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The potential of *Rhizophora mucronata* and *Sonneratia caseolaris* for phytoremediation of lead pollution in Muara Angke, North Jakarta, Indonesia

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Abstract. *Rumanta M. 2019. The potential of* Rhizophora mucronata *and* Sonneratia caseolaris *for phytoremediation of lead pollution in Muara Angke, North Jakarta, Indonesia. Biodiversitas 20: 2151-2158.* Environmental pollution by heavy metals has become a serious problem in Jakarta Bay. Mobilization of heavy metals as a result of anthropogenic activities has caused the release of heavy metals into the environment, one of which is Pb. Several methods have already been used to clean up the environment from these kinds of contaminants, but most of them are costly and difficult to get optimum results. Recently, phytoremediation is an effective and affordable technological solution used to extract or remove inactive metals and metal pollutants from contaminated soil and water. This technology is environmentally friendly and potentially cost-effective. These study objectives are (i) to find the accumulating capability of Pb in each plant tissues (roots, stems, and leaves) of *R. mucronata* and *S. caseolaris*; (ii) to find stomatal morphological characters of *R. mucronata* and *S. caseolaris*. All samples (roots, stems, and leaves) were collected from Muara Angke mangrove forest in North Jakarta. The accumulation of Pb is higher in *S. caseolaris* leaves than in roots, and stems, and than those in *R. mucronata*. The concentrations of Pb in roots, stems, and leaves of *S. caseolaris* were respectively 4.83 µg/g, 3.37 µg/g and 15.57 µg/g and in *R. mucronata* were 10.50 µg/g, 5.13 µg/g and 13.33 µg/g. Generally, the stomata of mangrove species that live in polluted ecosystems are longer and wider than the stomata of the same mangrove species that live in a non-polluted ecosystem. This is strongly suspected of being related to the physiological adaptation of heavy metal accumulation. This study showed that *S. caseolaris* is the most suitable species as a phytoremediation agent in the Muara Angke mangrove ecosystem.

Keywords: Phytoremediation, lead, pollution, potential, mangrove, Muara Angke

INTRODUCTION

Mangroves are one of the most productive intertidal wetland ecosystems and play an important role as a major primary producer in the estuary zone (Agoramoorthy et al. 2008). Cheng et al. (2012) asserted that these ecosystems contribute to protection against erosion and stabilization of coastal landscapes and other communities around them. Rivera-Monroy et al. (1998) and Analuddin et al. (2017) asserted that mangroves play an important role in tropical and subtropical regions by exporting organic materials to support the survival of various organisms including phytoplankton. MacFarlane et al. (2007) stated that mangrove ecosystems serve as habitat and nursery area for many juvenile fish and crustaceans, which have both direct and indirect socio-economic importance.

Similar to other wetland ecosystems, mangrove ecosystems have experienced significant input of contaminants as a result of anthropogenic activities (MacFarlane et al. 2007). Among the major pollutants from anthropogenic inputs are heavy metals (MacFarlane 2002). One of the heavy metals that have become a serious concern lately is Pb as the most serious, toxic and persistent environmental pollutants (Cheng et al. 2012).

Recently, physiological responses to heavy metals have widely been reported in macrophyte plants (MacFarlane et al. 2007; Huang and Wang 2010; Gogorcena et al. 2011). MacFarlane and Burchett (2001), Liu et al. (2009), and Huang and Wang (2010) stated that mangroves can act as phytoremediators against heavy metals in the estuary zone, so it must be considered to support bioremediation activities in polluted environments. Nonetheless, each mangroves species has a different accumulation ability for each type of heavy metals (Rumanta 2018). This ability correlates with the physiological mechanisms possessed by each mangrove species (Cheng et al. 2014).

Qian et al. (2012) and Rumanta (2018) asserted that the accumulation of heavy metals in plant tissues is determined by the bioavailability of elements in the sediment and the efficiency of plants to absorb and translocate in roots and vascular tissues. Martin et al. (2006), Morrissey and Guerinot (2009) said that the bioavailability and toxicity of metals in sediments are positively correlated with pH, salinity, redox potential, minerals and organic content, population biota, and synergistic interactions between these two variables. Cheng et al. (2014) asserted that the mechanisms of metal tolerance in mangrove plants are still poorly understood. As such, it is crucial to understand the internal or external factors that may play important roles in metal uptake and tolerance in mangrove plants.

