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THE DIFFERENCES OF THE ELEMENTS CONTENT IN *RHIZOPHORA MUCRONATA* LEAVES FROM ASAHAN REGENCY, NORTH SUMATRA, INDONESIA*

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Abstract

Mangroves have a good mineral absorption system against change in environmental conditions, i.e., through the storage in leaves. This study aimed to determine the relationship of mineral contents to differences in the color levels of *R. mucronata* mangrove leaves. Theresults showed that the growth of leaves from young to old revealed decreased potassium content, while calcium and magnesium increased significantly. The order of microelementsfrom the largest to the smallest for green leaves or young leaves is Mn > Fe > Zn > Cu > B > Si, and for yellow leaves or old leaves is Mn > Fe > Zn > Cu > B > Si. The correlation of elements in mangrove leaves showed that potassium (0.78), copper (0.96), manganese (0.96), and zinc (0.95). The elements of copper and manganase that have a high correlation.

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Introduction

Mangrove forests in North Sumatra, Indonesia are widespread on the east coast and mainly found in Asahan Regency. The mangrove environment is influenced by biotic and abiotic factors in controlling nutrients available for plants (BEREZINA et al. 2017, FRIESS and WATSON 2017). Mangroves provide several ecological functions for organisms (GOESSENS et al. 2014, ARIYANTO et al. 2018a, ARIYANTO 2019). Mangrove forests in the tropical region are highly productive, marked with the presence of nitrogen, phosphorus, and elements (micro, meso, and macro). Several factors play a role in determining the pattern of use and storage of elements in forest ecosystems, including soil fertility, species composition, and age of vegetation.

Mangroves require various elements to support their growth. Plants have a range of different mechanisms to protect themselves from the absorption of toxic elements and to limit their transportation in plants (ALMEIDA et al. 2006). The pattern of translocation of elements in plants is highly dependent on the level of ion mobility and specific metabolic needs (MORRISSEY and GUERINOT 2009, FERNÁNDEZ and BROWN 2013). Mangroves through leaf organs have a function as storage of elements (ISHII et al. 2014, LECHTHALER et al. 2016).

Mangroves can absorb nutrients in coastal waters, which are reflected in nutrient status (GRITCAN et al. 2016) and elemental content (MAATHUIS 2009, ARIYANTO et al. 2018b). Elements consist of macro, meso, and microelements. Macroelements are nitrogen (N), phosphorus (P), and potassium (K). Meso elements are magnesium (Mg), calcium (Ca), and sulfur (S). Microelements are iron (Fe), manganese (Mn), zinc (Zn), boron (B), copper (Cu), molybdenum (Mo) and silicon (Si). PILON-SMITS et al. (2009) reported that plants require elements to increase the resistance to biotic pressures such as pathogens and herbivores, and abiotic pressures such as drought, salinity, and poisoning or nutritional deficiencies. The availability of these elements also has an effect on growth and reproduction productivity primary and secondary metabolism for cell defense, and from signal transduction to gene regulation, energy metabolism, and hormonal perception (HÄNSCH and MENDEL 2009, VATANSEVER et al. 2016, ARIYANTO et al. 2018c). This study aimed determine the relationship of element concentration to leaf colour difference with maturity *R. mucronata*.

Material and Methods

Sample Analysis

This research was conducted in February – May 2019. Leaf samples of *R. mucronata* were taken from Asahan Regency, North Sumatra, Indonesia (03°02′09″S dan 099° 51′31″E.). The leaves were taken 50 g. The research data analysis was carried out at the environmental Productivity Laboratory, IPB University.

Leaf samples (2 g) were dissolved in 10 mL perchloric acid and incubated at 100°C for 5 min. The processed samples were then treated with 10 mL of concentrated HNO_3, and it was followed by 10 ml concentrated H_2SO_4. Acid treatment was carried out at 100°C for 5 min each in the hot plate. Finally, the sample was evaporated and diluted with 10% HCl. The diluted samples were then filtered through washed acid-free filter papers. The main mineral elements (K, Mg, Ca) and trace elements (Fe, Zn, Mn, B, Cu, Mo, and Si) were determined in the Atomic Absorption Spectrophotometer, while total nitrogen and total phosphorus were determined using spectrophotometry (Pansu and Jacques 2003, APHA 2012).

Statistical Analysis

Data were expressed as mean ± SEM. The principal component analysis (PCA) was used to determine the analysis of the relationship between leaf color and the element's concentration. The principal component analysis displayed data in graphical form, data matrix, which consists of leaf color (row) and concentration variable (column). This analysis was performed using the Xlstat 2018 program.

