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ORIGINAL RESEARCH ARTICLE

Application of coconut shell charcoal and NPK fertilizer toward *Acacia mangium* growth on the soil of ex-limestone mining in Bogor, Indonesia

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ABSTRACT

Limestone mining is an activity that can cause damage and negative impact on the environment. Revegetation is needed to be done so that the damaged land condition can be returned in accordance with its designation. *Acacia mangium* is one of the species that can be used in revegetation of mining area. This study aims to increase the *A. mangium* growth response at the limestone mining land that can be used as a tool for consideration in revegetation activities. The design used in this experiment was a complete randomized design (CRD) factorial with 2 factors. The first factor was the application of coconut shell charcoal and the second factor was the application of NPK fertilizer. The results showed that the addition of coconut shell charcoal could give effect to the number of nodules with the best dose of 90 g and NPK fertilizer was able to give effect to the growth of diameter and the number of root nodules with the best dose of 15 g.

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INTRODUCTION

Gunung Kapur Ciampea – Bogor is an limestone ecosystem. Based on its biophysical condition, the land cover (vegetation) should be maintained in the form of forest. Forest play important role in the life support systems, especially the function of the water system (hido-orology system) in the ecosystem. Forest conversion into other uses can threaten the existence of forest vegetation and environmental functions (Oksana *et al*., 2012). At Gunung Kapur Ciampea has been granted permission for lime mining activities. Mining causes damage and negative impacts to the environment such as decreasing soil productivity, sedimentation, landslides, damage to flora and fauna, and changes the microclimate (Cakyayanti and Setiadi, 2014, Wasis and Andika, 2017).

Lime rock is a C extract that is widely used in industrial or production activities (Sukandarrumidi, 2009). The high lime mining activities may result in the damage to vegetation and soil horizon, loss of top soil, low organic matter, high pH, high soil temperature, trace deposits, and low diversity of soil microbial populations (Prayudyaningsih, 2014). Therefore, to be able to restore the function of damaged ecosystems needs to be done rehabilitation activities in the form of land improvement and tree planting (revegetation). Land improvement is needed to repair the damaged soil, one of them are with the addition of coconut shell charcoal or NPK fertilizer. Coconut shell charcoal plays a role in increasing fertility and plant growth. Bio-charcoal has a more effective capability in reducing nitrogen nutrient leaching compared to rice husk charcoal (Hariz *et al*., 2015). NPK fertilizers include inorganic compounds that play a role in increasing the amount of nutrients in the soil (Liliane *et al*., 2001, Atkinson *et al*., 2010). This fertilizer is easily dissolved in water and quickly absorbed by plants.

Revegetation is an activity that has the potential to restore and improve the productivity of land that has been damaged by mining. The success of revegetation depends on the selection of plant species capable of recovering soil damage and its adaptability on the soil characteristics, climate, and the ultimate goal of revegetation (Cakyayanti and Setiadi, 2014; Wasis and Andika, 2017). One of the most potentially species selected for

revegetation is *Acacia mangium*. *A. mangium* is a fast growing plants that can grow well in marginal pastures and mining sites (Yamashita *et al.*, 2008; Aggangan *et al.*, 2010). The form of adaptation by this species is symbiotic with rhizobium bacteria and forming root nodules on its root system. This study aims to examine the growth response of *A. mangium* on the ex-limestone mining media (soil) as well as the influence of coconut shell charcoal and NPK fertilizer on *A. mangium* growth.

MATERIALS AND METHODS

Experimental design

The research was conducted from February – July 2017 at Greenhouse of Silviculture Division and Forest Influence Laboratory, Department of Silviculture, Faculty of Forestry, Bogor Agicutural University (IPB). The materials used were *A. mangium* seedlings (3 month), coconut shell charcoal, NPK fertilizer, water, and media/soil (from ex-limestone mining land in Ciampea, Bogor, West Java), polybag, digital scales, sprinkler, calipers, rulers, calculators, oven. Observed parameters were growth of height, diameter, shoot root ratio, number of root nodule, biomass (dry and wet weight), and nutrient content in media. Generally, the procedure of this research were as follows:

Media preparation and planting

The soil from ex-limestone mining were weighed as 1 kg in dry air condition and mixed with coconut shell charcoal and NPK fertilizer. Dose of each coconut shell charcoal applications were 0 g, 30 g, 60 g, and 90 g. Dose of each NPK fertilizer applications were 0 g, 5 g, 10 g, and 15 g. *A. mangium* seedlings were planted into 48 prepared polybags (media) in the previous stage.