Redjala et al. (2011) stated that the accumulation of heavy metals can produce different responses in each plant tissues (i.e., roots, stems, and leaves). This is because each plant tissue has a specific physical and chemical substratum changes, including the level of contamination. Surya and Hari (2017) reported that mangroves have unique leaf anatomical structures, and are associated with adaptability in high saline environments. All mangroves species have a thick and concave stomata cuticle composition that plays a role in the transpiration process (Surya and Hari 2017). Souza et al. (2015) reported that studies of heavy metals accumulation using mangroves as subjects in biotic and abiotic compartments, including in mangrove ecosystems, are very necessary to assess the conservation status of coastal areas. In addition, the results of heavy metal accumulation studies can help provide a solution for understanding the absorption of heavy metals and a comprehensive translocation mechanism, because some of these elements can be very toxic when accumulating in plant cell (Valko et al. 2005).

Currently, studies that have examined the potential of *R. mucronata* and *S. caseolaris* as phytoremediation agent in the Muara Angke ecosystem, North Jakarta have never been reported. The results of a recent study showed that the increase of Pb residues in the Muara Angke area, North Jakarta experienced a significant increase (Hamzah and Setiawan 2010; Baum et al. 2015; 2016; Rumanta 2018). A right solution is needed with the use of specific phytoremediation agents to overcome the threat of Pb so as to minimize the distribution of Pb into living cells. To our knowledge, there are no previous studies of toxic metal Pb present in sediments and their uptake to biological compartments of *R. mucronata* and *S. caseolaris* in Muara Angke, North Jakarta as well as their influence on the stomata anatomy.

These study objectives are to examine and determine the mangrove species between *R. mucronata* and *S. caseolaris* which have great potential to act as phytoremediation agent in the Muara Angke mangrove ecosystem, North Jakarta. Determination of mangrove species that have the potential as phytoremediation agent is based on the ability of the species to accumulate Pb found in sediments, and their relationship with translocation mechanism, and the anatomy of the stomata. The results of this study will provide an implicit solution about species that have great potential to act as phytoremediation agent in the Muara Angke ecosystem, North Jakarta. Another advantage that will be given by this study is that the mangrove species that have been identified as having great potential as a phytoremediation agent, will be used to develop conservation of mangrove land in the Muara Angke ecosystem, especially in area that is close to industrial solid activities.

MATERIALS AND METHODS

Period and location of study

This research was conducted at mangrove forest in Muara Angke Wildlife Sanctuary, North Jakarta, Indonesia (Figure 1) in two periods based on the division of seasons, which were rainy season (November to March) and dry season (April to October) 2018. The time for taking research samples was in spot time, on 7 January 2018 during the rainy season and 9 June 2018 during the dry season. Pb tests on mangrove plants were done in the laboratory of Soil Research Institute in Bogor. While to investigate the morphological of stomata samples were taken from two different locations, which were from mangrove forest in Muara Angke wildlife sanctuary of North Jakarta and from mangrove forest in Panimbang area of Pandeglang District, Banten Province which served as control samples.

Analysis of Pb content in roots, stems and leaves of mangrove

This research was conducted by direct observation technique at Muara Angke (*in situ measurement*) and laboratory analysis. At the study site, five stations (ST1 to ST5) were selected for data collection (Figure 1) based on the mangrove forest zone around Muara Angke. The sites 2, 3, and 5 were chosen because they were near to the pollutant source of Pb particles. The sites 1 and 4 were located in the middle of the mangrove ecosystem in Muara Angke, and sites 3 and 5 were located around the river flow so that they have experienced high contamination pressure and under the influence of very strong industrial and domestic waste.

The samples of roots, stems, and leaves of *R. mucronata* and *S. caseolaris* were collected from five observation stations. Roots, stems, and leaves samples were collected with three replications (triplo), dried, then crushed, and weighed. Pb content was analyzed using *Atomic Absorption Spectrophotometer* (AAS). Leaves, stems, and roots samples were then ashed using muffle furnace at 435°F and digested using 1 ml of HNO_3 and ½ ml of $HClO_3$. These were filtered and made up to volume 25 ml using 25% HNO_3 and analyzed. The data of this study were analyzed using descriptive statistics.

Analysis of the morphological characteristics of stomata

The leaves samples of *R. mucronata* and *S. caseolaris* were collected from different intertidal zones in the Muara Angke mangrove ecosystem. The plant samples were identified in Herbarium Bogoriense, Bogor, Indonesia. One of the healthy plants was selected and the mature leaves from fifth and sixth node were taken for morphological studies. Sections were made at a position approximately halfway between the base and apex of a sector from one side of the lamina, stained with Toluidine blue 0 and mounted in 50% glycerin. The slides were analyzed using trilocular compound microscope model number 10093409 and images were taken using the Olympus Camera E-PL3. The Scanning Electron Microscopic images of leaf samples were taken using the Zeiss Ultra 55.

