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POPULATION, HABITAT, AND PHYTOCHEMICAL PROPERTIES OF *NIBUNG* (*Oncosperma tigillarium* [JACK.] RIDL.) IN RIAU, INDONESIA

DESTI[1,2*], R. MASTUTI[2], R. AZRIANINGSIH[2], and E.L. ARUMINGTYAS[2]

[1]Department of Biology Education, Faculty of Teacher Training and Education, Islamic University of Riau, Riau, Indonesia
[2]Department of Biology, Faculty of Mathematics and Natural Science, Brawijaya University, Malang, Indonesia
*Corresponding author's email: destibio@edu.uir.ac.id
Email addresses of co-authors: mastuti7@ub.ac.id, rodiyati@ub.ac.id, laras@ub.ac.id

SUMMARY

Nibung (*Oncosperma tigillarium* [Jack.] Ridl.) is a valuable palm species, widely used in construction and as a food and source of bioactive compounds in pharmaceutical industries. This significant *nibung* germplasm in the provincial mascot of Riau is facing threats from land conversion and urbanization. For its conservation strategies, it is essential to understand its profile about population, habitat, and important traits. This study aimed to characterize the population of *nibung* and its secondary metabolites linked to environmental conditions. In a comparison between coastal and non-coastal populations of *nibung*, the study revealed considerable environmental effects on its growth. Results showed that *nibung* from non-coastal locations (grown in sandy clay and clay loam soils) showed larger size but smaller clumps, while coastal samples (grown in silty clay soil) grew shorter, with larger clumps. The phosphate, linked to higher flavonoid contents, was abundant in non-coastal areas, and potassium negatively affected the stem size. These findings could play a crucial role in the *nibung's* genetic potential, development, and cultivation and help in conservation strategies, especially in Riau, Indonesia.

Keywords: *Nibung* (*O. tigillarium*), population, habitat, secondary metabolites, phytochemical properties, conservation strategies

Key findings: The soil and microclimate affect the population, habitat, and secondary metabolites of *nibung* (*O. tigillarium*). Nibung grown in non-coastal areas were notable with smaller clumps, larger stems, and higher flavonoid content. Meanwhile, it has more individuals per clump with smaller and shorter stems in coastal areas.

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INTRODUCTION

Nibung (O. tigillarium [Jack] Ridl.) is a monocotyledon species that belongs to the family Arecaceae, which has a wide utilization by the community (Dransfield and Uhl, 1998). The said family plants have served as a source of traditional food, a side dish, and livelihood. It has links to their secondary metabolite contents rich in lipophilic bioactive compounds, especially carotenoids, polyunsaturated fatty acids, tocopherols, and vitamin A. Moreover, these plants have massive phenolic compounds, fiber, and minerals (Souza *et al*., 2020).

Nibung is prevalent in Southeast Asia (Henderson and Borchsenius, 1997), including various regions in Riau Province and Sumatera, Indonesia. The said plant serves as a cultural emblem for the Malay community in Riau, becoming useful for numerous purposes, such as its trunk as a building material because of its strength, while its shoots are widely used in various events, including traditional dishes, for their special tastes and high-fiber content (Desti *et al*., 2019). The local community prepares a range of dishes using *nibung*, typically involving two main processes: boiling and subsequently making 'gulai lemak,' which includes coconut milk and some assortment of curry spices (Desti *et al*., 2024).

Nibung exhibited considerable adaptability, thriving in a wide range of environments, from coastal areas in Riau, including Bengkalis, Meranti Islands, Indragiri Hilir, Dumai, and Rokan Hilir, to non-coastal forests, such as in Kuantan Singingi, Indragiri Hulu, and Rokan Hulu, Indonesia. The topography of these areas plays a significant role in shaping the unique characteristics of flora at each location (BPS, 2021). These regencies comprise both lowland and highland terrains with diverse elevations in Riau, starting from a height of zero meters above sea level (masl) up to more than 400 masl. The wide distribution of *nibung* habitats highlights the critical role of abiotic factors, such as soil and microclimate, in shaping its characteristics across different environments (Broschat, 2008).

Understanding how *nibung* adapts to these environmental conditions offers insights into its ecological traits and supports sustainable resource management, especially in Riau. However, scientific information is lacking regarding *nibung*; hence, it is unfamiliar to the Riau community. Furthermore, the habitat degradation and land use variations also pose threats to the *nibung* population. As a result, the uncertainty on how to handle specific conservation issues lingers, as well as how to develop conservation strategies and research objectives.

The *nibung* population study emphasized the need to understand its characteristics, secondary metabolite composition, and the various factors affecting its traits. It includes investigating the link between environmental conditions and secondary metabolites, which play a pivotal role in the plant protection mode and have a wide range of applications (Pant *et al.,* 2021). These insights support conservation efforts, sustainable resource management, and the development of agronomic strategies to enhance *nibung's* cultivation while exploring its bioprospecting potential.

The analysis of population profile and secondary metabolite compounds of *nibung* can reveal the plant's profile concerning its growth factors in Riau Province. Therefore, analysis of its population profile is necessary because it is one of the crucial factors for describing the uniqueness of a population, such as observing vitality, periodicity, sociability, and stratification in plants (Braun-Blanquet, 2007). It also provides the population profile of *nibung* in Riau, as well as an analysis of secondary metabolites in this valuable species.

