

# UTILIZATION OF RIVER SLUDGE-SEDIMENT AS THE PLANTING MEDIA IN RECLAIMING CRITICAL MINED LAND: STUDY OF GROWTH AND LITTER PRODUCTION OF JABON (ANTHOCEPHALUS CADAMBA MIQ.)

Sugeng Priyono<sup>1</sup>, Ibrahim<sup>2</sup>, Soemarno<sup>1</sup>, Sykhfani<sup>1</sup>, and \*Lily Montarich Limantara<sup>3</sup>

<sup>1</sup>Soil Science Department, Faculty of Agriculture, University of Brawijaya, Malang, Indonesia

<sup>2</sup>Faculty of Forestry, Mulawarman University, Samarinda, Indonesia

<sup>3</sup>Department of Water Resources, Faculty of Engineering, University of Brawijaya, Malang, Indonesia

\*Corresponding Author, Received: 05 Aug. 2018, Revised: 30 Aug. 2018, Accepted: 20 Oct. 2018

**ABSTRACT:** The action taken for post-mining critical land reclamation is physical reclamation followed by biological reclamation, i.e. planting vegetation (revegetation). The alternative action for post-mining critical land reclamation is the use of river sediment sludge as an soil ameliorant. This study aims to determine the growth of plant and litter production of *Antocephalus cadamba* Miq. On post-mining land. The experimental design used was completely randomized design, with the treatment of planting media in the form of a mixture of river sediment-sludge with topsoil material. There are five treatment of planting media, namely: P0 (without river sediment); P1 (25% river sediment); P2 (50% river sediment); P3 (75% river sediment), and P4 (100% river sediment). Each treatment was repeated four times. Observations were made on the physical properties of planting media and the growth of plant (*A. cadamba*), namely: soil bulk density, soil texture, soil pore, litter weight, content of N, P and K of litter, plant height, and diameter of stem. Results showed a decrease in percentage of clay fraction when the *A. cadamba* plant was three months old at all treatments, except P4; while the soil bulk density increases. The percentage of micro pores increases with increasing percentage of river sediment, while total pore decreases, except for P4 treatment. The addition of river sediment on topsoil material as a planting medium was able to increase the litter production of *A. cadamba*. The N-content of litter was highest in treatment P2, while the content of P and K of litter was highest in P3 treatment. Increased plant height and stem diameter occurred along with the increasing percentage of addition of river sediment on planting medium up to the P3 treatment.

**Keywords:** River sludge, *Antocephalus cadamba* Miq., texture, bulk density, porosity, *A. cadamba* litter

## 1. INTRODUCTION

Excessive exploitation of natural resources has a negative impact on the sustainability of nature, degradation of agricultural land and forest degradation [1]-[2]. One form of exploitation activity that causes land degradation is coal mining openly [3]-[4]. This mining activity has a negative impact on soil physics and chemical characteristics [5]-[6]. Land degradation caused by mining includes soil structure, soil texture, soil porosity and soil bulk density. While soil chemical degradation includes soil pH, soil CEC, base saturation, C-organic and N-total content. The further negative impact of mining activities is the change of forest function into the unproductive land (critical land).

The usual action taken to reclaim critical post-mining land is by physical reclamation followed by biological reclamation, i.e. planting vegetation (revegetation). But very shallow post-mining landfills are generally a factor in the failure of such actions. In addition, the low content of soil organic matter of post mining land

is also a cause of land reclamation failure. An alternative action to succeed reclamation activities is the use of river sediment sludge as a soil ameliorant. The principle of this ameliorative technique is to improve physical and chemical properties of soil [5] and soil biology [7]-[8]. The application of sewage sludge can improve soil physical properties such as texture, infiltration rate, soil moisture retention, soil respiration [9], soil porosity, soil bulk density and soil aggregate stability [10]. Efforts to increase the content of soil organic matter can be done with the utilization of residual litter of plants, domestic wastes, manure, and planting any cover crop. The addition of organic materials has the potential to improve characteristics of post-mining land, as it can increase the capacity of soil moisture retention, improve soil CEC, improve soil structure, and decrease the bulk density of soil [5].