Data collection

Data collection was done by doing measurement of height and diameter of the seedlings. Beside that, total wet weight (TWW) and total dry weight (TDW) measurements were done after the harvesting. The harvested plants were separated between the root and shoot. Each part (root and shoot) was weighed using a digital scales. TWW was the sum of the weight of wet roots and wet shoot weight. TDW was measured after the plant part was dried in an oven at 70° C for 24 hours and then weighed using a digital scales. TDW was the sum of root dry weight and shoot dry weight. The calculation of the number of root nodules was done by counting the root nodules on each root of the plant observed. The root shoot ratio was calculated based on the ratio of the total dry weight of the shoot to the total dry weight value of the root. The analysis of nutrient content (in the media/soil) was conducted at the Laboratory of the Department of Soil Science and Land Resources, Faculty of Agriculture, IPB.

Data analysis

This experiment used completely randomized design factorial with 2 factors. Each treatment was done by 3 repetitions. The first factor was coconut shell charcoal (A_0 = 0 g, A_1 = 30 g, A_2 = 60 g, and A_3 = 90 g). The second factor was NPK fertilizer (P_0 = 0 g, P_1 = 5 g, P_2 = 10 g, and P_3 = 15 g). To analyze the treatment effect on each growth parameter observed, we used ANOVA analysis and Duncan's Multiple Range Test to knowing the best treatment which affect the *A. mangium*'s growth. (Mattjik and Sumertajaya 2013; Stell and Torries 1991; Wibisono, 2009)

RESULTS AND DISCUSSION

The result of this study that showing the effect of coconut shell charcoal and NPK toward the growth of *A. mangium* was showed on Table 1.

This study showed that the addition of coconut shell charcoal gave a significant effect on the number of root nodule of *A. mangium* seedlings. The addition of NPK fertilizer gave a different effect on the growth of diameter and number of root nodule of *A. mangium*. Meanwhile, for the combination of coconut shell charcoal addition and NPK fertilizer did not give any significant effect on all parameters. This study also showed that *A. mangium* could grow on media of ex-limestone mine. Growth is an increase in plant dimension that was influenced by genetic and environmental factors. This genetic factor is brought by plants that are inherited directly from the elder, while the environmental factor was the result of modification of the habitat of a plant (Wasis and Andika, 2017). *A. mangium* is a plant that able to grow well in critical land. This species has a good adaptability in various soil types and environmental conditions including limestone minerals (Krisnawati *et al.*, 2011; Prayudyaningsih, 2014).

Table 1. Effect of coconut shell charcoal and NPK fertilizer impact on growth of *A. mangium* seedlings.

Parameter	Treatment		
	Coconut shell charcoal	NPK fertilizer	Coconut shell charcoal and NPK fertilizer
Height	0.8056^{tn}	0.8744^{tn}	0.9138^{tn}
Diameter	0.7157^{tn}	0.0336^{*}	0.3376^{tn}
Total wet weight	0.7941^{tn}	0.8532^{tn}	0.2626^{tn}
Total dry weight	0.6562^{tn}	0.6189^{tn}	0.3055^{tn}
Root shoot ratio	0.3029^{tn}	0.7352^{tn}	0.8823^{tn}
Number of root nodules	0.0192^{*}	0.0334^{*}	0.3220^{tn}

Remarks: * = treatment had significant effect on 95% confidence interval with significant value (P-value) <0.05 (α). tn = treatment had no significant effect on 95% confidence interval with significant value (P-value)> 0.05 (α)