MATERIALS AND METHODS

Study area

This study, carried out in Riau Province, Indonesia, encompassed both coastal and non-coastal areas, with two regencies in each representative location (Figure 1). The coastal areas included Bengkalis and Meranti Island,

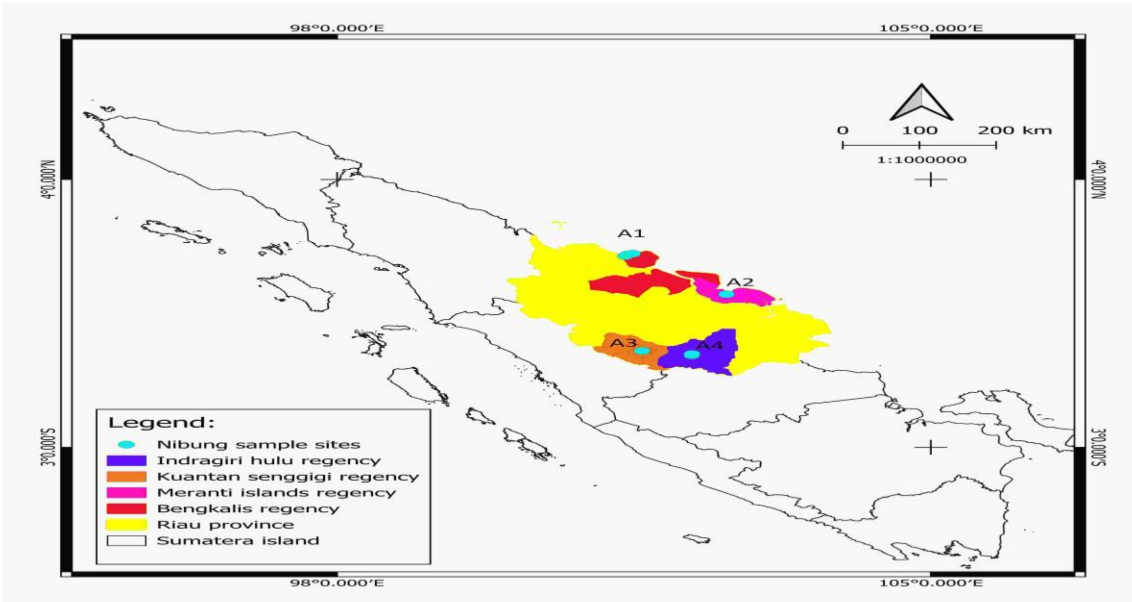

Figure 1. *Nibung* locations in Riau, consisting of coastal locations, namely, Tanjung Medang Village, Rupat Island, Bengkalis Regency (A1) and Mekong Village, Pulau Meranti District (A2), and non-coastal locations, consisting of Sentajo Protected Forest, Kuantan Singingi District (A3) and Talang Durian Cacar Village, Indragiri Hulu Regency (A4).

while the non-coastal consisted of Kuantan Singingi and Indragiri Hulu, Indonesia. The first location was the Tanjung Medang Village, located on Rupat Island in the North Rupat Subdistrict of Bengkalis Regency. The second location was the Mekong Village, situated in the Tebing Tinggi District of Meranti Island Regency. The third location was the Sentajo Protected Forest, found in the Sentajo Raya District of Kuantan Singingi Regency. The fourth location was the Talang Durian Cacar Village, located in the Peranap Subdistrict of Indragiri Hulu Regency.

Population analysis

The application of the transect sampling method assessed the *nibung* population and its habitat, with the data collected along transects (Brancalion *et al.,* 2012; Yudaputra, 2018). All the locations were accessible by foot, through existing footpaths, until finding a *nibung* clump. The creation of a straight-line transect resulted from the first point where the *nibung* appeared to the South. Then, making a square plot along the transect line enabled researchers to see the observed population. A 20 m × 20 m square plot aided in assessing the juvenile and mature, while a 2 m × 2 m square plot within the 20 m × 20 m plot was for seedlings. The documentation of subplots totaled 72 in this study.

For *nibung*, field observations of the known locations succeeded in describing its population profile, which includes characterization of vitality, periodicity, sociability, and stratification (Table 1). Several characters and criteria served as guidelines for observing the vitality, periodicity, sociability, and stratification of *nibung*, as explained below (Braun-Blanquet, 2007).

In this study, the number of individuals per clump, averages of diameter, and height of mature individuals (stem height) were the parameters used for describing the population of *nibung* in Riau (Widyatmoko *et al*., 2005; Yudaputra, 2018). Measurements included the number of individual plants within each clump, stem diameter at breast height (DBH) for adults to determine the basal area, and height of the mature stem (Ratsirarson *et al.,* 1996; Elias *et al.,* 2019).

Table 1. Criteria of vitality, periodicity, sociability, and stratification of *nibung.*

Criteria	Vitality	Periodicity	Sociability	Stratification
1	*nibung* was found in the form of a tree, not growing well, and with no shoots or seedlings	if no flowers and fruits were found	the individual of the *nibung* lives solitary	-
2	*nibung* was found in the form of a tree, not growing well, and with shoots or seedlings	if only flower was found	individual lives in small groups	-
3	*nibung* was found in the form of a tree, growing well, but with no shoots or seedlings	if only fruit was found	if the individual lives in large groups/rows	-
4	*nibung* was found in the form of a tree, growing well, with shoots or seedlings	if flowers and fruits were found	individual lives in colonies covering the surface of the ground	-
5	-	-	individual lives in very large groups	-
A	-	-	-	if the height is more than 30 m
B	-	-	-	if the tree height is 20–30 m
C	-	-	-	if the tree height is 4–20 m
D	-	-	-	if the height is 1–4 m
E	-	-	-	if the height is 0–1 m

Analysis of soil characteristics and microclimate

Around the *nibung* sites, the soil sampling process included clearing the soil surface of grass and litter. Subsequently, digging the soil to a depth of 30 cm had a distance of approximately 120 cm from the *nibung's* clump. The placing of the obtained soil samples into a plastic bag followed. Analysis of the collected soil samples continued at the Soil Laboratory, Faculty of Agriculture, University of Riau, Indonesia.