Statistical analysis

One way ANOVA was used to test the difference of Pb concentration between *R. mucronata* and *S. caseolaris* using SPSS software version 21.

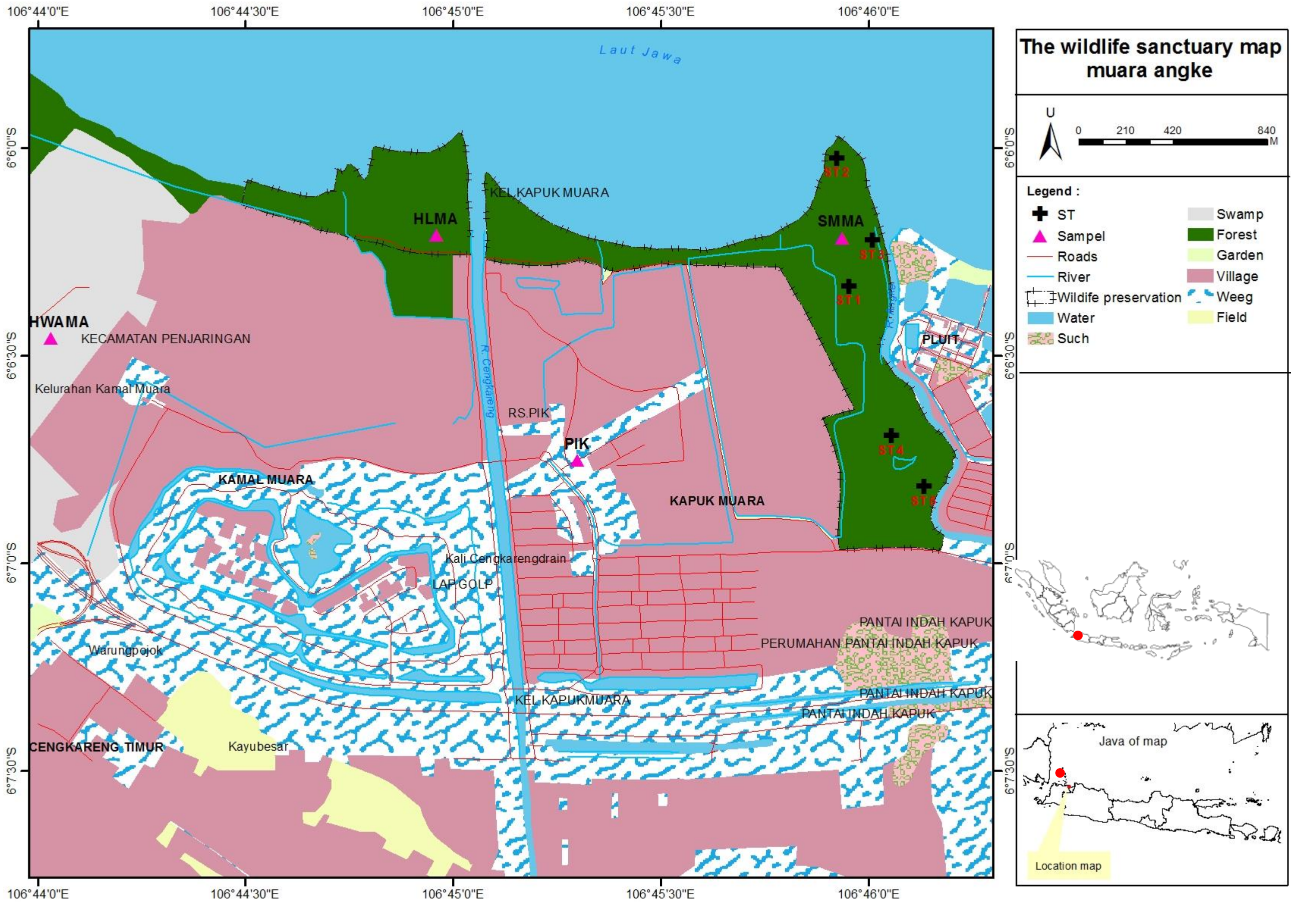

Figure 1. The locations of five sampling sites in Muara Angke, Jakarta, Indonesia analyzed in this study

RESULTS AND DISCUSSION

Pb content in roots, stems and leaves of mangrove

Based on the laboratory analysis, the concentration values of heavy metal Pb on roots, stems and leaves of *R. mucronata* and *S. caseolaris* in two different seasons (rainy and dry seasons) are presented in Table 1 and Table 2, respectively. The data in Tables 1 and 2 explain the accumulation of Pb in each mangrove tissues. The results of this accumulation indicate the effectiveness of Pb accumulation from each part of the mangrove. Understanding of heavy metal Pb in plant tissues is the key to proving the applicability of phytoremediation (Mwegoha 2008).