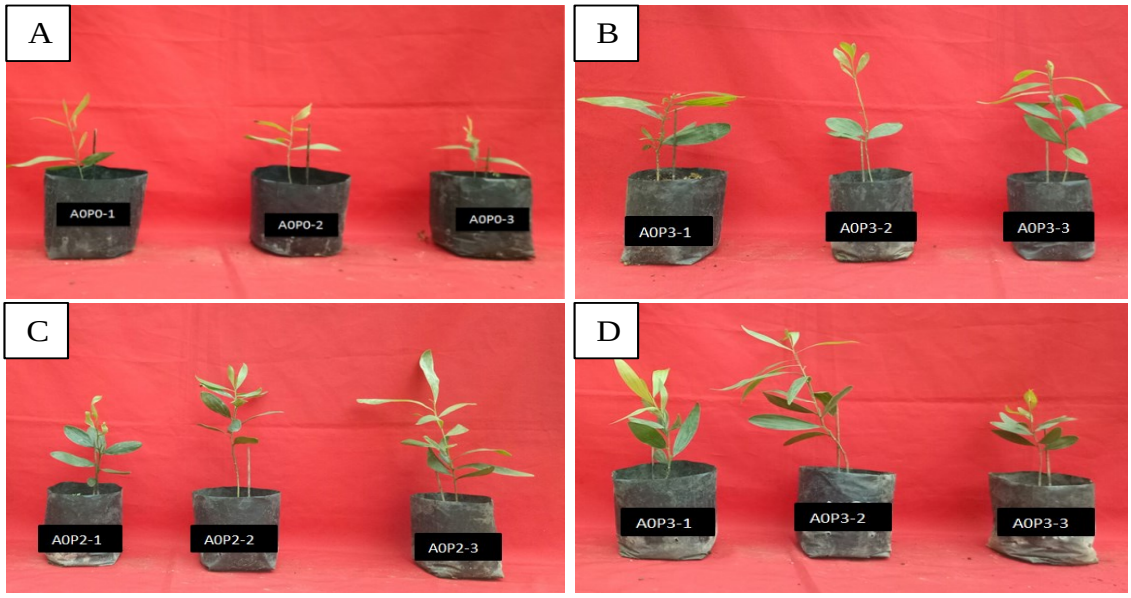

Figure 1. *Growth of A. mangium with the addition of NPK fertilizer dosage 0 g (A), dose 5 g (B), dose 10 g (C), and dose 15 g (D).*

Table 2. Duncan test results of the effect of NPK fertilizer on the growth of seed diameter *A. mangium*.

Treatment NPK fertilizer	Average diameter growth (cm)	Percent increase (%)
Dose of 0 g	0.68b	0.00
Dose of 5 g	0.70b	2.94
Dose of 10 g	1.02ab	50.00
Dose of 15 g	1.19a	75.00

Remarks: Number followed by the same letter showed no significant different treatment at 95% confidence interval.

Table 3. The average of root-shoot ratio and the comformity to planted of *A. mangium*.

Treatment	Root shoot ratio	Conformity to planted
A_2P_1	2.70	Suitable
A_1P_2	3.25	Not suitable
A_1P_3	3.53	Not suitable
A_3P_3	3.56	Not suitable
A_2P_0	3.64	Not suitable
A_1P_1	3.68	Not suitable
A_3P_0	3.79	Not suitable
A_3P_2	3.88	Not suitable
A_2P_3	3.91	Not suitable
A_1P_0	4.05	Not suitable
A_3P_1	4.10	Not suitable
A_0P_3	4.19	Not suitable
A_0P_1	4.20	Not suitable
A_0P_0	4.53	Not suitable
A_2P_2	4.56	Not suitable
A_0P_2	5.12	Not suitable

Remarks : Suitable = Root shoot ratio 1-3; Not suitable = Root shoot ratio > 3.