Soil characteristics included soil physics, namely, soil texture (consisting of sand, silt, and clay). Furthermore, acquiring the soil's chemical composition comprised the following steps: pH (with the 1:5 extraction method), C-organic content (with the Walkley and Black method), total N (with the Kjeldahl method), P_2O_5 (with the Bray 1 method), K_2O (with the 25% HCl method), cation exchange rate (with the 1N NH4-Acetate pH7 method), Ca and K, and the cation exchange capacity (Zulkarnaen *et al.,* 2022). Obtaining the base saturation (BS) and Fe used the AAS method.

The use of the "Map Coordinate" application obtained the coordinate data downloaded from the Vivo29E smartphone and determined the position of each location. Collection of the microclimate data also took place from the Riau Meteorology, Climatology, and Geophysics Center (BMKG), Riau, Indonesia, including temperature, humidity, rainfall, and wind speed (Zulkarnaen *et al.,* 2022).

Analysis of secondary metabolite content

The investigation of secondary metabolites (alkaloids, flavonoids, phenols, and saponins) in the *nibung* population was successful. Twelve *nibung* accessions' sampling across four locations ensued during September-November 2023. Qualitative tests identified metabolites through color variations, as performed using established methods: Mayer's test for alkaloids, the foam test for saponins, the ferric chloride test for phenols, and the Mg-hydrochloride reduction test for flavonoids (Gutiérrez-Grijalva *et al.* (2020). Quantitative assessment measured the total phenols and flavonoids in the heart and buds of *nibung* that tested positive only. The Folin-Ciocalteu method, as employed, utilized the UV-Vis Spectrophotometer Agilent Cary 8454 for obtaining the total quantitative testing result (Sammanta *et al*., 2024). All analytical procedures transpired at the Vahana Scientific Laboratory in Padang, West Sumatera, Indonesia.

Data analysis

Descriptive analysis (+/-) representing secondary metabolites continued with one-way analysis of variance (ANOVA), UPGMA clustering, PCA, and Pearson correlation analysis. These examined the relationship between the four *nibung's* locations regarding population characteristics, habitat, and secondary metabolites.

RESULTS AND DISCUSSION

Population profile

All *nibung* populations found had the same form as trees and had good growth rates, growing in small groups, and were producing fruits. The *nibung* in Riau Province has the same criteria of vitality, periodicity, and sociability; however, it has different stratifications (Table 2).

Habitat appears to have remarkable effects on the *nibung's* clump, with immediate consequences for differences in tree diameter and height, indicating its varied characteristics. *Nibung* from the coastal areas had nearly twice as many individuals per clump compared with non-coastal locations. Non-coastal populations exhibited taller trunks with a large diameter, likely due to higher soil phosphate levels and lower potassium levels than coastal areas. Conversely, in coastal areas, *nibung* populations exhibited higher individual density per clump, with smaller diameters, reflecting adaptation to local environmental conditions. These findings aligned with the *nibung* population in other locations in Riau, with classifications according to habitat type (Fitmawati *et al.,* 2022). Similar patterns also emerged in other palm species, *palmiteiro* (*Euterpe edulis*) and *motacú* (*Attalea princeps*) producing larger trunks in higher locations with low diameter (Brancalion et al,. 2012; Elings, 2018).

In this case, the habitat and soil conditions, especially the soil chemical content, affected the *nibung's* population in Riau (Table 3). The chemical composition of the soil also showed differences between coastal and non-coastal locations, especially for C-organic content, total phosphate, and soil potassium, as well as CEC values (Brancalion *et al.,* 2012). In non-coastal locations with higher CEC, soil organic C, and total phosphate values, the larger and taller stems were evident. Reports disclosed several factors affected the size of palm trees (Pulido *et al.,* 2007). The DBH in *palmiteiro* (*E. edulis*) had notable habitat-mediated effects, particularly soil-related factors (Brancalion *et al*., 2012). Likewise, *motacú* (*A. princeps*) sustained influences from the chemical conditions of the soil (Elings, 2018).

Habitat profile

Soil analysis showed significant differences in the physical and chemical properties of the soil surrounding the *nibung's* habitat in Riau (Table 3). Soil from non-coastal locations, namely, in Kuantan Singingi, exhibited a sandy clay texture, and samples from Indragiri Hulu have a clay loam texture. The soil from coastal areas, i.e., Bengkalis and Meranti Islands, tends to be silty loam.

Soil composition is an essential factor, and the soil texture has a correlation regarding *nibung's* diameter and its height. These findings were greatly analogous to the findings of previous research on the effects of soil characteristics on tree regeneration of the other palm member, *motacú* (*A. princeps*), where the regeneration of palm has a negative relation with clay content (Elings, 2018). Brancalion *et al.'s* (2012) findings revealed soil chemistry considerably affects the palm growth, with *E. edulis* in the nutrient-rich Atlantic Forest showing larger stems, while sodium-rich Restinga Forest soils resulted in slower growth and smaller diameter.