The accumulation of Pb on roots, stems and leaves of *R. mucronata* during the rainy and dry seasons shows a significant difference (Table 1). The highest percentage of Pb accumulation was in leaves (13.33 µg/g during the rainy season and 1.72 µg/g during the dry season), then in roots (10.50 µg/g during the rainy season and 2.65 µg/g during the dry season), and the lowest was in stems (5.13 µg/g during the rainy season and 0.71 µg/g during the dry season). Based on the data in Table 1, the highest concentration of Pb in *R. mucronata* from the highest to the lowest species is in leaves, followed by roots and stems.

Rumanta (2014) reported that in the rainy season, Pb levels in sediments and water in several rivers estuaries in the bay area of Jakarta tends to be much higher than in the dry season. This condition is supported by the fact that during the rainy season floods often occur in the Jakarta city and the pollutants from industrial and domestic wastes to be submerged and carried away by flood to flow through the river to the Jakarta Bay. In flooding condition, the Angke Rivers also can carry a lot of pollutants including Pb heavy metal to coastal waters in the Muara Angke Wildlife Sanctuary. Thus, it makes sense if in the rainy season the Pb content in mangroves plant is higher than in the dry season.

Table 1. The accumulation of Pb (µg/g) in *R. mucronata* in the rainy and dry seasons

Number	**Parts of plant**	**Content of Pb ($\bar{X}$ ± SD)**	
		Rainy season	**Dry season**
1	Roots	10.50 ± 1.70 AB	2.65 ± 0.87 A
2	Stems	5.13 ± 4.05 A	0.71 ± 0.15 B
3	Leaves	13.33 ± 3.30 B	1.72 ± 0.44 A

Note: *One-way Anova*: Different letters in the same column show significant differences

Table 2. The accumulation of Pb (μg/g) in *S. caseolaris* in the rainy and dry seasons

Number	Parts of plant	Content of Pb ($\bar{X}$ ± SD)	
		Rainy season	Dry season
1	Roots	4.83 ± 1.55 A	3.34 ± 2.18 A
2	Stems	3.37 ± 0.95 A	0.43 ± 0.32 B
3	Leaves	15.57 ± 4.93 B	2.11 ± 1.72 AB

Note: *One-way Anova*: Different letters in the same column show significant differences

Table 2 shows that the accumulation of Pb in the roots, stems and leaves of *S. caseolaris* during the rainy and dry seasons shows a significant difference. The highest percentage of Pb accumulation was in leaves (15.57 μg/g during the rainy season and 2.11 μg/g during the dry season), then in roots (4.83 μg/g during the rainy season and 3.34 μg/g during the dry season), and the lowest was in stems (3.37 μg/g during the rainy season and 0.43 μg/g during the dry season). Based on the data in Table 2, the highest concentrations of Pb in *S. caseolaris* from the highest to the lowest was in leaves, followed by roots, and stems. This is similar to that in the *R. mucronata* species (Table 1).

The results of this study are consistent with the research conducted by Hamzah and Setiawan (2010) and Rumanta (2018) which found the highest concentration of Pb in mangroves in leaves than in stems and roots. Rumanta (2018) asserted that there is a positive correlation between the high Pb concentration in the leaves and the translocation mechanisms. This is supported by Hamzah and Setiawan, (2010) which reported that the high concentration of Pb in leaves because the Pb content absorbed by the root is transported to the leaves through the stem in the same direction as the transpiration mechanism.

In the root system, there are endodermic cells in the form of cork-shaped membranes in the transverse and radial walls called the Casparian strip membrane (Selanno et al. 2015). The Casparian strip membrane functions as a protector of the movement of water and sediment that contain organic and inorganic elements which will move towards the xylem vessels. Physiologically, all the elements that have passed through the Casparian membrane, and have reached the xylem vessels, will be transported to the leaf. Generally, the organic elements that are successfully transported to the leaf will be used for photosynthetic mechanisms, while inorganic elements in the form of substances contained in heavy metals will accumulate and result in an abscess process (Silva et al. 2006). MacFarlane and Burchett (2001) and Kammaruzaman et al. (2008) stated that the presence of Casparian strip membrane plays a very important role in maintaining physiological stabilization in plants which results in plants not experiencing overcapacity to certain elements and can survive in ecosystems with high levels of pollutants. This mechanism makes mangroves can act as biological agents of phytoremediator that are very effective and efficient as an implicit solution to overcome heavy metal contamination in polluted aquatic ecosystems (Cho-Ruk et al. 2006; Rumanta 2018).