Various types of forest plants can be used in post-mining critical land reclamation activities, including "Jabon" (*Antocephalus cadamba* Miq.). Sahu and Dash [2] mentioned that suitable plant

species planted on post-mining land should be selected through plant tolerance to pollutants, fast growing species with the thick leaves, and indigenous plants; making it easy to adapt to the local environment, as well as plants that have economic value. *A. cadamba* is one of the fast growing species [11]-[12], therefore cultivation of *A. cadamba* is expected to support soil conservation, agroforestry and critical land reclamation programs. This is supported by extensive canopy of *A. cadamba* plant and the role of *A. cadamba* in increasing the C-organic content of soil [11]. The results of Ayub et al. [12] on the post coal mining of forest lands in East Kalimantan concluded that *A. cadamba* has potential to be developed for post-coal mining remediation, since *A. cadamba* is resistant to low soil pH, low soil fertility status, and high metal concentrations in the post-mining land. This study aims to observe growth of plants and litter production of *Antocephalus cadamba* Miq on the post-mining land.

## 2. MATERIALS AND METHODS

This study was conducted on post-mining land of PT. Panca Prima Mining located in Sambutan village, East Kalimantan province, which is geographically located at 00° 31' 49.26" and 00° 31' 49.44" South Latitude, 117° 11' 52.44" and 117° 11' 52.26" East Longitude.

The experimental design used in this study was Completely Randomized Design with the treatments is mixture planting medium of different percentage of river sediment and topsoil material. There are five treatments of planting media, that are: P0 (without river sediment); P1 (25% of river sediment); P2 (50% of river sediment); P3 (75% of river sediment) and P4 (100% of river sediment). Each treatment is repeated four times.

Prior to this study, preliminary studies of the treatment plots were planted with *Calopogonium mucunoides* as cover crops. Planting this cover crop aims to determine the effect of mixing of river sediment with topsoil on improving the properties of planting media and its impact on the growth of *Calopogonium mucunoides*. In the preliminary research, the physical properties are analyzed (bulk density, texture and pore distribution of soil) and chemical

properties (pH, CEC, Base saturation, N-total, P-available, K-exchangeable, C-organic and Al-saturation) on the sample of planting media. Observations on the cover crop are the rate of ground-coverage by cover crop every ten days and the weight of biomass at the end of study.

At the end of preliminary study, the harvesting of *Calopogonium mucunoides* biomass are then dried. The biomass of cover crop that has been harvested is then returned to each of the original plots. Furthermore, *A. cadamba* seedlings were planted on each plot. Seedlings of *A. cadamba* are three months old that have experienced selection based on high uniformity and stem diameter, and relatively healthy, not attacked by pests. Observations were made on the physical properties of planting media and plant variables *A. cadamba* with details:

### 2.1 Physical properties of soil

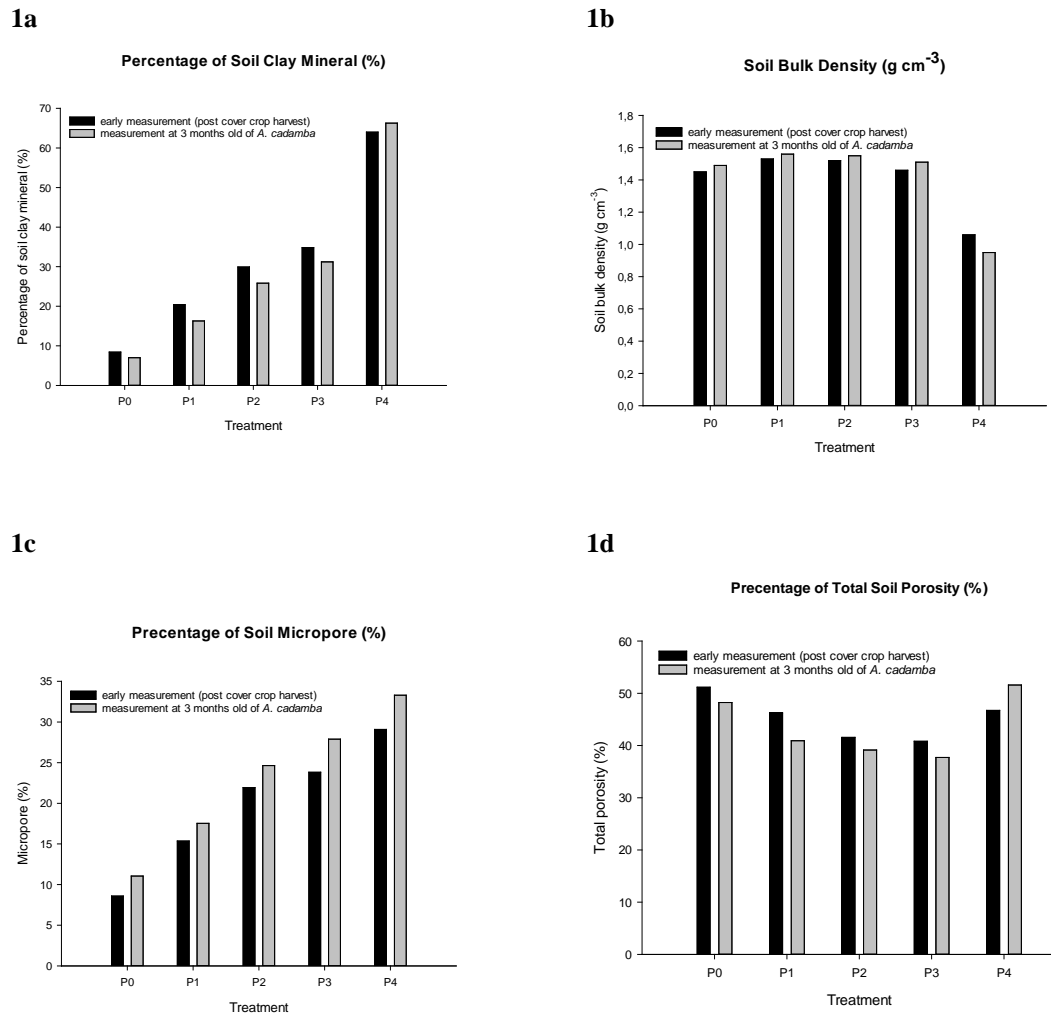
The observed physical properties of soil are the soil bulk density, soil texture and soil pore distribution. Soil texture was analyzed using the Pipette method. The soil bulk density was analyzed by using cylinder method, while the pore distribution in soil was analyzed using gravimetric method.

### 2.2 Plant growth of *A. cadamba*

Fresh weight of litter: measurements were made by weighing the dry weight of the litter of plants every two weeks. Litter drying is done using an oven at 45°C until it reaches a constant weight. The method used in this activity is the modification of vacuum oven drying AOAC 934.01 [13]. The litter is then returned to the original planting medium. Nutrient content of litter: Total content of N, P, and K. Plant height of *A. Cadamba*: the height of *A. cadamba* plant is measured using a meter from the ground surface to the highest jabon leaf shoots. Stem Diameter of *A. Cadamba*: measurement of stem diameter of *A. cadamba* plant was done by using the sliding term.

## 3. RESULTS AND DISCUSSION

### 3.1. Physical properties of the planting media

Fig. 1. Physical properties of planting media after three month age of *A. cadamba*

### 3.1.1. Clay Fraction

Soil texture is a relatively stable physical character of the soil, this character affects plant growth in post-mining land [4]. Figure 1a shows a tendency to decrease the percentage of clay fraction when *A. cadamba* plants are 3 years old at all treatments, except the P4 treatment. Increasing the percentage of river sediment in the planting medium can increase the percentage of clay fraction of the planting medium. It is seen that the addition of 100% sediment (P4 treatment) has the highest clay fraction content compared to other treatments, while the lowest clay content is found in the control treatment without the addition of river sediment (P0).