Duncan test results (Table 2 and Figure 1) showed that the average growth of diameter of *A. mangium* on ex-limestone mining soil with 0 g NPK fertilizer (control soil) had no significant effect on soil with 5 g NPK (2.94%) and 10 g NPK (50%). However treatment with 15 g NPK had a significant effect on the growth of diameter (75% from the control). It showed that *A. mangium* had the best diameter growth if planted on ex-limestone mining soil with the addition of 15 g of NPK fertilizer. In the other hand, the lowest diameter growth of *A. mangium* planted on ex-limestone mining soil was showed by the treament of the addition of 5 g NPK fertilizer. Achiri *et al.* (2017) said that the addition of NPK fertilizer affects to the growth of stem diameter. Nutrient content of N, P, and K have a great influence on the increase of stem diameter (Siregar and Utami, 2002; Herdiana *et al.*, 2008; Prayudyaningsih 2014).

Table 3 showed that the addition of coconut shell charcoal and NPK fertilizer had hight effect toward root shoot ratio (from 3.25 to 5.12), except A_2P_1 treatment gave effect as 2.70. These results showed that shoot biomass was greater than that of root biomass, generally in this research. The results of this study indicated that root growth was very low as a result of low availability of water and nutrients generally in the medium of limestone soil. The value of root shoot ratio can be used to see the balance between root capability in absorbing water and nutrients as well as the ability of plant shoot in the process of transpiration and the rate of photosynthesis (Wahyudi, 2009; Wulandari and Susanti, 2012). Plant growth is called has well performance when it has a value of shoot root ratio ranging from 1-3 (Mokany *et al.*, 2006, Wasis and Andika, 2017).

Duncan test results (Table 4) showed that the number of root nodules of *A. mangium* seedlings on ex-limestone mine media by the addition 0 g of coconut shell charcoal (control) did not give significantly different effect with the 30 g coconut shell charcoal. However 60 g and 90 g coconut soil caharcoal additions gave a significantly different effect on the number of root nodule. These results showed that by increasing doses of coconut shell charcoal could increase the number of root nodule of *A. mangium* seedling. Bio-charcoal has a porous structure and a large surface area that provides such advantages as a habitat for the root nodule-forming bacteria, stimulates nodulation and fixation, and modifies the availability of N in the soil to be utilized by plants (Atkinson *et al.*, 2010, Ogawa and Okimori, 2010, Pereyra *et al.*, 2015).

Table 5 showed that the number of root nodule of *A. mangium* on ex-limestone mining media with NPK fertilizer dose 0 g (control) did not give significantly different effect with the addition of 5 – 10 g NPK fertilizer. However the addition of 15 g NPK fertilizer was significantly effected on the root nodule number of *A. mangium*. This treatment could produce 145.45% increase of root nodule from the control treatment. The addition of NPK fertilizer in the media/soil was able to trigger the formation of root nodules. This phenomenon was indicated by the significant influence on the formation of the number of root nodule of *A. mangium*. Nutrients that played a role in the formation of the number of root nodules was phosphorus. This P element is indispensable for rapid and healthy root development and stimulates the formation of root nodule by *Rhizobium* sp. bacteria. (Singh *et al.*, 2007).

Tabel 6 showed the soil properties analysis on the media. This analysis compared the control treatment and the treatment with 60 g coconut shell charcoal (A_2) and 5 g NPK fertilizer (P_1). The A_2P_1 treatment was the best treatment which could produced the best root shoot ratio growth. Soil texture was determined by using the diagram of USDA soil texture triangle. Control treatment had sandy clay loam texture with 52.15% sand, 22.24% silt, and 25.61% clay. On the other hand, the addition of coconut shell charcoal and NPK fertilizer (A_2P_1 treatment) had loam texture with 47.46% sand, 30.51% silt, and 22.13% clay. Loam soil is ideal soil texture to support the plant growth, and generally it contains 22.5-52.5% sand, 30-50% silt, and 10-30% clay (Hardjowigeno, 2003; Hanafiah, 2005).