Table 2. Individual variation and measurement of attributes in *nibung* at Riau.

No.	Criteria	Locations			
		Coastal		Non-coastal	
		Bengkalis	Meranti Island	Kuantan Singingi	Indragiri Hulu
1	Vitality	Vit. 4	Vit. 4	Vit. 4	Vit. 4
2	Periodicity	Per. 3	Per. 3	Per. 3	Per. 3
3	Sociability	Soc. 2	Soc. 2	Soc. 2	Soc. 2
4	Stratification	Stratum B	Stratum B	Stratum A	Stratum A
5	Mean number of individuals per a clump	8 ± 2.6[b]	11.67 ± 2.1 [b]	6.67 ± 2.6 [a]	5.67 ± 2.3 [a]
6	Average of diameter of mature stems (cm)	15.1 ± 2.3 [ab]	12.27 ± 1.08 [a]	17.33 ± 2.75[bc]	21.07 ± 2.68 [c]
7	Average of height of mature individuals (m)	11.15 ± 2.7 [a]	10.27 ± 2.3 [a]	16.58 ± 2.6 [ab]	17.87 ± 2.1 [b]

Note: numbers followed by the same letter in the same parameter are not significantly different.

Table 3. Abiotic factors of *nibung's* habitat in Riau.

Criteria	Locations			
	Coastal		Non-coastal	
	Bengkalis	Meranti Island	Kuantan Singingi	Indragiri Hulu
Soil characteristics				
Texture				
Sand (%)	31.93	23.91	66.60	57.68
Silt (%)	51.90	50.73	10,56	13.13
Clay (%)	16.17	25.36	22.84	29.19
Chemical content				
pH H_2O	5.37	4.62	5.50	5.24
C-organic (%)	1.31	12.04	1.53	2.90
N total (%)	0.18	0.83	0.18	0.11
P_2O_5 (ppm)	8.17	14.22	29.90	15.67
K_2O (mg/100 g)	40.51	54.47	38.22	30,37
Ca (me/100 g)	0.16	4.02	0.33	0.28
K (me/100 g)	0.18	0.73	0.14	0.14
CEC (me/100 g)	14.72	42.59	18.69	17.85
BS (%)	5.98	34.02	4.92	4.78
Fe (ppm)	9680	6225	11985	6000
Micro-climate				
Temperature (°C)	27.64	28.84	27.29	27.51
Humidity (%)	82.09	85.71	85.08	86.27
Wind speed (km/h)	0.56	1.46	1.69	0,97
Precipitation (mm)	6.47	18.72	10.08	4.49

Environmental data from *nibung* sampling sites in Riau revealed the habitat differences (Table 3). Coastal locations have lower humidity, higher temperatures, and nearly double the rainfall of non-coastal locations, despite reduced wind speed. Average rainfall at coastal locations was almost twice as high as at non-coastal locations. Higher rainfall in coastal areas supports larger *nibung* clumps, like the lipstick palm (*Cyrtostachys renda*) in Sumatra, which indicates the water-sensitive peat swamp ecosystems (Widyatmoko *et al.,* 2005).

These findings align with the studies on tropical palms, and the habitat variability and soil composition substantially affect the growth and population profile. Tropical forests are highly variable ecosystems wherein these processes occur and can provide a mosaic of different habitat conditions (Pulido *et al*., 2007;

Table 4. Qualitative test results for the secondary metabolites in *nibung* from Riau.

Nibung parts	Parameters	Code/locations											
		B1	B2	B3	M1	M2	M3	K1	K2	K3	I1	I2	I3
Heart of palm	Alkaloid	-	-	-	-	-	-	-	-	-	-	-	-
	Flavonoid	-	-	-	-	-	-	-	-	-	-	-	-
	Saponin	-	-	-	-	-	-	-	-	-	-	-	-
	Phenol	+	+	+	+	+	+	+	+	+	+	+	+
Buds	Alkaloid	-	-	-	-	-	-	-	-	-	-	-	-
	Flavonoid	-	-	-	-	-	-	+	+	+	+	+	+
	Saponin	-	-	-	-	-	-	-	-	-	-	-	-
	Phenol	+	+	+	+	+	+	+	+	+	+	+	+

Note: coastal locations: B1 = Bengkalis 1, B2 = Bengkalis 2, B3 = Bengkalis 3 and M1 = Meranti 1, M2 = Meranti 2, M3 = Meranti 3; non-coastal locations: K1 = Kuantan Singingi 1, K2 = Kuantan Singingi 2, K3 = Kuantan Singingi 3 and I1 = Indragiri Hulu 1, I2 = Indragiri Hulu 2, and I3 = Indragiri Hulu 3.

Jansen *et al*., 2012; Otárola and Avalos, 2014). Geographical and ecological factors influence the family Arecaceae populations (Souza *et al*., 2020), i.e., date palms, which adapt to abiotic stress through protective strategies. Al-Kaabi (2021) highlighted the Sultana cultivar's tolerance linked to variations in secondary metabolite properties.

Secondary metabolites

The qualitative tests authenticated the presence of secondary metabolites in *nibung* (Table 4). The results showed each part of the *nibung* has positive phenol content in all samples tested and flavonoids in the buds of samples from non-coastal locations (Kuantan Singingi and Indragiri Hulu). Phenols and flavonoids' positive identification surfaced in all parts of the *nibung*. Phenols, including flavonoids, were the significant bioactive compounds in the family Arecaceae, promoting root and stem growth (Souza *et al*., 2020; Ngaffo *et al*., 2021).

