The response of seedling growth of *Rhizophora apiculata* to various concentrations of Sidoarjo mud

AE Prihatiningrum*, S Arifin, Sutarman and M Abror
Department of Agrotechnology, Muhammadiyah University of Sidoarjo, Jawa Timur, Indonesia

* prihatiningrum@umsida.ac.id

**Abstract.** This study aims to determine the effect of some concentration of *Lusi* mud (Sidoarjo mud) as a medium to grow mangrove plants on the growth of *Rhizophora apiculata* seedlings. A total of 24 experimental units arranged in a randomized block design with treatment were *Lusi* mud concentration on planting medium, ie: 10%, 20%, 30%, 40%, and 50%. The variables observed were plant height, stem diameter, long root leaf area and wet weight and dry weight of plant. Data obtained were analyzed statistically by an analysis of variance and HSD test were used to indicate the significant differences between the mean values (p<0.05). The results showed that the 10% *Lusi* mud concentration responded to the growth of canopy, root length, and wet weight and dry weight of *R. apiculata* plants similar to those in the control treatment. At concentrations of 20%, 30%, 40%, up to 50% of *Lusi* mud, plants are able to grow well despite lower growth rates compared with no *Lusi* mud

1. **Introduction**

Hot mud eruption in Renokenongo village, Porong sub-district, Sidoarjo regency, East Java that produce massive mudflow has threatened the existence of agricultural land and mangrove area around it. At the beginning of the mud volume reaches about 100,000 m$^3$ per day with a composition of 70% in the form of sand and 30% liquid and about six years later the overflow volume only reaches 30,000 m$^3$ per day [1]. Since 2012 Sidoarjo mud material (*Lusi*) consists of the 84.47% delicate soil which is dominated by clay size particles about 54.47% of total dry weight and classified as high plastic mud [2]. Sediments act as sinks and sources of contaminants in aquatic systems due to their physical and chemical properties [3], [4]. The results of the analysis of mud materials in villages within the affected area of *Lusi* were found to contain heavy metals (Cu, Cd, Pb), sulphides, and phenols above the permitted maximum threshold [5]. Heavy metals of cadmium (Cd) and lead (Pb) are known as toxic metals [6]–[8] that can get into food chain and resulting in various adverse effects in animals and humans [9], [10].

The overflowing mud flows through the Porong River to the sea which will produce sediment and accumulate pollutants contained in *Lusi* in almost part of the coastline of Sidoarjo Regency which is a mangrove area. Under normal conditions, mangroves in addition to the role of protecting the land from tidal and rob, as a habitat and spawning ground for fish and other aquatic organisms, can also recover the coast from pollutants carried over the river [11], [12]. The mangrove rehabilitation and...
conservation will fail and the damage can not be avoided not only caused by human activities but also by natural phenomena [13], including in the case of this *Lusi* mudflow. To protect and conserve land and mangrove areas a systematic conservation and restoration strategy is required by utilizing all data that can be considered in the decision making [14]. In addition to build regional capacity and shoreline protection, developing technology and the role of mangrove seedling are being concern in the past five decades [15]. One type of mangrove plant that developed population in order to accelerate the mangrove rehabilitation process as part of the effort to mitigate the threat of *Lusi* sediment accumulation is *Rhizophora apiculata*. Therefore it is necessary to test the ability to grow *R. apiculata* to various concentrations of *Lusi* mud that may be accumulated in the coastline. This study aims to determine the effect of several concentrations of Sidoarjo mud as a medium for growing mangrove plants to the growth of *R. apiculata*.