Organic C is an organic material that has an important role in the soil, especially in providing essential nutrients with sufficient quantities for plant growth (Wasis and Noviani, 2010; Wulandari *et al.*, 2102). The result of soil chemical analysis showed that the control soil contained very low organic C (0.82%), while on the soil given the addition of coconut shell charcoal and NPK fertilizer (A_2P_1) had a high organic C content (3.27%). The high content of organic C in the soil might be caused by the addition of coconut shell charcoal. Coconut shell has highest chemical component such as lignin (Rodrigues and Pinto, 2007). Lignin is a compound that acts as an organic C-source (Kusuma *et al.*, 2013). N element is an essential nutrient that needed by plants. The function of the N element is to improve and stimulate the growth of stems, branches, leaves and assist in the establishment of protein (Hardjowigeno, 2003; Lingga and Marsono, 2008). The result of soil chemical analysis showed that the control soil had a very low N-total content (0.08%), while media/soail with the addition of coconut shell charcoal and NPK fertilizer had a moderate N-total content (0.21%). This phenomenon showed that coconut shell charcoal and NPK fertilizer could increase the N content in the soil. Nitrogen can improve the process of photosynthesis, increasing the number of leaves, and the plant could growth optimally (Mansur, 2013).

In other hand, the addition of coconut shell charcoal and NPK fertilizer is also able to increase the P content in the soil. P element has a function to strengthen the stem, cell division, and root development (Hardjowigeno, 2003). The content of P available in the control was 120.03 ppm, while on the soil with the addition of coconut shell charcoal and NPK fertilizer had a higher P content (172.19 ppm). Coconut shell charcoal and NPK fertilizer contain phosphorus that can be utilized by plant growth. The use of NPK fertilizer and coconut shell charcoal can increase P content especially in poor nutrient soil (Gani, 2009; Roidah, 2013). The cation exchange capacity (CEC) is the number of cations that can be absorbed by the soil per unit of soil weight, CEC value can be used in determining the high level

Table 4. Duncan test results of coconut shell charcoal effect on the number of root nodules of *A. mangium* seedlings.

Treatment coconut shell charcoal	Number of root nodule	Percent increase (%)
Dose of 0 g	3.08b	0.00
Dose of 30 g	6.08ab	97.40
Dose of 60 g	11.50a	273.38
Dose of 90 g	11.58a	275.97

Remarks : Number followed by the same letter showed no significant different treatment at 95% confidence interval.

Table 5. Duncan test results of NPK fertilizer effect on the number of root nodule of *A. mangium* seedlings.

Treatment NPK fertilizer	Number of root nodules	Percent increase (%)
Dose of 0 g	5.50b	0.00
Dose of 5 g	5.00b	-9.09
Dose of 10 g	8.25ab	50.00
Dose of 15 g	13.50a	145.45

Remarks : Number followed by the same letter showed no significant different treatment at 95% confidence interval.

of soil fertility (Hardjowigeno, 2003). The result of soil analysis showed that CEC found in control and soil with the addition of coconut shell charcoal and NPK fertilizer had high CEC value were 36.01 me/100g and 35.09 me/100g, respectively. Those CEC condition were caused by soil condition which dominated by basic cations such as K, Na, Mg, and Ca. Soil with high CEC is dominated by alkaline cations will have high alkali saturation (Hardjowigeno, 2003). This condistion also supported by the presence of clay fraction with negative charges, so the cation excahange will be higher (Dharmawan and Siregar, 2008, Wasis and Noviani, 2010).

Based on the cation arrangement, the control soil contains elements of K (0.83 me/100g), Na (0.86 me/100g), Mg (2.36 me/100g), and Ca (78.27 me/100g). Soil with the addition of coconut shell and NPK fertilizer contained elements of K, Na, and Ca were very high (Table 6). The addition of coconut shell charcoal and NPK fertilizer were able to increase the element K, Na, Mg in the soil. Element K plays a role in the opening of stomata, root development, and increase resistance to drought and disease, while Mg plays a role in the formation of chlorophyll and activator enzyme that closely related to the metabolism of carbohydrates (Hardjowigeno, 2003; Kastono, 2005). Na element is able to give effect to plant growth and production, but if Na ratio with other cation is too high then plant growth can be hampered (Hanafiah, 2005). Different with K, Na, and Mg elements, Ca in the ex-limestone mining soil was decreasing when the soil was treated by the addition of coconut shell charcoal and NPK fertilizer. However, Ca in the soil with the addition of coconut shell charcoal and NPK was still high. Ca with high condition due to an inhibition on *A. mangium* growth. White and Broadley (2003) said when Ca element was so high, it can be a toxic to the plant.