Results

Element N, P, K

The level of macro-elements consisting of nitrogen (N) and phosphorus (P) showed different levels of contents. The nitrogen content had a higher concentration value compared to phosphorus. The higher concentration of nitrogen showed that the dominant macro element found in the leaf was nitrogen. Figure 1 shows the differences in percentage N & P between green leaves and yellow leaves.

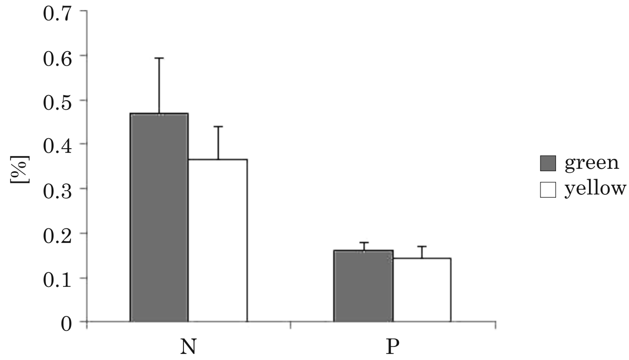

Fig. 1. The differences between green leaves and yellow leaves (N, P) in *R. mucronata* in Asahan Regency, North Sumatera, Indonesia

Figure 2 shows the potassium (K) content had a different concentration at the leaf color level. The green leaf had a higher concentration the yellow leaves. The results howed that *R. mucronata* had supported of N and P as expressed by the concentration of these elements in leaves.

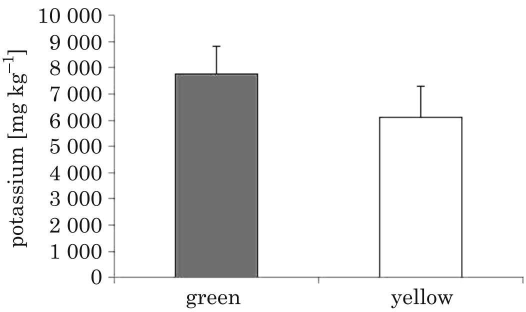

Fig. 2. The potassium (K) content of green and yellow leaves in *R. mucronata* in Asahan Regency, North Sumatera, Indonesia

Element Mg, Ca

Atomic absorption spectrophotometry analysis showed differences in calcium and magnesium contents in *R. mucronata* leaves. Figure 3 shows the difference in the content of Mg and Ca in *R. mucronata* mangrove leaves based on the leaf color level. The green leaf has 134 Mg content (61,153.663 ± 4,277.63 mg kg^{-1}) and Ca content (36,087.147 ± 4,193.55 mg kg^{-1}) which are higher than those in the yellow leaves. The more leaves experience aging, the less Mg and Ca contents.

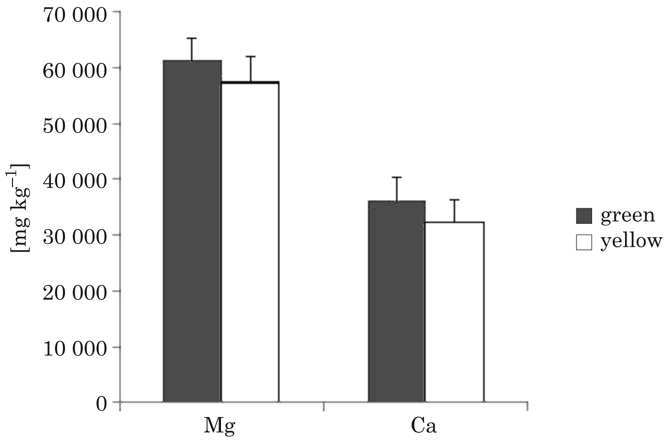

Fig. 3 The Mg and Ca content of green and yellow leaves in *R. mucronata* in Asahan Regency, North Sumatera, Indonesia

Element Fe, Mn, Zn, B, Cu, Mo, Si

Table 1 shows that the content of microelements consisting of Fe, Mn, Zn, B, Cu, Mo, Si concentrations had differences based on the color of *R. mucronata* leaves. Overall, green leaves showed a higher content of microelements than yellow leaves. The descending order of microelements concentrations in green leaves is Mn > Fe > Zn > Cu > B > Si and in yellow leaves is Mn > Fe > Zn > Cu > B > Si. The concentration of elements in green leaves towards yellow leaves of *R. mucronata* shows changes along with the aging of leaves.