Quantitative analysis of *nibung's* heart of palm and buds showed the varied content of phenols and flavonoids in four locations (Figure 2) obtained by UV-Vis spectrophotometry. In the heart of *nibung*, the highest phenol content was prominent in the Bengkalis location (Figure 2A), followed by *nibung* found at the Kuantan Singingi (2.5 mEQ/g). In added details, more than 1 mEQ/g of heart of *nibung's* phenol reached estimation in samples from the Indragiri Hulu. These values were almost one-third of the sample from the phenol content of samples from Bengkalis, and the lowest was in the samples of Meranti Island. For buds, Kuantan Singingi had the highest phenol content (4 mEQ/g), followed by Bengkalis (3 mEQ/g) and Meranti Island (2 mEQ/g), while Indragiri Hulu had the lowest (1.06 mEQ/g). Flavonoids only emerged in *nibung* buds obtained from non-coastal areas (Kuantan Singingi and Indragiri Hulu), while coastal area samples gave negative results (Figure 2B). In short, samples from Kuantan Singingi seem to have the highest averages of phenol and flavonoid contents.

Differences in the *nibung's* habitats received influences from abiotic and microclimatic factors, which also affect the secondary metabolite content in its heart and buds. Environmental variations, such as temperature and water, trigger adaptive responses altering secondary metabolite production (Thakur *et al*., 2019; Li *et al*., 2020). The variations in rainfall conditions and relief positions can cause a mosaic of soil types that vary greatly in the landscape (Brady and Weil, 1996). In another example, oil palms exposed to different environmental pressures adapt to abiotic pressures by producing secondary metabolites (Adrian *et al*., 2024).

Nibung populations made different clusters based on characteristics and metabolite content. At a 2500 Euclidean distance, *nibung* populations form three clusters: Indragiri Hulu, Kuantan Singingi, and a combined Meranti Island-Bengkalis group. Indragiri Hulu closely resembles Kuantan Singingi but differs significantly from Bengkalis

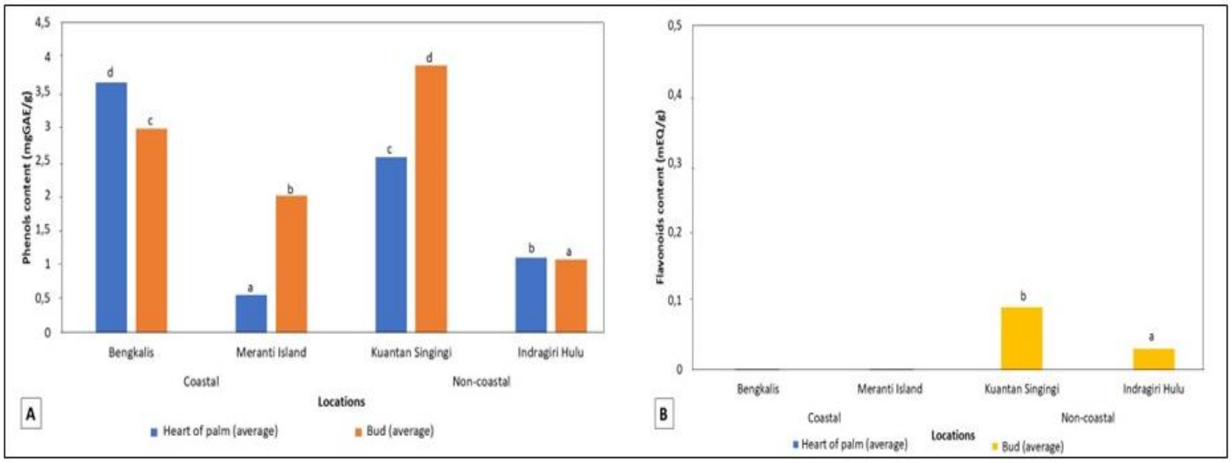

Figure 2. Secondary metabolite content of *nibung* from Riau. Note: numbers followed by the same letter in the same parameter are not significantly different.

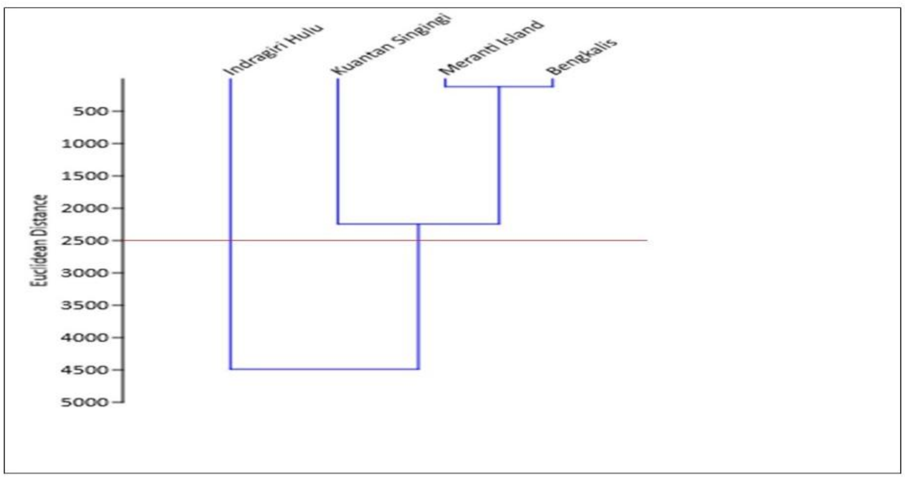

Figure 3. Phenotype tree construction using the Unweighted Pair Group Method with Arithmetic Mean (UPGMA) showing clustering based on the Euclidean distance in *nibung* across four different locations in Riau.

