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The Accumulation of NaCl in The Coastal Plant Leaves of Mangrove, Bariongtonia, and Pes-Caprae Formations

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ABSTRACT

This study aims to compare the salt content (NaCl) in the leaves of several types of coastal plants that grow in different formations, Mangrove, Barringtonia, and Pres-Caprae. The study was conducted in the coastal area of Lais District, North Bengkulu Regency using direct survey methods in the field and laboratory analysis using a refractometer. The results showed that there were 10 species of coastal plants from three formations, Barringtonia, Mangrove, and Pes-Caprae. The highest salt content was found in the Acanthus species ilicifolius (2.75‰) from the Mangrove formation, while the lowest levels were found in Canavalia maritima (0.75‰) from the Pes-Caprae formation. The difference in salt content is thought to be influenced by the location of its habitat in the coastal area and its ability to adapt both structurally and physiologically so that it can survive in an environment with extreme salt content . The results of this study provide important information about the adaptation of coastal plants to environments with salinity and can be the basis for further research on salt concentration in coastal plants.

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1. INTRODUCTION

The coast is an area where land and sea meet and have high biodiversity, especially coastal plants that adapt to extreme environmental conditions. Coastal plants in Indonesia consist of various formations, such as Mangrove, Barringtonia, and Pes-Caprae, each of which has different characteristics and adaptations to salt levels [1]. The salt content (NaCl) in coastal plant leaves is an important indicator for understanding plant adaptation to high-salt coastal environments. This ecosystem is very important for maintaining ecological balance, providing habitat for various species, and offering protection against coastal erosion. Each formation has different features and adaptations that allow it to thrive in saline environments, which contribute to its ecological roles and benefits [2].

Coastal environments have unique characteristics, such as high salinity, exposure to strong winds, and tidal fluctuations. These conditions require coastal plants to develop special adaptation mechanisms, one of which is the ability to regulate salt levels in their body tissues. Coastal plants have various strategies to overcome salt stress, such as salt accumulation in vacuoles, salt secretion through special glands, and regulation of transpiration rates [3], [4]. The study of salt levels in coastal plant leaves is important for understanding how these plants adapt to extreme environments.

Mangrove plants can thrive in high salinity environments, including anatomical [5], physiological [6], and molecular [7]. These adaptations allow mangrove forests to not only survive but also perform important ecological functions in coastal ecosystem [8]. However, studies comparing salt levels in coastal plants from various formations, such as Barringtonia and Pes-Caprae, are still limited. Plants from this formation also have an important role in the coastal ecosystem, such as protecting the coastline from abrasion and providing habitat for various marine biota so this study will provide a more comprehensive picture of the adaptation of coastal plants to environments with high salt content.

Lais District, North Bengkulu Regency, was chosen as the research location because it has a high diversity of coastal plants and coastal conditions that are influenced by sea tides. This location also has three different coastal plant formations, Barringtonia, Mangrove, and Pes-Caprae, making it possible to compare the salt content between formations. The salinity of seawater in Lais District, North Bengkulu Regency ranges from 21-22‰, which is included in the high salinity category, thus providing an interesting ecological challenge to study. The main objective of this study was to determine the NaCl salt content in the leaves of several types of coastal plants and to compare the salt content between species and coastal plant formations. This study also analyzed factors that influence differences in salt content, such as transpiration rate and the presence of salt gland trichomes. The results of this study are expected to provide new information on the adaptation of coastal plants to saline environments and become a basis for further research. Therefore, this study is expected to provide a deeper understanding of the mechanisms of adaptation of coastal plants to saline environments. In addition, the results of this study can also be a basis for the management and conservation of coastal ecosystems, especially in dealing with climate change which can affect seawater salinity in the future.

2. METHOD

2.1 Research Location

The research was conducted in Air Padang Village, Lais District, North Bengkulu Regency. The research location has a high diversity of coastal plants and coastal conditions influenced by the ebb and flow of seawater.