Table 1

Content of Fe, Mn, Zn, B, Cu, Mo, Si [mg kg^{-1}] in the leaves of *R. mucronata* in Asahan Regency, North Sumatra, Indonesia

Microelements	Green leaves	Yellow leaves
Boron (B)	4.67 ± 2.43	4.51± 0.46
Copper (Cu)	4.72±1.19	6.99±3.44
Manganese (Mn)	460.34±15.87	391.44±124.76
Zinc (Zn)	11.75±7.06	4.67±1.06
Iron (Fe)	16.83±9.65	14.06±4.511
Silica (Si)	0.43±0.07	0.40±0.06

The relationship between leaf color conditions and elemental content

Figure 4 shows a PCA analysis of the relationship between the color differences of *R. mucronata* leaves that has three eigenvalues. The analysis of the first main component had an eigenvalue of 4.36 (variance 39.69%), the second had 3.62 (variant 33.61%), and the third had 1.52 (variance 10.54%). The three eigenvalues describe the data diversity of 87.13% (cumulative % / total variance). The loading factor illustrates the relationship of the effect of different colors of *R. mucronata* mangrove leaves to produce PCA 1 including potassium (0.78), copper (0.96), manganese (0.96), and zinc (0.95); while PCA 2 produces total P (0.97), magnesium (0.96), calcium (0.73), and iron (0.72); and PCA 3 involving boron (0.88).

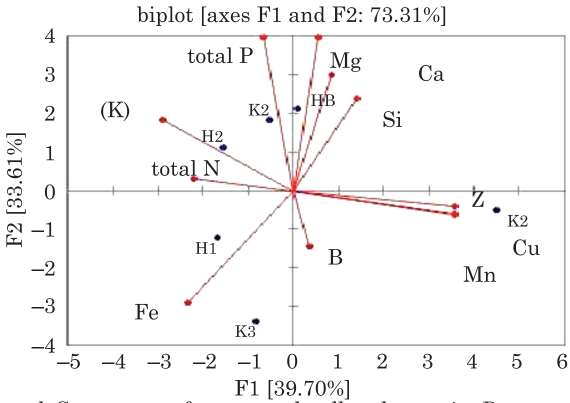

Fig. 4. The Mg and Ca content of green and yellow leaves in *R. mucronata* in Asahan Regency, North Sumatera, Indonesia

Discussion

Phosphorus has an important role in the nucleotide chain, dark photosynthetic reaction, respiration, other metabolisms, and membrane-forming phospholipids. The nitrogen content had a higher concentration value compared to phosphorus (Figure 1). The P content of *R. mucronata*'s leaves was 0.06% and N was 0.6% (ANANDA et al. 2007) When the leaf is aging, the concentration of nitrogen, phosphorus, and potassium decreases (LIN and WANG 2001). High levels of calcium and phosphorus can function as a good supplement (COOPOOSAMY and MAGWA 2007). MEDINA et al. (2015) reported that the N concentration was significantly higher in *R. mangle* for all leaf stages. In the case of *Rhizophora*, N and P concentrations were higher than the values reported for mangrove forests in the

Caribbean. Wang mentioned that seasonal changes could affect the content of elements in the leaves. LOVELOCK et al. (2007) showed that the nutrient content of mangrove leaves (nitrogen and phosphorus contents) correlates well with the level of nutrient addition and natural variability in the concentration of nutrients in the environment. The green leaf had a higher concentration than the yellow leaves in Potassium (Figure 2). Potassium (K) is an important element due to its role in regulating the opening and closing of stomata (ANDRES et al. 2014). Stomata help to maintain water balance, and pumps of potassium ion support this process. Potassium is the third most common limiting factor for plant growth. The development of leaves from young to old tends to decrease potassium content (ZHENG et al. 1999). Figure 3 showed that the green leaf has high Mg and Ca content. ADHIKARI et al. (2018) reported that the Ca and Mg contents were mostly found and in high amounts, i.e., 6,412.8 mg kg^{-1} and 8,640 mg kg^{-1}. These results showed lower contents when compared to this study. TANOI and KOBAYASHI (2015) found that (Mg) decreases when the leaves are old or mature. Also, another study reported that decreased Mg content could lead to the performance of enzyme and metabolic functions (HERMANS et al. 2013, Guo et al. 2016). TRÄNKNER et al. (2018) revealed that Mg plays an important role in the process of photosynthesis.