(Figure 3). Principal component analysis (PCA) comprehends a grouping of four different *nibung* population profiles based on the locations (Figure 4). Thus, the PCA analysis showed influences on the population and secondary metabolites of *nibung* resulted from variations in habitat conditions.

Nibung population in the Bengkalis location showed distinction in high pH, potassium, Fe, N-total, and phenols content of the *nibung* palm heart and buds, with low C-organic, humidity, and smaller stem diameter (Figure 4). Furthermore, Meranti Island had characteristics of higher temperature, humidity, wind speed, precipitation, Base Saturation (BSA), and numerous individuals per clump, with a low pH, P_2O_5, Ca, and flavonoids in the buds. However, in contrast, the *nibung* populations in Kuantan Singingi and Indragiri Hulu were characterized by higher mature trunks and diameter, P_2O_5, and bud's flavonoid contents, while lower K_2O and number of individuals per clump.

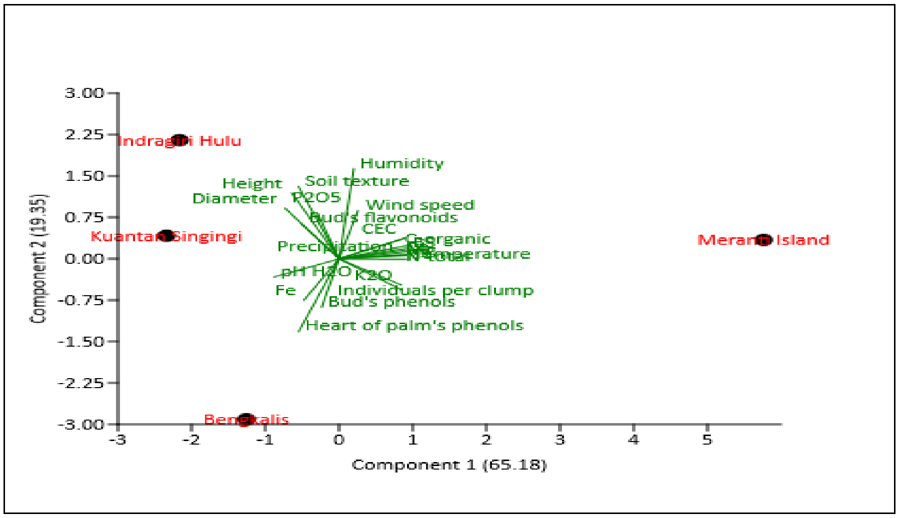

Figure 4. Biplot of the PCA analysis in *nibung* from Riau.

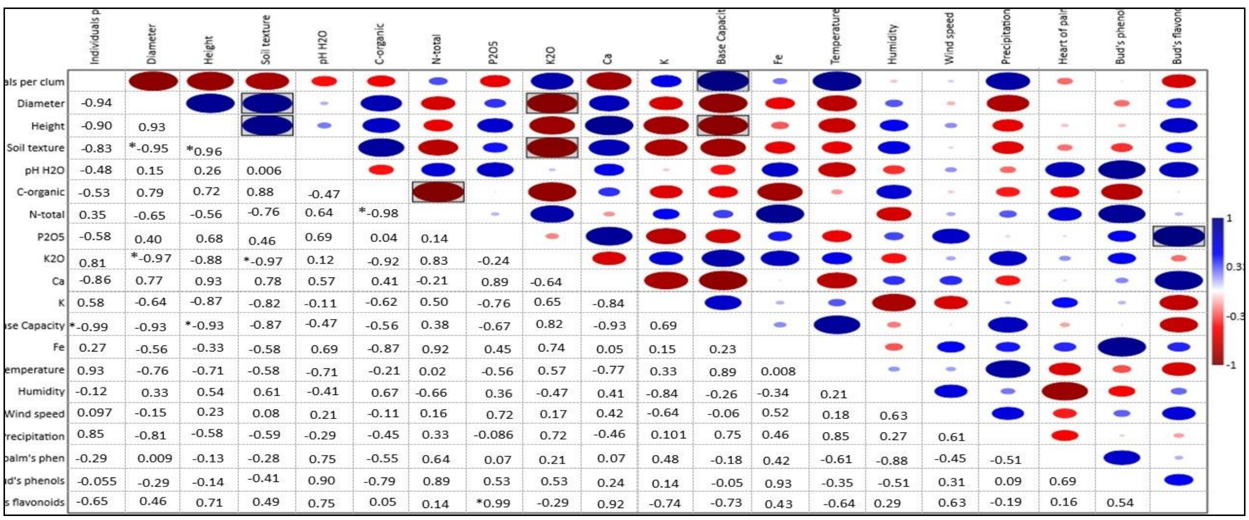

Figure 5. Pearson correlation analysis shows the relationship among the *nibung* population, habitat, and secondary metabolites. Note: (*) indicate positive correlations, while unmarked values show none. Blue boxes highlight significantly positive correlations, red boxes indicate significantly negative correlations, and unboxed points are not significantly different.