2.2 Research Procedures

Sampling

Samples were taken randomly from 10 species of coastal plants found in three formations, Barringtonia, Mangrove, and Pes-Caprae. The leaves taken were the 4th leaf from the tip of the stem with 4 replications for each type of plant. The identification of plants species at the sampling site was conducted using mobile apps (PlantNet). In addition, the representative sample of plants were collected and identified using reference books (Flora of Java, Flora Malesiana, and Panduan Lapangan Tumbuhan Pantai) at Laboratory of Biology, University of Muhammadiyah Bengkulu.

2.3 Laboratory Analysis

Leaf samples were dried in an oven for 72 hours at 80°C, then crushed until smooth. A total of 0.2 grams of sample was dissolved in 10 ml of distilled water and shaken for 24 hours. The solution was then centrifuged for 10 minutes, and the resulting clear water was measured for salt content using a refractometer [9].

2.4 Data Analysis

Salt content data were analyzed statistically using the Anova test if the data were normally distributed and homogeneous or the Kruskal-Wallis test if the data were not distributed. Furthermore, if there was a difference in salt content from the three plant formations, it was continued with the Post -Hoc test.

3. RESULTS AND DISCUSSION

3.1 Types of Coastal Plants Found

This study successfully identified 10 species of coastal plants belonging to three main formations, Barringtonia, Mangrove, and Pes-Caprae. Table 1 shows a list of species found along with their respective formations:

Table 1. Types of coastal plants found in Air Padang Village, Lais District, North Bengkulu

No	Species Name	Indonesian/Regional Name	Formation
1.	*Erythrina orientalis*	Sea Chest	Barringtonia
2.	*Calophyllum inophyllum*	Jumping	Barringtonia
3.	*Cerberus mango*	Bintaro	Barringtonia
4.	*Hibiscus tiliaceus*	Waru	Barringtonia
5.	*Pongamia pinnate*	Malapari	Barringtonia
6.	*Avicennia marina*	Fire-fire	Mangrove
7.	*Sonneratia alba*	Fastener	Mangrove
8.	*Acanthus ilicifolius*	Jeruju	Mangrove
9.	*Lumnitzera littoral*	Enumerated	Mangrove
10.	*Canavalia maritime*	Sea Beans	Pes-Caprae

From the table 1, it can be seen that the Barringtonia formation has the largest number of species (5 species), followed by the Mangrove formation (4 species), and the Pes-Caprae formation only has 1 species.

3.2 Salt Content in Coastal Plant Leaves

Salt content (NaCl) in coastal plant leaves was measured using a refractometer. The measurement results showed significant variations in salt content between species and formations. Table 2 below presents the average salt content for each species.

Table 2. Average NaCl salt content in coastal plants in Air Padang Village

No	Species Name	Salt Content (‰)	Formation
1.	*Erythrina orientalis*	0.62	Barringtonia
2.	*Calophyllum inophyllum*	0.87	Barringtonia
3.	*Cerberus mango*	0.62	Barringtonia
4.	*Hibiscus tiliaceus*	0.62	Barringtonia
5.	*Pongamia pinnate*	0.50	Barringtonia
6.	*Avicennia marina*	0.50	Mangrove
7.	*Sonneratia alba*	1.00	Mangrove
8.	*Acanthus ilicifolius*	2.75	Mangrove
9.	*Lumnitzera littoral*	0.62	Mangrove
10.	*Canavalia maritime*	0.75	Pes-Caprae

From the table 1, the highest salt content is found in the *Acanthus species. ilicifolius* (2.75‰) from the Mangrove formation, while the lowest levels were found in *Pongamia pinnata* and *Avicennia marina* (0.50‰). In general, the Mangrove formation has the highest average salinity (1.22‰), followed by the Pes-Caprae formation (0.75‰), and the Barringtonia formation (0.65‰).