The highest percentage of clay fraction is found in P4 treatment. This clay fraction has the ability to absorb water and binds soil particles (silt and sand) [14]. This becomes one of the factors of the soil compaction on the P4 treatment plot. Soil compaction due to high fraction of clay can inhibit the growth of the plant, because the

soil bulk density increased and it can disrupt the roots growth and development [15].

### 3.1.2. Bulk density of soil

The bulk density of soil can be used as an indicator of soil compaction and soil health indicator. The bulk density of soil can affect rainwater infiltration, root growth, soil moisture availability, soil porosity, nutrient availability in the soil, and activities of soil micro organisms. Soil texture affects the bulk density of soil. Sandy soils have a relatively high bulk density due to the low total pore. While clayey soils usually and loamy soils have a high porosity and relatively low bulk density [16].

Figure 1b shows an increasing tendency of soil bulk density when *A. cadamba* plant is 3 months age in all treatments, except the P4 treatment. The high bulk density of post-mining soils may inhibit the growth of plant roots [3][15]. Results of this study are in accordance with the statements of Glab and Gondek [17] where the

addition of sediment as a soil amendment does not always decrease soil bulk density. The decrease of soil bulk density due to the addition of sludge-sediment as a soil amendment depends on the content of organic matter in the sludge-sediment. The application of sludge for soil amendment acts as an organic material that can improve soil aggregation, increase soil aggregate stability, reduce soil bulk density and increase soil porosity [8].

This study showed that the addition of 100% of river sludge on planting medium (P4 treatment) was able to reduce the bulk density compared to other treatments. Therefore, the optimum dose of sediment addition as a soil amendment in this study is the addition of 100% of river sediment. These results indicate a correlation between high clay fraction on P4 with decreasing bulk density. Chaudhari et al. [16] states that clay and loam soils have relatively low bulk density, whereas sand soils have relatively high bulk density. Other research results indicate that the addition of 15-60 Mg ha<sup>-1</sup> of sediments significantly affected the decrease of bulk density [18].

### 3.1.3. Micro Pore

Fig. 1c shows a trend of increasing the percentage of soil micro pore at the time of 3 months old of plants. Increasing the percentage of micro pore occurs along with the increase of percentage of the river sediment in the planting medium. It is seen that the sequence of micro pore increase is P0 < P1 < P2 < P3 < P4. The increase of micro pore in this study is thought to be due to the compaction of planting medium. This is in accordance with the opinion that the soil compaction process can lead to decreased macro pore, while the micro pores are increasing [19].

The high micro pore in planting medium 100% of river sediment (P4 treatment) along with the high percentage of clay fraction in planting medium (Fig. 1a). Micro pores can bind water and the water contained in these micro pores does not undergo drainage due to gravity. This is in line with Hillel's [14] statement where clay fractions have a high absorbing and binding capacity when compared to sand fractions.

### 3.1.4. Total pore of soil

Fig. 1d shows a tendency of total pore decline of soil at 3 months old of plant, except for P4 treatment. Addition of river sediment on topsoil planting-media of 25% (P1), 50% (P2) and 75% (P3) actually lowered the total pore of soil compared with no addition of river sediment (P0) at 3 months age of plant. While the addition of

100% of river sediment on topsoil planting-media can increase the total pore of soil, although the percentage of improvement is still relatively low. Results of this study do not match the results of previous studies which concluded that the application of sludge on soil causes an increase in total pore in the soil [21]. Increasing the total pore in soil after the addition of sludge as a soil amendment is due to the organic material content in the sludge that plays a role in improving soil aggregation [19]. The application of sludge as a soil amendment acts as an organic material that can improve soil structure, increase soil aggregate stability, reduce soil bulk density and increase soil porosity [8].

The percentage of total pores has a correlation with the bulk density of soil, the higher bulk density so the total pore decreases and vice versa. The decrease of soil pore in this study is suspected due to the compaction of planting medium. The plot of each treatment in this study was limited by wooden planks so that the soil was not able to expand horizontally. In addition, the intensity of rainfall is high enough to encourage the soil compaction, so the soil porosity decreases. Soil compaction can have an impact on soil structure, decreasing the number and size of soil pore, increasing the soil bulk density, and reduction of root growth [22].