2. Experimental Method
Three months *R. apiculata* seedlings from a special seedling of mangrove plants in Mojokerto, Indonesia, from a uniform population were randomly selected to be used as test plants. Meanwhile, prepared planting media which is a mixture of *Lusi* mud and mud indigenous mangrove habitat that is not polluted by any pollutant with the following composition: 0% and 100%, 10% and 90%, 20% and 80%, 30% and 70%, 40% and 60%, and 50% and 50% respectively. Each was repeated 4 times, so that 24 units of experiments were obtained. Into the polybags that already contain the mixed plant media of these two kinds of sludge seeded *R. apiculata* seedlings from the nursery. Taking into account environmental conditions, the experiments are arranged in a Randomized Block Design. Every day, morning (at 7:00) and afternoon (at 17:00). Every day, morning (7:00) and evening (17:00 o'clock), plants watered with sea water which free from heavy metals to keep the condition resembling the nature that is always wetted until submerged in water. The variables observed in this experiment were: (i) plant height (cm) measured from the root end of the root to the growing point every week starting 7 days after planting (DAP), (ii) stem diameter (cm) measured weekly using a vernier calipers, (iii) leaf area (cm²), calculated every 2 weeks by converting them in the form of drawings using millimeter block paper, (iv) root length (cm), calculated by measuring the length from the root tip to the root root (cm) at the end of the observation, (v) the wet weight of the plant (gr) is calculated by weighing the total weight of leaves, stems and roots from the tip of the observation, and (vi) dry weight of the plant (gr) calculated by weighing the wet weight of the cured plant until the constant weight at the end of the observation. All observation data were analyzed by using variance analysis (ANOVA) followed by 5% HSD test to know the difference between treatments.

3. Results and Discussion
The result of variance analysis showed that the difference of mud sidoarjo concentration had significant effect (p <0.05) on plant height since 21 DAP. The mean of plant height in response to planting medium is presented in Table 1.

| Treatment | Observation time (DAP) |
|-----------|------------------------|
|           | 7  | 14 | 21  | 28  | 35  | 42  | 49  | 56  |
| *Lusi* 0% | 26.78 | 27.30 | 27.80b | 28.43c | 28.85d | 29.33e | 30.13f | 30.48c |
| *Lusi* 10% | 26.85 | 27.33 | 27.83b | 28.28bc | 28.73cd | 29.25c | 29.83bc | 30.50c |
| *Lusi* 20% | 26.05 | 27.05 | 27.48b | 27.85abc | 28.23bc | 28.58bc | 29.00bc | 29.45bc |
| *Lusi* 30% | 25.68 | 26.23 | 26.53ab | 26.83abc | 27.13abc | 27.43abc | 27.78abc | 28.23ab |
| *Lusi* 40% | 25.68 | 26.15 | 26.53ab | 26.70ab | 26.78ab | 27.05ab | 27.35a | 27.48a |
| *Lusi* 50% | 25.55 | 25.70 | 25.85a | 26.50a | 26.58a | 26.80a | 26.95a | 27.03a |
Means followed by the same letter in the same row are not significantly different at \( p<0.05 \).

The result of variance analysis showed a significant effect (\( p<0.05 \)) treatment of Sidoarjo mud content difference on observation of stem diameter of \( R. \) apiculuta on 28-56 DAP. **Table 2** shows the average diameter of 7-56 DAP stem.

**Table 2.** The mean of stem diameter in response to the \( Lusi \) mud at 7-56 DAP (cm)

| Treatment | 7   | 14  | 21  | 28  | 35  | 42  | 49  | 56  |
|-----------|-----|-----|-----|-----|-----|-----|-----|-----|
| \( Lusi \) 0% | 0.42| 0.42| 0.44| 0.45ab | 0.47b | 0.48b | 0.49b | 0.48b |
| \( Lusi \) 10% | 0.42| 0.43| 0.43| 0.44ab | 0.45b | 0.46b | 0.47b | 0.47ab |
| \( Lusi \) 20% | 0.39| 0.39| 0.39| 0.41ab | 0.42ab | 0.43ab | 0.44ab | 0.45ab |
| \( Lusi \) 30% | 0.36| 0.36| 0.37| 0.38a  | 0.39a  | 0.39a  | 0.40a  | 0.40a  |
| \( Lusi \) 40% | 0.36| 0.36| 0.37| 0.37a  | 0.38a  | 0.39a  | 0.39a  | 0.40a  |
| \( Lusi \) 50% | 0.36| 0.37| 0.37| 0.38a  | 0.38a  | 0.39a  | 0.39a  | 0.40a  |

Means followed by the same letter in the same row are not significantly different at \( p<0.05 \).

The result of variance analysis showed that the difference of \( Lusi \) mud content was not significant (\( p>0.05 \)) to mangrove leaf area. The mean of leaf area at 14-56 DAP is shown in **Table 3**.