Habitat conditions, particularly soil composition, considerably influence the *nibung* trunk size. Non-coastal areas were prevalent with higher phosphate (P_2O_5) and lower potassium (K_2O) and produced larger and taller trunks. In contrast, the coastal locations provided higher potassium levels and revealed smaller trunks and more individuals per clump due to a negative correlation of potassium with the trunk diameter. Base saturation also appeared positively correlated with the number of individuals per clump. Soil phosphate (P_2O_5) indicated a positive correlation with flavonoids in *nibung's* buds (Figure 5). Soil chemistry remarkably affects the flavonoid content in palms, with nutrient-rich soils enhancing metabolic processes and poor soils limiting secondary metabolite production (Schachtman and Liu, 1999; Yang *et al*., 2018). Environmental factors, such as high temperatures and increased phenol and flavonoid synthesis, protect the plants from oxidative stress and UV damage (Taiz and Zeiger, 2010; Zandalinas *et al*., 2018). Enzymes like the phenylalanine ammonia-lyase (PAL) were evident. They are crucial in producing compounds under stress conditions, supporting the palm's adaptation to extreme conditions of drought and heat (Lattanzio, 2013; Sharma *et al*., 2019).

Variations in flavonoid concentration in the palm heart and phenols of *nibung's* buds can be referable as a mechanism of adaptation to their environment. According to Kadja *et al*. (2020) and Li *et al*. (2020), differences in growing locations can affect plant metabolic pathways. These results were in line with other palm members, such as oil palm (Tahir *et al*., 2022), date palm (Al-Kaabi, 2021), and *E. edulis* (Brancalion *et al*., 2012), where the morphology and metabolome of the palm group had influences from their growing environment. Several biosynthesis and metabolism pathways' alterations came from different environments, characterized by the abundance of primary and secondary metabolites, including phenolic acids and flavonoids in palms (Brancalion *et al*., 2012; Tahir *et al*., 2022). In plants, effects on phenolic variations resulted from environmental factors, which adjust the content of its bioactive compounds, as per its habitat (Ayaz *et al*., 2007).

CONCLUSIONS

Nibung populations' influences come from environmental factors, such as soil texture, potassium, and phosphate levels. Non-coastal locations, with higher phosphate and lower potassium levels, support larger trees with higher flavonoid content. The coastal areas yield smaller trees due to the potassium's negative impact on stem size. These findings provide essential baseline data for *nibung* conservation and cultivation strategies, promoting its further development with sustainable use in Riau, Indonesia.

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REFERENCES

Adrian M, Wulandari R, Sembiring E, Natawijaya A (2024). Metabolomic profiling unravels divergent adaptive responses of oil palm (*Elaeis guineensis)* seedlings to drought stress under shaded and unshaded conditions. *Biodiversitas* 25(6): 2404–2414.

Al-Kaabi NAG (2021). Abiotic stress effect on growth and photosynthetic characteristics in Emirati date palm varieties. Thesis, United Arab Emirates University, pp. 948.

Ayaz FA, Torun H, Ayaz SE, Correia PJ, Alaiz M, Sanz C, Grúz JI, Strnad M (2007). Determination of chemical composition of Anatolian carob pod *(Ceratonia siliqua* L*.):* Sugars, amino and organic acids, minerals and phenolic compounds. *J. Food Qual.* 30(6): 1040–1055.

BPS (2021). The Central Bureau of Statistics of Riau Province (BPS), Indonesia.

Brady NC, Weil RR (1996). The Nature and Properties of Soils. Prentice Hall International Editions. University of Michigan, USA.

Brancalion PHS, Vidal E, Lavorenti NA, Batista JLF, Rodrigues RR (2012)*.* Soil-mediated effects on potential *Euterpe edulis* (Arecaceae) fruit and palm heart sustainable management in the Brazilian Atlantic Forest. *For. Ecol. Manag.* 284: 78–85.

Braun-Blanquet J (2007). Plant Sociology. The study of plant communities. Hafner London.

Broschat TK (2008). Palm nutrition guide. University of Florida, Gainesville.

Desti, Fitmawati, Yulis PAR, Isda RM (2019). Characterization of the ethnobotany of Riau Province's mascot flora (*Oncosperma tigillarium* (Jack) Ridl). Proceed. 2nd Int. Conf. ICoSET: pp. 250–253.

Desti, Mastuti R, Azrianingsih R, Arumingtyas EL (2024). Local uses and traditional knowledge of *nibung* (*Oncosperma tigillarium*) in Riau Province, Indonesia. *Biodiversitas* 25 (5): 2043–2050.

Dransfield J, Uhl NW (1998). Palmae. Families and genera of vascular plants. Volume IV. Flowering Plants. Monocotyledons. Springer, Berlin, pp. 306–389.

Elias GA, Colares R, Antunes AR, Padilha PT, Lima JMT, Santos R (2019). Palm (Arecaceae) communities in the Brazilian Atlantic Forest: A phytosociological study. *FLORAM.* 26(4): 1–9.

Elings J (2018). Population profile of the *motacú* (*Attalea princeps*). M. Sc. Thesis, Forest and Nature Conservation, University of Wageningen, Netherlands.Fitmawati, Desti, Juliantari E, Novela D, Kapli H (2022). Molecular phylogeny of Nibung (*Oncosperma tigillarium* [Jack.] Ridl.) inferred from trnL-F intergenic spacer sequences. SABRAO J. Breed. Genet. 54(1): 175-183.

Fitmawati, Desti, Juliantari E, Novela D, Kapli H (2022). Molecular phylogeny of *Nibung* (*Oncosperma tigillarium* [Jack.] Ridl.) inferred from trnL-F intergenic spacer sequences. SABRAO J. Breed. Genet. 54(1): 175-183.