This study describes that the Mn content was higher than the other contents. Mn is a major contributor to various photosynthetic processes (MILLALEO et al. 2010). The concentration of Mn in this study is the most abundant in microelements. This finding has similarities in average concentration in the range of mangrove ecosystems (LEWIS et al. 2011, BAYEN 2012). The content of Cu and Zn in this study showed a higher content than the study reported by SARI et al. (2018) i.e., Cu 0.0865 mg kg^{-1} and Zn 1.6385 mg kg^{-1}. Comparison in this study also showed a higher content of Zn, Mn, and Fe than the study conducted by DUDANI et. al. (2017) i.e., the content of Zn 0.275 ± 0.049, Mn 0.269 ± 0.067, and Fe 3.36 ± 0.240 [mg kg^{-1}]. PAHALAWATTAARACHCHI et al. (2009) also revealed that mature leaves have a higher content than young leaves, i.e., Zn (8.36), and Cu (3.23). HOSSAIN et al. (2001) reported that Cu content in the leaves of *Rhizophora mucronata* was 2.58 mg kg^{-1}. ADHIKARI et al. (2018) also reported that Cu and Zn contents were 10.49 and 3.2 mg kg^{-1}, respectively.

Comparisons also occur if Fe is compared to Zn and Cu in Table 1. Fe had a higher content than Zn and Cu. This research has the same results of the study conducted by AL HAGIBI et al. (2018) that found higher Fe content than Zn and Cu in *R. mucronata* mangrove leaves from Yemen. This study revealed that Silicon (Si) had the lowest concentration compared to the other microelements, which is in the range of 0.40 – 0.43 mg kg^{-1}.

The results of this study showed a lower value compared to a study conducted by Zhang et al. (2013), which obtained 0.51 mg kg^{-1}. Sahebi et al. (2015) mentioned that Si plays an important role in reducing plant susceptibility to various biotic and abiotic pressures.

In Figure 4, the elements found in *R. mucronata* mangrove show the value of relationships in several elements. Elements of Cu, Mn, and Zn were elements that dominate the element contents in *R. mucronata* mangrove leaves. The content is higher and inversely proportional to the content of elements K and Fe. These results indicated that the difference in absorption of elements in various parts of the mangrove is influenced by several factors, i.e., season, tissue age, morphology, and physiology (Lewis et al. 2011). Cu and Zn act as important elements of micronutrients, which are involved in enzymes. The presence of Cu and Zn in high levels of concentration can cause damage to metabolic processes at the cellular level, inhibit enzyme reactions and anti-oxidative processes, delay growth, and cause the death of biota (Vatansever et al. 2016). Mejías (2013) mentioned that mangrove ecosystems could absorb elements through the root and translocate them to other parts of the plant. Excessive Mn concentrations in plant tissues can change various processes, such as enzyme activity, absorption, and translocation that cause oxidative stress (Ducic and Polle 2005). The concentration of Mn depends on plant species and genotypes in a species (Fernando and Lynch 2015).

This research showed element that high correclation i.e., potassium (K), copper, manganese (Mn) and zinc. Potassium (K) is an essential nutrient that affects most of the biochemical and physiological processes that influence plant growth and metabolism (WANG et al. 2013). K concentrations in green leaves were weakly but positively correlated with growth rates (Feller et al. 2009). Copper is required for chlorophyll formation, cata lyzes various processes in plant metabolism. Manganese acts mainly as part of the enzymatic system in plants, activates several important metabolic reactions, has a direct effect on photosynthesis helping in the synthesis of chlorophyll, accelerates germination and maturity and increases the availability of phosphorus and calcium. Manganese is an essential element for plants, intervening in several metabolic processes, mainly in photosynthesis and as an enzyme antioxidant-cofactor (Millaleo et al. 2010). The Zn plays very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome. Plant enzymes activated by Zn are involved in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, regulation of auxin synthesis and pollen formation. The regulation and maintenance of the gene expression required for the tolerance of environmental stresses in plants are Zn dependent (Cakmak 2000)

Conclusions

Development of leaves from young to old tends to decrease the potassium content, while calcium and magnesium increased well. In general, the elements found in *R. mucronata* mangrove showed the value of relationships in several elements. Elements of Cu, Mn, and Zn were elements that dominate the element contents in *R. mucronata* mangrove leaves. These contents were higher and inversely proportional to the content of potassium and iron.

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