Tangahu et al. (2011) asserted that recently phytoremediation has become an effective and affordable technological solution used to extract or remove inactive metals and metal pollutants from contaminated soil. Phytoremediation is a mechanism by using plants to clean up contamination in soil, sediment, and water. The expected advantage of the application of mangrove plants as phytoremediation agents is the achievement of good environmental quality. In addition, Cho-Ruk et al. (2006) stated that plant species having metal accumulating capacity are known as hyperaccumulator. Cho-Ruk et al. (2006) stated that the phytoremediation mechanism utilizes the unique and selective absorption capacity of plant root. The mechanism of absorption of plant is supported by the mechanism of translocation, bioaccumulation, and the ability of degradation of contaminants found throughout the body of the plant.

Tables 1 and 2 show that the ability of Pb accumulation in *R. mucronata* was lower than *S. caseolaris*. During the rainy session, *R. mucronata* was able to accumulate Pb with a maximum concentration of 13.33 μg/g, while *S. caseolaris* was able to accumulate Pb with a maximum concentration of 15.57 μg/g. The results of this study are in accordance with the research conducted by Pahalawattaarachchi et al. (2009) which reported that *R. mucronata* has limited ability to act as a phytoremediation agent for polluted areas in Alibag, India. Pahalawattaarachchi et al. (2009) also stated that the absorption activity of *R. mucronata* is very dependent on bioavailability capabilities, and this study reveals that phytoremediation capacity of *R. mucronata* varies from metal to metal.

Ali et al. (2013) stated that the concentration of heavy metals that accumulate in the environment will go through a physiological mechanism and will accumulate in the tissues of living organisms. Physiologically, the elements found in heavy metals will accumulate in the body tissues of living organisms called "bioaccumulation" and their concentration will increase when the elements move from a lower trophic level to a higher trophic level. Ali et al. (2013) asserted that environmental pollution can become more and more serious with increasing industrialization and the disturbance of natural biogeochemical cycles. Based on its constituent components, heavy metals have different chemical components than other organic substances, so basically, heavy metals cannot be degraded and continue to accumulate in the environment. The ability of a plant species to accumulate every element contained in certain heavy metals refers to phytostabilization mechanism. This phytostabilization mechanism can be used to predict plants that can be used as phytoremediators (Moreno et al. 2008). Pahalawattaarachchi et al. (2009) asserted that mangrove ecosystem has the capacity to act as a sink or buffer and remove/immobilize heavy metals before reaching the nearby aquatic ecosystems.

Table 2 shows that *S. caseolaris* has a far more maximum capacity in accumulating heavy metal. This can be seen from the level of accumulation of Pb in the leaves, which reached 15.57 µg/g during the rainy season. Research conducted by Nazli and Hashim (2010) showed that *S. caseolaris* possess the capacity to take up selected heavy metals via its roots and storing them in its leaves without any sign of intoxication. Study conducted by Nazli and Hashim (2010) concluded that *S. caseolaris* has a great potential to act as phytoremediation agent in Peninsular Malaysia mangrove ecosystem. The results of this study also suggest that *S. caseolaris* can be utilized as a phytoremediation agent to reduce heavy metal pollution in Muara Angke, North Jakarta, which continues to increase from year to year.

Nazli and Hashim (2010) asserted that *S. caseolaris* has very high Pb accumulation ability suggesting that this species is better than *R. mucronata*. Research conducted by Chua dan Hashim (2008) stated that the high accumulation of heavy metals in leaves can be caused by plants directly obtaining heavy metal input through absorption of leaves directly, especially in industrial areas, such as in Muara Angke. Wulp et al. (2016) reported that the Jakarta Bay received a large number of pollutants sourced from agricultural activities, industry and domestic wastes from Jakarta metropolitan areas even from the nearby provinces such as West Java. In addition, the coastal areas of Jakarta Bay are the outlets of 13 watersheds (DAS), making the coastal areas of Jakarta Bay as areas of accumulated sediments, nutrients and pollutants from upstream, which have negative effects on biological productivity and water quality of Jakarta Bay waters (Dsikowitzky et al. 2016).

Research conducted by Wulp et al. (2016) implied that waste disposal into the environment will cause pollution and play a role in causing Pb contamination in Jakarta Bay which disturbs public health (Cordova et al. 2012). Baum et al. (2015) asserted a clear distinction of benthic and fish communities between reefs in Jakarta Bay and reefs along the Thousand Islands (*Kepulauan Seribu*) further north. Wulp et al. (2016) reported that heavy metal contaminants already have occupied in a high gradient around the Jakarta Bay. In this study, the mangrove ecosystem in Muara Angke, North Jakarta is very close to many industrial estates and other anthropogenic activities, so that all activities can serve as Pb sources. Therefore the heavy metal inputs into the mangrove forest in this study were sourced from surface runoffs and domestic effluents from the surrounding land use such as agricultural activities, industry, and human settlement.