**Table 3.** The mean of leaf area in response to the \( Lusi \) mud at 14-56 DAP (cm\(^2\))

| Treatment | 14  | 28  | 42  | 56  |
|-----------|-----|-----|-----|-----|
| \( Lusi \) 0% | 5.35| 5.87| 6.39| 6.79|
| \( Lusi \) 10% | 5.01| 5.43| 5.74| 6.07|
| \( Lusi \) 20% | 5.06| 5.23| 5.54| 5.66|
| \( Lusi \) 30% | 4.81| 4.96| 5.26| 5.38|
| \( Lusi \) 40% | 4.77| 4.85| 5.09| 5.18|
| \( Lusi \) 50% | 4.46| 4.66| 5.07| 5.12|

Variation analysis also showed significant effect (\( p<0.05 \)). The difference of \( Lusi \) mud concentration to root length and wet weight and dry weight of \( R. \) apiculuta with mean value of each treatment is shown in **Table 4**.

**Table 4.** The mean of root length and wet weight and dry weight of the plant in response to the \( Lusi \) mud

| Treatment | root length (cm) | wet weight (g) | dry weight (g) |
|-----------|------------------|----------------|----------------|
| \( Lusi \) 0% | 29.63 e           | 13.37 c         | 4.05 d         |
| \( Lusi \) 10% | 29.15 e           | 12.90 b         | 3.92 cd        |
| \( Lusi \) 20% | 24.25 d           | 12.66 ab        | 3.72 bc        |
| \( Lusi \) 30% | 20.63 c           | 12.58 ab        | 3.58 b         |
| \( Lusi \) 40% | 16.13 b           | 12.50 ab        | 3.49 b         |
| \( Lusi \) 50% | 12.63 a           | 12.43 a         | 3.08 a         |
Means followed by the same letter in the same row are not significantly different at p <0.05.

Except for leaf area, all plant growth variables grown at Lusi mud concentration above 10% indicate lower value than without Lusi mud. This suggests that heavy metals, sulphides, phenols, and various other toxic compounds inhibit root growth and normal nutrient uptake. In the original mangrove muddy media used in this experiment was dominated by sand and a little organic material [1] which had little ability to bind or retain heavy metals [16], thus the higher the mud content the disturbance to the roots and growth of the higher the plant. Plants have developed mechanisms for sustaining growth under mud-covered conditions as indicated by equally identical leaf area between Lusi mud treatments and all treatment concentrations (Table 3). Young plants have high growth potential due to high sucrose support [17] obtained from photosynthetic processes that depend on water and sunlight. The sugars of photosynthesis are very important in the growth of juvenile phase crop tissues [18], so as shown in Table 2 and 4 that the stem diameter and biomass of plants treated by Lusi mud are quite high.

4. Conclusion
The difference of Sidoarjo mud concentration significantly influence the growth of plant height, stem diameter, root length and wet weight and dry weight of Rhizophoraapiculuta plant. The 10% sidoarjo mud concentration provided normal growth for R. apiculuta as in the control treatment, while at concentrations of 20%, 30%, 40%, up to 50% of Sidoarjo mud crops are able to grow well despite the relatively lower growth response compared with no Sidoarjo mud.

