 a	46.24 a	5.30 bcd
(AK 5) Kandang Limun	121.26 b	4 abc	30.18 bc	43.18 ab	5.40 bcd
(AK 6) Bentiring 3	88.69 f	3.8 abc	27.34 de	40.43 bc	4.59 ef
(AK 7) Pematang Gubernur	103.91 cd	3.97 abc	27.69 cd	35.73 d	5.63 bc
(AK 8) Urai	93.97 ef	3.88 abc	24.92 e	35.28 d	4.54 f
(AK 9) Marga Mulia	106.79 c	3.93 abc	32.37 b	41.06 bc	5.04 de
(AK 10) Karang Tinggi	134.69 a	3.57 c	30.01 bc	42.89 ab	6.39 a

Note : Values followed by the same letter within a column are not significantly different

The observed phenotypic divergence aligns with broader principles of crop physiology and genetics: distinct varieties possess unique allelic combinations that govern growth architecture, stress responsiveness, and resource allocation efficiency. Genetic heterogeneity among cultivars directly influences morphological traits, yield potential, and adaptive capacity factors that are especially critical in marginal environments such as coastal zones.

Regarding leaf traits, Accession 1 (Padang Genting village) produced the highest mean leaf number (4.44 leaves per plant), whereas Accession 3 recorded the lowest (3.51 leaves). Leaf width was maximized in Accession 4 (35.80 cm) and minimized in Accession 8 (24.92 cm). Similarly, leaf length peaked in Accession 4 (46.24 cm; Bentiring subdistrict) and was lowest in Accession 8 (35.28 cm). For stem diameter an indicator of structural robustness and assimilate partitioning Accession 10 again demonstrated superiority (6.39 cm), contrasting with the narrowest stem observed in Accession 8 (4.54 cm).

These morphological disparities underscore the role of genetic constitution in determining phenotypic expression under uniform environmental conditions. Furthermore, they highlight the potential for selecting high-performing accessions for targeted breeding or direct cultivation in coastal areas, where resilience and vigorous vegetative growth are essential for productivity

The tallest local food taro plants were observed under the 15 cm water flooding treatment, as indicated by the variables of plant height, leaf width, and stem diameter (Table 3).

Table 3. Average growth of local food taro accessions under different water flooding depths

Waterlogging level (cm)	Plant height (cm)	Number of leaves (leaves)	Leaf width (cm)	Leaf length (cm)	Stem diameter (cm)
0	106.81 b	4.01 a	30.63 a	42.76 a	5.31 a
15	111.28 a	3.98 a	30.78 a	42.61 a	5.42 a
30	105.13 b	3.76 a	27.43 b	37.04 b	5.22 a

Note: Means followed by the same letter in the same column are not significantly different according to DMRT at the 5% level

Analysis results demonstrate that the 15 cm flooding depth treatment showed a significant difference in plant height. The 30 cm flooding depth treatment significantly affected leaf width and leaf length. However, no significant differences were found among the treatments for the number of leaves and stem diameter. The taro plants exhibited plant heights ranging from 105.13 to 111.28 cm; leaf numbers between 3.76 and 4.01 leaves; leaf widths between 27.43 and 30.78 cm; leaf lengths from 37.04 to 42.76 cm; and stem diameters between 5.22 and 5.42 cm.

These findings align with those of Njuguna *et al*. (2023) and Cahyanti *et al*. (2022), who reported that water management practices had a highly significant effect on plant height and tiller number, as well as a significant impact on stem diameter and canopy width of taro plants. This indicates that taro cultivated in adequately flooded or moist conditions exhibits normal growth, reflecting its adaptability to wet or waterlogged environments. Furthermore, providing optimal environmental conditions, supplemented by adequate nutrient supply, is essential for promoting healthy taro growth (Njuguna *et al*., 2023 ; Santosa, 2020 ; Hidayatullah, 2020).

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CONCLUSION

Accession had a highly significant effect ($p < 0.01$) on plant height, leaf width, leaf length, and stem diameter, indicating substantial genetic variability among the evaluated accessions in their growth responses. In contrast, waterlogging level significantly affected leaf width and leaf length ($p < 0.01$) and plant height ($p < 0.05$), but not the number of leaves or stem diameter. The lack of significant interaction between accession and waterlogging level suggests that the relative performance of accessions remained consistent across the tested waterlogging conditions.Among the ten accessions, Karang Tinggi (AK 10) exhibited superior performance in plant height (134.69 cm) and stem diameter (6.39 cm), while Bentiring 2 (AK 4) produced the widest leaves (35.80 cm) and longest leaves (46.24 cm). Conversely, Urai (AK 8) and Bentiring 3 (AK 6) showed comparatively lower growth metrics, particularly in plant height and stem diameter. Concerning waterlogging tolerance, taro plants subjected to 15 cm of waterlogging exhibited the highest plant height (111.28 cm), statistically comparable to the control (0 cm), and maintained similar leaf dimensions and stem diameter. However, at 30 cm waterlogging, significant reductions were observed in leaf width (27.43 cm) and leaf length (37.04 cm), indicating that prolonged or deeper waterlogging negatively impacts leaf development, although plant height and stem diameter remained relatively stable. These outcomes provide a scientific basis for developing taro-based cropping systems resilient to climate-induced flooding in coastal regions. Future research should integrate yield and tuber quality assessments under waterlogged conditions to validate the agronomic potential of the identified high-performing accessions. Additionally, breeding programs could utilize these accessions as parental lines to develop waterlogging-tolerant taro cultivars suited for marginal coastal environments.

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