Gutiérrez-Grijalva EP, López-Martínez LX, Contreras-Angulo LA, Elizalde-Romero CA, Heredia JB (2020). Chapter 5. Plant alkaloids: Structures and bioactive properties. M.K. Swamy (Ed.), Plant-Derived Bioactives: Chemistry and Mode of Action, Springer, Berlin, pp. 85–117.

Henderson A, Borchsenius F (1997). Evolution, Variation, and Classification of Palms. New York Botanical Garden Press, Bronx, New York.

Jansen MJ, Zuidema PA, Anten NPR, Martínez-Ramos M (2012). Strong persistent growth differences govern individual performance and population dynamics in a tropical forest understorey palm. *J. Ecol.* 100: 1224–1232.

Kadja BA, Kouamé RMBK, Janat A (2020). Biological and pharmaceutical sciences influence of temperature on the phytochemical composition and the antioxidant and anticariogenic activities of extracts from the husk of the fruit of *Cocos nucifera* l. (Arecaceae). *GSC Biol. Pharm. Sci.* 12(2): 179–187.

Lattanzio V (2013). Phenolic Compounds: Introduction. Natural products. Springer, Berlin, Heidelberg, pp. 1543–1580.

Li Y, Kong D, Fu Y, Sussman MR, Wu H (2020). The effect of developmental and environmental factors on secondary metabolites in medicinal plants. *Plant Physiol. Biochem.* 148: 80–89.

Ngaffo CMN, Tankeo SB, Guefack MF, Nayim P, Wamba BEN, Kuete V, Mbaveng AT (2021). Phytochemicals analysis and antibiotic-modulating activity of *Cocos nucifera*, *Glycine max*, and *Musa sapientum* methanol extract against multidrug-resistant gram-negative bacteria. *Invest. Med. Chem. Pharmacol*. 4 (2): 53.

Otárola MF, Avalos G (2014). Demographic variation across successional stages and their effects on the population profile of the neotropical palm *Euterpe precatoria*. *Am. J. Bot.* 101(6): 1023–1028.

Pant P, Pandey S, Dall'Acqua S (2021). The influence of environmental conditions on secondary metabolites in medicinal plants: A literature review*. Chem. Biodivers.* 18, e2100345.

Pulido MT, Valverde T, Caballero J (2007). Variation in the population profile of the palm *Sabal yapa* in a landscape shaped by shifting cultivation in the Yucatan Peninsula, Mexico. *J. Trop. Ecol.* 23(2): 139–149.

Ratsirarson J, Silander Jr JA, Richard AF (1996). Conservation and management of a threatened Madagascar palm species, *Neodypsis decaryi*, Jumelle. *Conserv. Biol.* 10(1): 40–52.

Sammanta RV, Permatasari L, Muliasari H, Rachmalia IMN, Fersiyana DR (2024). Determination of total flavonoid content from extract and fractions of mangrove *(Rhizopora mucronata)* leaves. *Acta. Chim. Asiana.* 7(2): 502–508.

Schachtman D, Liu W (1999). Molecular pieces to the puzzle of the interaction between potassium and sodium uptake in plants. *Trends Plant Sci*. 4: 281–287.

Sharma A, Shahzad B, Rehman A, Bhardwaj R, Landi M, Zheng B (2019). Response of phenylpropanoid pathway and the role of polyphenols in plants under abiotic stress. *Molecules* 24(13): 2452.

Souza FG, de Araújo FF, Farias DdeP, Zanotto AW, Neri-Numa IA, Pastore GM (2020). Brazilian fruits of arecaceae family: An overview of some representatives with promising food, therapeutic and industrial applications. *Int. Food Res. J.* 138: 963–969.

Tahir NI, Rozali NL, Rahmah ARS, Amiruddin MD, Hwa LF, Shaari K, Abas F, Othman A, Parveez GKA, Ramli US (2022). Metabolome study of oil palm (*Elaeis guineensis* Jacq.) planted in different environment conditions. *Trop. Plant Biol.* 15: 211–232.

Taiz L, Zeiger E (2010). Plant Physiology (5th Ed.). Sinauer Associates.

Thakur M, Bhattacharya S, Khosla PK, Puri S (2019). Improving production of plant secondary metabolites through biotic and abiotic elicitation. *J. Appl. Res. Med. Aromat. Plants* 12: 1–12.

Widyatmoko D, Burgman MA, Guhardja E, Mogea JP, Walujo EB, Setiadi D (2005). Population status, demography and habitat preferences of the threatened lipstick palm *Cyrtostachys renda* Blume in Kerumutan Reserve, Sumatra. *Acta Oecol.* 28: 107–118.

Yang L, Wen KS, Ruan X, Zhao YX, Wei F, Wang Q (2018). Response of plant secondary metabolites to environmental factors. *Molecules* 23: 762.

Yudaputra A (2018). Habitat suitability and population structure of an endemic palm species *(Pinanga arinasae)* in Bali, Indonesia. Research Thesis, Graduate School, University of Florida.

Zandalinas SI, Balfagón D, Arbona V, Gómez-Cadenas A (2018). Modulation of antioxidant defense system by salicylic acid in palms exposed to heat stress. *Environ. Exp. Bot.* 147: 196–205.

Zulkarnaen RN, Helmanto H, Wihermanto W, Primananda E, Robiansyah I, Kusuma YWC (2022). Population study of Endemic Java Palm *(Pinanga javana)* in Mount Ungaran, Semarang, Central Java, Indonesia. *Biosaintifika* 14 (1): 48–56.