References
[1] Anonymous, “Lumpur Sidoarjo (Lusi) Frequent Ask Question (FAQ),” Badan PenanggulanganLumpur Sidoarjo, 2013. [Online]. Available: http://www.bpls.go.id. [Accessed: 09-May-2017].
[2] L. Handoko, A. Rifai’ti, N. Yasufuku, and R. Ishikura, “Physical Properties and Mineral Content of Sidoarjo Mud Volcano,” Procedia Eng., vol. 125, pp. 324–330, Jan. 2015.
[3] H. Pekey, “Heavy metal pollution assessment in sediments of the Izmit Bay, Turkey,” Environ. Monit. Assess., vol. 123, no. 1–3, pp. 219–231, 2006.
[4] C. Marchand, E. Lallier-Vergès, F. Baltzer, P. Albéric, D. Cossa, and P. Baillif, “Heavy metals distribution in mangrove sediments along the mobile coastline of French Guiana,” Mar. Chem., vol. 98, no. 1, pp. 1–17, 2006.
[5] D. Irfandi and M. . Wibisono, “Pengaruh Paparan Gas Toksi Lumpur Panas Pada Faal Paru,” Maj. Kedokt. Respirasi, vol. 4, no. 2, p. 2013, 2003.
[6] K. Senthil Kumar, K. S. Sajwan, J. P. Richardson, and K. Kannan, “Contamination profiles of heavy metals, organochlorine pesticides, polycyclic aromatic hydrocarbons and alkylphenols in sediment and oyster collected from marsh/estuarine Savannah GA, USA,” Mar. Pollut. Bull., vol. 56, no. 1, pp. 136–149, Jan. 2008.
[7] H.-S. Lim, J.-S. Lee, H.-T. Chon, and M. Sager, “Heavy metal contamination and health risk assessment in the vicinity of the abandoned Songcheon Au–Ag mine in Korea,” J. Geochemical Explor., vol. 96, no. 2–3, pp. 223–230, Feb. 2008.
[8] H.-X. Weng, Y.-M. Zhu, Y.-C. Qin, J.-Y. Chen, and X.-H. Chen, “Accumulation discrepancy of heavy metal and organic pollutants in three near-shore depositional environments, southeastern China,” J. Asian Earth Sci., vol. 31, no. 4–6, pp. 522–532, Jan. 2008.
[9] M. D. Sanborn, A. Abelsohn, M. Campbell, and E. Weir, “Identifying and managing adverse environmental health effects: 3. Lead exposure.,” CMAJ, vol. 166, no. 10, pp. 1287–92, 2002.
[10] M. P. Waalkes, “Cadmium carcinogenesis in review,” J. Inorg. Biochem., vol. 79, no. 1–4, pp. 241–244, Apr. 2000.
[11] M. Chatterjee, S. Massolo, S. Sarkar, A. Kumar Bhattacharya, B. D. Bhattacharya, K. K. Satpathy, and S. Saha, An Assessment of Trace Element Contamination in Intertidal Sediment Cores ofSunderban Mangrove Wetland, India for Evaluating Sediment Quality Guidelines, vol. 150. 2009.
[12] G. Neukermans, J. G. Kairo, and N. Koedam, Mangrove species and stand mapping in Gazi Bay
(Kenya) using Quickbird Satellite Imagery, vol. 53. 2008.

[13] C. Giri, Z. Zhu, L. L. Tieszen, A. Singh, S. Gillette, and J. A. Kelmelis, “Mangrove forest distributions and dynamics (1975–2005) of the tsunami-affected region of Asia,” *J. Biogeogr.*, vol. 35, no. 3, pp. 519–528, 2008.

[14] K. Ponnambalam, L. Chokkalingam, V. Subramanian, and J. Muthuswamy Ponniah, “Mangrove distribution and morphology changes in the Mullipallam creek, south eastern coast of India,” *Int. J. Conserv. Sci.*, vol. 3, no. 1, pp. 51–60, 2012.

[15] S. Y. Lee, J. H. Primavera, F. Dahdouh-Guebas, K. Mckee, J. O. Bosire, S. Cannicci, K. Diele, F. Fromard, N. Koedam, C. Marchand, I. Mendelssohn, N. Mukherjee, and S. Record, “Ecological role and services of tropical mangrove ecosystems: A reassessment,” *Glob. Ecol. Biogeogr.*, vol. 23, no. 7, pp. 726–743, 2014.

[16] S. Dudani, J. Lakhmapurkar, D. Gavali, and T. Patel, *Heavy Metal Accumulation in the Mangrove Ecosystem of South Gujarat Coast, India*, vol. 17. 2017.

[17] G. Wu and R. Scott Poethig, *Temporal Regulation of Shoot Development in Arabidopsis Thaliana By Mir156 and Its Target SPL3*, vol. 133. 2006.

[18] M. Massoumi, F. A. Krens, R. G. F. Visser, and G. J. M. De Klerk, “Etiolation and flooding of donor plants enhance the capability of Arabidopsis explants to root,” *Plant Cell. Tissue Organ Cult.*, vol. 130, no. 3, pp. 531–541, 2017.