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ORIGINAL RESEARCH ARTICLE



Growth of *Agathis dammara* (Lamb. Rich.) seedling on gold tailing with addition of coconut shell charcoal and compost

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ABSTRACT

Tailing produced by gold mining activities may cause environmental damage, such as decreasing of soil fertility and endangering ecosystem. Tailing also can decrease the soil characteristics and its fertility. Thus, it is not able to carry the plant growth as well. The addition of coconut shell charcoal and compost on tailing may improve the condition of soil properties (physical, chemical, and biological) and its fertility. *Agathis dammara* (Lamb. Rich.) is one of pioneer tree species that can be potentially used on revegetation process in post mining land. This research was carried out to assess the effect of adding coconut shell charcoal and compost on the growth of *A. dammara* seedling in tailing medium. This research uses complete random design (CRD) factorial. The result of this research shows that giving coconut shell charcoal and compost manure does not have significant effect to all parameter viz height, diameter, total wet weight (TWW), total dry weight (TDW), and root-shoot ratio (RSR) of *A. dammara*. The addition of coconut shell charcoal and compost gave the significant effects on total dry weight (TDW) of *A. dammara* seedling. The best treatment was the addition of 0 g coconut shell charcoal and 20 g compost (AOB1). Generally, the addition of coconut shell charcoal and compost could improve the soil characteristics and support the growth of the *A. dammara* seedling on tailing medium.

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INTRODUCTION

The natural resources is divide into two categories. Those are the renewable natural resources and non-renewable (depletable) natural resources. Non-renewable natural resource is the natural resource which does not have ability on biologically regeneration or can not renew if its sources have completed in the nature. It is formed by the geological process with a long time (period) to be available again and ready to be used (Fauzi, 2006). The mining commodity is one of the non-renewable natural resources. In the extraction process to split the mining mineral (mineral target) can produce the waste in environment, namely tailing. Tailing as a mining waste is able to causing serious problems in the environment, such as pollution in ecosystem and land (soil) degradation. Tailing has specific characteristics, such as marginal (poor on soil nutrients) and containing heavy metals which may defile the environment (Setyaningsih *et al.*, 2012; Setiadi and Cakyanti, 2014; Winata *et al.*, 2016). However, the post mining land must be rehabilitated to be safe,

stable, and productive ecosystem. Revegetation is one of post land mining rehabilitation steps. Species matching (species election) and the soil improvement are the important part to achieve the success of revegetation. Thus, the tailing characteristics improvement is the important step to support the growth of the plants. Related to species election, *A. dammara* (*Agathis dammara* Lamb. Rich.) is one of the pioneer tree species which is potentially used as revegetation plants in tailing medium (Renden *et al.*, 2006; Danu *et al.*, 2011; Uthbah *et al.*, 2017). The tailing improvement can be conducted by the addition of coconut shell charcoal and compost. The addition of coconut shell charcoal and compost aim to improving the soil (medium) structure, increasing macro and micro nutrient, and decreasing heavy metals contents (Yuniwati *et al.*, 2012; Wasis and Istantini, 2013; Winata *et al.*, 2016). The aims of this study were to analyze the growth of *A. dammara* seedling in the tailing and to analyze the influence of coconut shell charcoal and compost increment toward the *A. dammara* seedling growth in the tailing.

MATERIALS AND METHODS

Time and location

This research was conducted from June–September of 2015 in the greenhouse of Silviculture Division and Forest Influence Laboratory of Department of Silviculture, Faculty of Forestry, Bogor Agricultural University (IPB). Tailing was taken from the gold mining area in Pongkor, Bogor, West Java, Indonesia. The tailing properties analyze was conducted in Laboratory of Soil Science and Land Resources, Faculty of Agriculture IPB.

Materials and tools

Materials used in this study were *Agathis dammara* (Lamb. Rich.) seedling (age : 3 month) which has 20 cm of height, gold mining tailing, coconut shell charcoal, and compost. Tools used in this study were digital scale, ruler (60 cm), caliper, polybag (20 × 20 cm), digital camera, tallysheet, writing tools, oven.

Medium preparation and plantation

Planting medium used was tailing of the gold mining waste. Tailing was weighed as 1 kg, then placed into the polybag. After that, coconut shell charcoal and compost were added and mixed with tailing until homogenous. The doses of coconut shell charcoal were 0, 25, 50, 75, and 100 g. In other hand, the doses of compost were 0, 20, 40, and 60 g. After the planting mediums were ready, *A. dammara* seedlings were planted in the medium in polybag.