Based on the statistical analysis of the salt content data above, it shows that the data is not normally distributed, and the variance is homogeneous. Therefore, a non-parametric test was carried out. Kruskal-Wallis and continued with the Post-Hoc test. The results of the Kruskal-Wallis test showed significant differences in the salt content of plant leaves between formation groups ($p < 0.05$). The results of the Post-Hoc test revealed that the salt content of plants in the Mangrove formation was significantly higher than in the Barringtonia and Pes-Caprae formations. However, there was no significant difference between the salt content of plants between the Barringtonia and Pes-Caprae formations.

3.3 Discussion

The results of this study indicate that there are significant differences in salt levels between species and coastal plant formations. The highest salt levels were found in the *Acanthus species. ilicifolius* (2.75‰) from the Mangrove formation, while the lowest levels were found in *Pongamia pinnata* and *Avicennia marina* (0.50‰). This difference is closely related to the accessibility of seawater to the plant formations found. The location and type of coastal plant formations play an important role in determining the salt content in leaves. Coastal plants in Air Padang Village can be grouped into three formations, Barringtonia, Mangrove, and Pes-Caprae. Each formation has different environmental characteristics, which affect the salt content in leaves. The Barringtonia formation is usually found in higher coastal areas and is less affected by sea tides. Plants in this formation, such as *Erythrina orientalis*, *Calophyllum inophyllum*, and *Hibiscus tiliaceus*, tend to have lower salt levels due to its less saline environment. The adaptations of Barringtonia to moderate salinity levels imply that its leaves are not required to accumulate high levels of salt [10]. Mangrove formations grow in muddy coastal areas that are influenced by the ebb and flow of seawater. Plants in this formation, such as *Acanthus ilicifolius*, *Sonneratia alba*, and *Avicennia marina*, have higher salt levels due to their highly saline environment. Mangrove plants have special adaptations, such as breathing roots (pneumatophores) and salt glands, which help them survive in salty environments [11], [12]. The Pes-Caprae formation is usually found in sandy coastal areas exposed to strong winds and sea spray. Plants in this formation, such as *Canavalia maritima,* have a lower salt content compared to the Mangrove formation, but higher than the Barringtonia formation [13].

The three groups of coastal plants (Mangrove, Barringtonia, and Pes-Caprae) have distinctive characteristics that are developed as adaptations that are directly correlated with the distance of their habitat from seawater and the intensity of salt exposure. The Mangrove Formation is the closest zone to seawater that has high salinity, located in the intertidal zone that is routinely inundated by tides (0–50 m from the coastline). Plants in this location have distinctive adaptation characteristics in the form of: salt glands in the leaves (*Acanthus ilicifolius*) which function to excrete active salts through secretion; respiratory roots or pneumatophores (*Avicennia marina*), which function to overcome anaerobic conditions and help excrete salts; accumulation of salts in vacuoles, functions to localize Na^+ and Cl^- to avoid cell poisoning. High salt exposure from seawater requires active excretion mechanisms and root adaptation to survive in oxygen-poor mud. Mangroves grow in zones with seawater salinity of 20–35‰ and high sedimentation [14].

Barringtonia is a zone with moderate salinity, located in the supratidal zone (50–200 m from the coastline), only exposed to sea spray or occasional flooding. Typical plant adaptations in the Barringtonia formation include thick cuticle leaves (*Hibiscus tiliaceus*) that function to reduce evaporation and salt absorption; salt exclusion in the roots, which functions to limit the entry of Na^+ into the tissue; develops a deep root system, functions to reach less salty groundwater. Salt exposure is not constant, so plants rely on passive defense (cuticle) and ion selection in the roots. Barringtonia is dominant in zones with soil salinity of 5–15‰ [15].