## 3.2. Characteristic of *A.cadamba*

### 3.2.1. Litter production of *A.cadamba*

Table 1 shows that the addition of river sediment on topsoil planting medium was able to increase the litter production of *A.cadamba*. The planting media 50% sediment (P2) and 75% sediment (P3) increased the production of litter and significantly different from other treatments. While litter production on the planting medium containing 25% sediment (P1) and 100% sediment (P4) was not significantly different with control treatment.

The planting medium containing 75% of river sediment (P3 treatment) in this study is an efficient dose in increasing the litter production of *A.cadamba*. While the medium planting of 100% river sediment (P4 treatment) has a negative impact on the decrease of litter production. This is guessed due to a flooding water on the surface of plot. Water flooding on the planting medium has a correlation with the observation of some physical characters of planting media, such as micro pores. High percentage of soil micro pore can inhibit soil drainage process, so that soil aeration becomes worse [3]. This does not support plant growth and optimal plant biomass production. The production of plant biomass is

influenced by several factors: soil water movement, soil aeration, and root growth. If these factors are in poor condition, it can inhibit the

absorption of nutrients and water by plant roots [6].

Table 1. Fresh weight and nutrient content of litter of *A. cadamba*

Treatment	Fresh weight of litter (g m <sup>-2</sup> )		Nutrient content (%)					
			N		P		K	
P0	7.24	a	1.28	a	0.20	a	3.31	a
P1	7.00	a	1.65	b	0.24	b	3.37	a
P2	10.70	b	2.13	c	0.28	c	4.60	b
P3	13.25	b	2.30	c	0.29	c	4.96	b
P4	5.96	a	1.74	b	0.24	b	4.52	b
LSD 5%	2.61		0.17		0.03		0.54	

### 3.2.2. Nutrient content of litter of *A.cadamba*

The treatment of addition of river sediment on the topsoil material was able to increase nutrient content in the litter of *A.cadamba* (Table 1). These river sediment are rich in organic materials, Nitrogen, Phosphorus, Calcium, Magnesium, Sulfur and other micro nutrients needed by plants and soil microorganisms [8][18]. The highest content of N in the litter of *A. cadamba* was found in P2 treatment and was significantly different from other treatments, except for P3 treatment. The highest content of P in litter of *A.cadamba* was in P3 treatment and was significantly different from other treatments, except for treatment P2. The highest content of K in the *A.cadamba* litter is in P3 treatment and is significantly different from the P0 and P1 treatments.

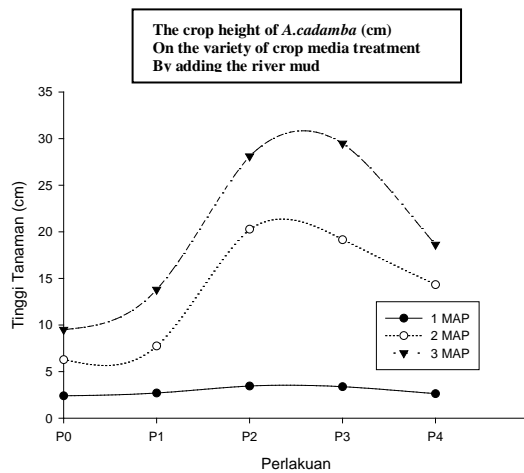
This study shows that the effectiveness of the addition of sediment-sludge as a soil amendment to the N content in the litter of plants is found in P2 treatment (50% sediment). Previous research has shown that adding sludge to soils (doses of 0, 25, 50, 75, 100 and 125 Mg ha<sup>-1</sup>) can increase the N content in vegetation leaves [23]. The low N-content of plant litter on the P4 treatment plot (100% sediment) is suspected

because in the plot there is a flooding of rainwater on the soil surface. This flooding causes the inhibition of processes of mineralizing N organic into N-available forms [22].