The results of this study indicate that the mechanism of translocation of Pb can be maximized in *S. caseolaris* than in *R. mucronata*. Moreover, the samples of the leaves of *S. caseolaris* did not show any sign of intoxication even when Pb concentrations exceeded the general range in found plants. This suggests that *S. caseolaris* leaves are tolerant to heavy metals by imparting minimal physiological effects to the leaves (De Lacerda et al. 1993).

Morphological characteristics of stomata

The results of scanning electron microscope (SEM) of two mangrove species *R. mucronata* (Figure 2) and *S. caseolaris* (Figure 3) shows that both the adaxial and the abaxial epidermal cells are more or less similar in size, where the adaxial epidermal cells are larger in size compared to those of abaxial cells. The epidermal cells are polygonal in outline with anticlinal walls straight or slightly arched in all species studied. The epidermal layer is completely covered by a very thick cuticle. The length and width of the epidermal cells vary across species. The maximum epidermal cell size was observed in *S. caseolaris* and the smallest epidermal cells was that of *R. mucronata*.

SEM results show that the walls of epidermal cells of *S. caseolaris* species are tortuous and bumpy. At all mangrove sites studied, the leaf samples did not show visual damage, such as chlorosis and necrosis, or anatomical changes. Although these injuries are commonly reported for plants sensitive to particulate materials (Silva et al. 2006), field observations showed that the particles remain on the leaf surface for a short time, and are easily washed out by rainfall.

SEM results showed that in the adaxial part of *R. mucronata* collected from mangrove ecosystem in Muara Angke, there was an accumulation of particulate material in plants that were more exposed to this pollutant (Figure 2, Upper). This was compared with the results of SEM of *R. mucronata* collected from the outside of Muara Angke which acts as a control. The SEM results indicate that there is a negative correlation between the results of SEM of *R. mucronata* collected from the mangrove ecosystem area of Muara Angke, North Jakarta with *R. mucronata* collected from the control location (Figure 2, Lower). It can be seen that in the adaxial part of the sample from the control location there is no deposition.

The results of the micromorphology analysis of *S. caseolaris* samples collected from the mangrove ecosystem in Muara Angke, North Jakarta showed that there is particulate material strongly suspected to be a pollutant substrate (Figure 3). This differs from the samples of *S. caseolaris* collected from the control location. Figure 3 shows the micromorphological features of diagnostic value observed in *S. caseolaris* species. Results on the leaf epidermal peel showed that stomata of the leaf of *S. caseolaris* are amphistomatic. SEM results indicate that the stomata of *S. caseolaris* are cyclocytic and staurocytic types.

The stomata of all studied species appeared to be sunken. In *R. mucronata* anomocytic cyclocytic stomata are found, while those in *S. caseolaris* are cyclocytic and staurocytic. The results of epidermal incision provide information regarding the micromorphological characters that the stomata of *R. mucronata* are hypostomatic. In *R. mucronata* lower epidermal layer cell is interrupted by secretory pores. These pores are lined by four to five layers of radially arranged flattened epithelial cells. Transverse section revealed that the leaves of *S. caseolaris* are isobilateral and epidermal cells in *S. caseolaris* have cubical shape. In *S. caseolaris*, stomata could be located on both the epidermises and are amphistomatic. Guard cells are covered by thick cuticle which forms prominent ledges over the stomata pores.