Pes-Caprae formation is the furthest zone (low salinity), located in the sandy coastal zone (>200 m from the coastline), only exposed to sea breeze spray. The typical characteristics of plant adaptation in this formation are succulent saun (*Canavalia maritima*), which functions to store water to dilute salt; many root hairs, which function to filter salt during water absorption; fast growth rate with a short life cycle to avoid long-term salt accumulation. Minimal salt exposure causes plants in this formation to adapt to focus on efficient water use and salt avoidance. Pes-Caprae grows in zones with soil salinity <5‰ [8].

Morphological characteri of plants, such as leaf structure, roots, and salt gland trichomes, also affect the salt content in leaves. Coastal plant leaves have different structures, which affect their ability to regulate salt content. *Acanthus leaves ilicifolius* has a thick cuticle layer and fewer stomata, which helps reduce water loss through transpiration. The thick leaf structure and thick cuticle help coastal plants reduce water loss and accumulate salt in the leaves [16]. Mangrove plants, such as Avicennia marina and *Sonneratia alba* have respiratory roots (pneumatophores) that help them take oxygen from the air when the roots are submerged in seawater. These respiratory roots also help remove salt from plant tissues. Respiratory roots are an important morphological adaptation that helps Mangrove plants survive in salty environment [17]. Several species of coastal plants, especially from the Mangrove formation, have salt gland trichomes on the leaf epidermis. These trichomes function to secrete Na^+ and Cl^- ions outside the leaf tissue, thus helping to maintain the salt balance in the plant body. Species with more active salt gland trichomes, such as *Acanthus ilicifolius*, tend to have higher salt levels in the leaves [18].

Physiological characteristics of plants, such as transpiration rate, ion regulation, and accumulation of osmoprotectant compounds , also affect the salt content in leaves. High transpiration rates in some species, such as *Acanthus ilicifolius* , causing greater salt accumulation in the leaves. The intensive transpiration process causes water to evaporate faster, so that salts dissolved in water are left in the leaf tissue. The transpiration rate is influenced by environmental conditions, such as temperature, humidity, and light intensity [19]. Coastal plants have complex ion regulation mechanisms, which help them regulate ion balance in cells, for example, Mangrove plants have ion transporter proteins, such as $Na+/H+$ antiporter, which help remove $Na+$ ions from cells and maintain ion balance in plant tissues. Ion regulation is an important physiological mechanism that helps coastal plants survive in salty environment [20]. Coastal plants also accumulate osmoprotectants compounds, such as proline and glycine betaine, which help protect cells from osmotic stress due to high salt levels. The accumulation of osmoprotectants compounds is an important physiological strategy that helps coastal plants survive in saline environment [3].

The results of this study are in line with previous research conducted, which found differences in salt levels in several types of Mangroves [1]. However, this study goes further by comparing salt levels in coastal plants from various formations, thus providing a more comprehensive picture of coastal plant adaptation to salty environments. Other research also found that salt levels in coastal plant leaves varied between species and formations, with the highest salt levels found in species from the Mangrove formation. It was [1]also reported that species from the Mangrove formation have better adaptation mechanisms to salty environments compared to species from other formations [21], [22].

The results of this study have important implications for the conservation and management of coastal ecosystems. Coastal plants, especially from Mangrove formations, play an important role in protecting the coastline from abrasion and providing habitat for various marine biota. By understanding the adaptation mechanisms of coastal plants to saline environments, we can develop more effective conservation strategies to protect coastal ecosystems from the impacts of climate change.

4. CONCLUSION

This study provides new insights into the adaptation mechanisms of coastal plants to saline environments. Differences in salinity levels between species and formations indicate that coastal plants have diverse adaptation strategies to survive in environments with extreme salinity levels. Of the 10 species of coastal plants found in this study, they came from three formations, Barringtonia, Mangrove, and Pes-Caprae. The highest salinity was found in the *Acanthus species. ilicifolius* (2.75‰) from the Mangrove formation, while the lowest levels were found in *Canavalia maritima* (0.75‰) of the Pes-Caprae formation. The results of this study can be a basis for further research, especially in facing climate change that can affect seawater salinity in the future.

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