Soil pH balance played a role in supporting plant growth due to soil pH could describe the condition of macro and micro nutrient availability in the soil. The soil chemical analysis results showed that the control soil has a neutral pH value (7.42), as well as with soil enhanced coconut shell charcoal and NPK fertilizer which has a neutral pH value (7.03). Soil with neutral pH has the ability to provide optimal nutrient for plant growth (Nduwumuremyi, 2013). In addition, soil pH also played a role to support the root nodules establishement which has symbiosis with rhizobium bacteria in the soil. Rhizobium bacteria are able to grow well in soil with neutral pH. Wadhwa *et al.* (2017) said the optimum pH that supports rhizobial growth is about 6-7, while the minimum growth is about pH 8 and pH 9. Organism activities in the soil could be used as an indicators of soil quality. The benefits of soil organisms are to support the process of nutrient cycling, modification of soil structure, nitrogen fixation, soil decomposition, soil structure dynamics, and symbiosis with plants (Widyati, 2013; Barrios, 2007; Wasis *et al.*, 2018). Coconut shell charcoal on marginal soil (ex-limestone mining soil) could invite the presence of soil organisms. Bio-charcoal has a function as a habitat for soil organisms and support their life cylce (Shalsabila *et al.*, 2017). The soil organisms that found in the media were ants and earthworms. Ant is able to increase soil porosity, influence pH to be neutral, and increase nutrient content in soil (Frouz and Jilkova, 2008). Earthworms are a species that potentially to increase porosity and soil aggregation, and can play a role in restoring mine land (Shipitalo, 2004, Boyer and Wratten, 2009).

Table 6. Soil (planting media) properties analysis.

Number	Treatment	Control	Criteria *	Coconut shell charcoal and NPK fertilizer (A_2P_1)	Criteria *
1	Texture (%)				
	Sand	52.15		47.36	
	Silt	22.24	Clay loam	30.51	Sandy clay loam
	Clay	25.61		22.13	
2	Organic C (%)	0.82	Very low	3.27	High*
3	Nitrogen (N)-total (%)	0.08	Low	0.21	Medium
4	Phosphorus (P) (ppm)	120.03	Very high	172.19	Very high
5	CEC(me/100g)	36.01	High	35.09	High*
6	pH	7.42	Netral	7.03	Netral*
7	Cation				
	Potasium (K) (me/100g)	0.83	High	5.29	Very high
	Sodium (Na) (mg/100g)	0.86	High	1.63	Very high tinggi
	Magnesium (Mg) (me/100g)	2.36	High	3.41	High
	Calcium (Ca) (me/100g)	78.27	Very high	68.97	Very high
8	Alumunium (Al) (me/100g)	Tr	-	Tr	-
9	Alkali Saturation (%)	100	Very high	100	Very high

Remarks : * = Criteria based on Balai Penelitian Tanah (2009) ; Tr = not measurable.

Conclusion

The single increment of coconut shell charcoal or NPK fertilization in the ex-limestone mining media gave a significant effect toward the growth of *A. magium* seedling, especially on its diameter growth and root nodule number. The best treatment for increasing the seedling's diameter growth was 15 g NPK, where this treatment was not significantly different with 10 g NPK increment. In addition, these treatments also gave the best result on the root nodule growth. In other hand, the treatment of 90 g coconut shell charcoal addition also gave the best the growth of diameter. This treatment was not significantly different with 60 g coconut shell charcoal addition. Generally, the increment of coconut shell charcoal and/or NPK fertilization could be supporting the growth of *A. mangium* seedling, also improving the soil (ex-limestone mining media) characteristic.

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