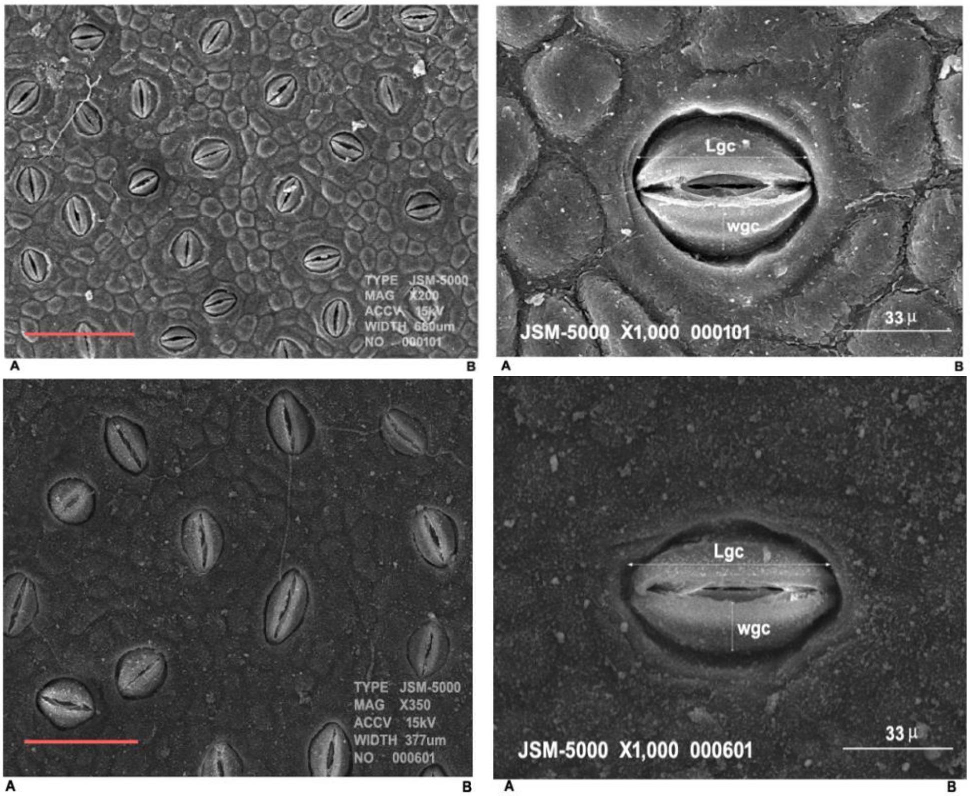

Figure 2. Stomata characteristic on epidermis surface of *R. mucronata*: *Upper* (collected from Muara Angke); *Lower* (collected from Panimbang, Pandeglang, Banten which acts as a control); Note: Lgc (length guard cell), wgc (width guard cell)

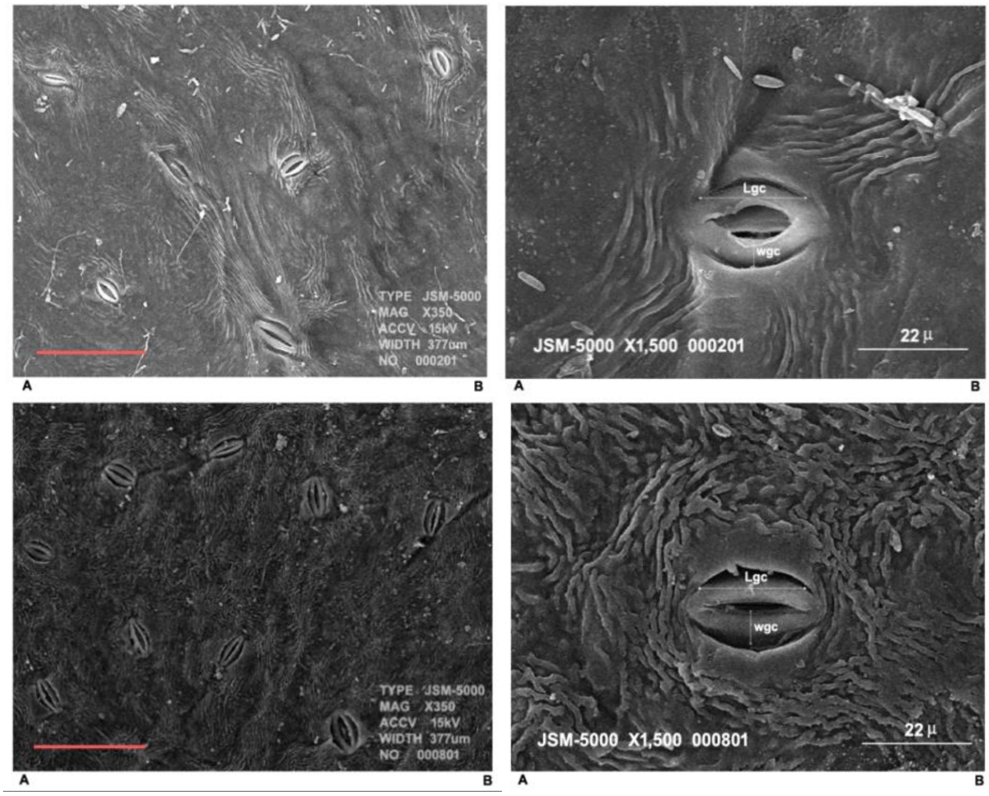

Figure 3. Stomata characteristic on epidermis surface of *S. caseolaris*: *Upper* (collected in Muara Angke); *Lower* (collected from Panimbang, Pandeglang, Banten which acts as a control); Note: Lgc (length guard cell), wgc (width guard cell)