This study shows that the effectiveness of the addition of sediment-sludge as a soil amendment to the P content in the *A.cadamba* litter is found in P3 treatment (75% sediment) and not significantly different from P2 treatment (50% sediment). Treatment of P4 that is planting media in the form of 100% river mud sediment was less efficient in increasing the content of P litter plants. This is assumed because the plot of treatment P4 happened to flood rainwater so that interfere with absorption process of P by plant root. The results of Tamanini *et.al.* [24] indicate that the concentration of P in the soil increases linearly with increasing of mud (sediment) doses.

Based on the observation result, it was found that the effectiveness of addition of sludge as a soil amendment to the K-content of litter was found in P3 treatment (75% sediment) and not significantly different with P2 treatment (50% sediment) and P4 (100% sediment). The same results are also shown by Hussein [22] that the increase in K-content in cucumber leaves is directly proportional to the increase in the proportion of sludge in soil growing media.

2a



2b

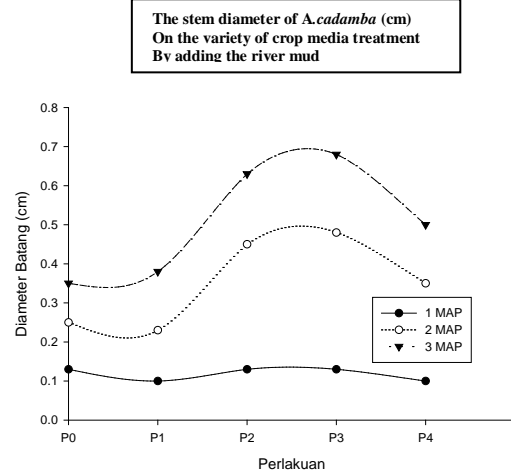


Fig. 2. Growth of *A. cadamba* under different treatment of river sediment and topsoil as the planting media.

### 3.2.3. Growth of *A. cadamba*

The increase in plant height and stem diameter of *A. cadamba* occurred along with the increasing percentage of addition of river sediment on topsoil planting medium, upto the P3 treatment (Fig. 2a and 2b). This supports the conclusion of Oklima et al. [25] that the application of soil ameliorant, in the form of coal ash and humic substances, significantly increased growth of jabon plants (*Anthocephalus chinensis*) on post-mining reclamation land. The application of sediment as a soil amendment can improve the physical, chemical and biological characteristics of soil, as well as improve soil fertility status, so as to support plant growth [8].

The curve in Fig. 2 shows a decrease in the plant-height and stem diameter of *A. cadamba* at the P4 treatment, when compared with P3, although it is still higher than control treatment at the plant age of 2 and 3 months after planting. The results of this study are in line with results of Kharub [7] study, which concludes that addition of sludge to the planting medium has a positive impact on lady-finger growth, the optimum dosage of plant media mixture is 50% sludge and 30% soil material.

The delayed growth of *A. cadamba* plant height in P4 treatment is suspected due to the occurrence of water flooding on the plot surface. This periodically flooding of soil surface may

interfere with *A. cadamba* growth and may even lead to the death of *A. cadamba*. Flooding of water in the soil surface has an impact on the decreasing growth of *A. cadamba*, which is on leaf area, plant height, biomass accumulation and root length when compared with control. Water flooding can also inhibit the growth of stem diameter of *A. cadamba* by 50%.

## 4. CONCLUSION

Addition of river sediment on topsoil material was able to increase clay fraction and soil micro pore of the planting media, while the bulk density and percentage of total soil pore decreased. The stem diameter, plant height and litter production of *A. cadamba* have increased along with the increasing percentage of addition of river sediment, except P4. The highest content of N in the litter is in P2 treatment, whereas the highest content of P and K of the litter is found in P3 treatment.

Stagnant surface water on the planting medium is seen on the plot during observation especially in the treatment of P4. This occurs because of the high intensity of rainfall at the study sites during the study. Therefore for the next study should be done on the greenhouse so that the effect of addition of river sediment on the physical properties of planting media can be known more accurately.

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