The results of this study indicate a positive correlation between the number of stomata, length and width of the stomata. Observations on two mangrove species (*R. mucronata* and *S. caseolaris*) showed that generally mangrove species that live in ecosystems with a high level of contamination generally have fewer stomata numbers. SEM results (Figures 2 and 3) show differences in the number of stomata in both species. The difference in the number of stomata is very closely related to the ability of the mangrove species in accumulating Pb. Generally, *R. mucronata* has high stomata distribution than *S. caseolaris*. The fewer number of stomata on *S. caseolaris* leaves is thought to have a correlation with the mechanism of physiological adaptation due to water deficit in the habitat. Generally, *S. caseolaris* mangroves occupy niche habitat with minimal water condition in the Muara Angke ecosystem.

Water deficit condition can affect leaf size, reduce cell size, and cause a decrease in stomatal density (Martínez et al. 2007; Xu and Zhou 2008). Study conducted by Lovelock and Feller (2003), reported that there is no correlation between decreasing stomata density and increasing salinity. Research results by Lovelock and Feller (2003) and Schwarzbachl and Ricklefs (2001) using the same mangroves species, *L. racemosa* and *A. germinans*, yielded the same conclusion that there is no correlation between stomata density and salinity.

The results analysis of the stomata lengths on the leaves of mangrove plants (*R. mucronata* and *S. caseolaris*) in two different ecosystems (Muara Angke and Panimbang as the control) showed significant differences (Figs. 2 and 3). Generally, the stomata of mangrove species that live in polluted ecosystems are longer and wider than the stomata of the same mangrove species that live in a non-polluted ecosystem. This is strongly suspected of being related to the physiological adaptation of heavy metal accumulation. The measurement results showed that the length and width of stomata *R. mucronata* that lived in the Muara Angke ecosystem had stomata lengths at the lower epidermis of 51.90 ± 0.20 µ and stomata widths of 32.14 ± 0.15 µ, while *R. mucronata* lived outside the ecosystem Muara Angke (control), has a stomata lengths of 50.10 ± 0.16 µ and a stomata widths of 31.56 ± 0.10 µ. Furthermore, the measurement results on the length and width of the stomata of the *S. caseolaris* mangrove showed that the species that lived in the Muara Angke ecosystem had stomata lengths at the upper epidermis of 31.20 ± 0.15 µ, while in the lower epidermis 32.85 ± 0 18 µ. For *S. caseolaris* (control), the lengths of the stomata at the upper epidermis is 30.70 ± 0.10 µ, while in the lower epidermis it is 31.80 ± 0.14 µ. The measurement results of the stomata width of *S. caseolaris* that live in Muara Angke, showed that the upper epidermis has a stomata widths between 20.05 ± 0.16 µ, whereas in the lower epidermis it has a stomata width between 21.08 ± 0.19 µ. For *S. caseolaris* (control), it has a stomata widths at the upper epidermis between 19.90 ± 0.12 µ, whereas in the lower epidermis it has a stomata widths between 20.87 ± 0.16 µ.

Based on the results of this study, we assumed that there is a positive correlation between stomatal length, stomatal width, and water deficit. This is strengthened by the fact that in the study location *S. caseolaris* occupied an ecological niche with a water deficit. The results of this study are consistent with the research conducted by Aasamaa et al. (2001) which asserted that stomatal length seems to decrease with increasing droughts. Drake et al. (2013) asserted that smaller stomata have faster dynamic characteristics, which has implications for improved long-term water use efficiency and lower risk of disruption of the leaf hydraulic system.

The results of this study showed that the guard cell shape in *S. caseolaris* is oval, while the shape of guard cells in *R. mucronata* is round but uneven. There are slight curves on the left and right side of the guard cells from *R. mucronata*. We assumed that the curve is related to the adaptive feature of *R. mucronata* mangrove. In *R. mucronata*, the outer wall of the guard cell is thicker than the inner wall, and this also occurs in *S. caseolaris*. The stomata size is slightly bigger in *R. mucronata* than *S. caseolaris*. The stomatal ledges can be seen very prominently in *S. caseolaris*, hence the stomata are more deeply sunken in *S. caseolaris* than *R. mucronata*.

The results of this study indicate that *S. caseolaris* has a better capacity than *R. mucronata* in accumulating Pb through its roots and translocate Pb to stems and leaves without any signs of intoxication. The results of this study also showed that the highest Pb concentrations were found in leaves, than to roots and stems. This suggests the potential of *S. caseolaris* as a phytoremediation species for mangrove ecosystems in Muara Angke, North Jakarta.

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