Maintenance

A. dammara seedlings maintenance was conducted through watering (pouring the water) in the morning and evening during four months.

Data collection

Data collection was conducted every week in the period of June–September 2015. The variables observed were height and diameter. In the last week *A. dammara* seedlings were harvested. After that, those were weighed to know the wet weight. Then, seedlings were dried off in the oven at 80°C as long as 24 hours (Wasis and Fathia, 2011; Wasis and Angga, 2017). After that, *A. dammara* seedlings were weighed again to know the dry weight. In other hand, two samples of soil / tailing (planting medium) were analyzed to know the soil characteristics. The two samples of these medium were soil / medium with control treatment and the best treatment which gave the best growth performance of *A. dammara*.

Experimental design and data analyze

Experimental design used was factorial completely randomized design with two factors. Factor A was coconut shell charcoal with 5 doses ($A_0=0$, $A_1=25$, $A_2=50$, $A_3=75$, $A_4=100$ g) and factor B ($B_0=0$, $B_1=20$, $B_2=40$, $B_3=60$ g) was compost with 4 doses and further the combinations A_0B_0 , A_0B_1 , A_0B_2 , A_0B_3 , A_1B_0 , A_1B_1 , A_1B_2 , A_1B_3 , A_2B_0 , A_2B_1 , A_2B_2 , A_2B_3 , A_3B_0 , A_3B_1 , A_3B_2 , A_3B_3 , A_4B_0 , A_4B_1 , A_4B_2 and A_4B_3 were used for the treatments. Each

treatments were conducted with four repetitions. Obtained data based on measurement of height, diameter, total wet weight (TWW), total dry weight (TDW), and Root-shoot ratio (RSR) was analyzed by using linear model (Mattjik and Sumertajaya, 2013; Stell and Torries, 1991; Wibisono, 2009). Only if there is significant effect, Duncan's Multiple Range Test will be measured for getting further statistic data.

RESULTS AND DISCUSSION

The growth of *A. dammara* seedling in the tailing

The influence of coconut shell charcoal and compost increment toward *A. dammara* seedling growth (height, diameter, total wet weight / TWW, total dry weight / TDW, and root-shoot ratio) were shown in Table 1.

Treatment of coconut shell charcoal increment had not significantly effect toward growth of height, diameter, also biomass (TWW and TDW), and root-shoot ratio. These facts were similar with treatment of compost increment toward *A. Dammara* seedling growth. However, the interaction between the increment of coconut shell charcoal and compost had a significantly effect on TDW. Growth is the increment of plant dimension, both height or diameter. The vertical growth (height) is the primary growth of the plant. It call as initial growth, while the horizontal growth (diameter) is the secondary growth. The abiotic (environmental) factors and the genetic factor (intern) have influences toward the height dan diameter growth, such as soil nutrient content, soil humidity, soil porosity, soil structure, soil acidity (pH), sunlight, and genetic characteristic among the plants within one species that give various expressions in the plant's growth. Figure 1 was showing influence of coconut shell charcoal and compost addition on height and diameter of *A. dammara* seedling.

Coconut shell charcoal increment gave an influence on the growth of height and diameter. The highest growth of *A. dammara* on the height and diameter were 7.83 cm and 0.17 cm, respectively. In other hand, compost addition also gave effect toward the growth of *A. dammara* on the height and diameter. The highest growth by compost treatment on the height and diameter were 7.5 cm and 0.15 cm, respectively. However coconut shell charcoal and compost increment were not significant to the height and diameter of *A. dammara* seedling which was planted in the tailing. This fact indicated that *A. dammara* was an adaptive species where could growth in the marginal land, such as tailing medium. In other hand, coconut shell charcoal and compost had important role to support the growth of *A. dammara* as well. Figure 2 was showing effect of coconut shell charcoal and compost increment toward the growth of biomass of *A. dammara* seedling in tailing.

The highest TWW of *A. dammara* seedling (10.24 g) was shown by 25 g coconut shell charcoal addition. Beside that, the addition of 20 g compost was also giving the highest TWW growth of *A. dammara* seedling (10.31 g). However the treatment of coconut shell charcoal and compost increment were not significantly different toward *A. dammara* seedling biomass which were planted in the tailing. Dry weight is able to show the plant's productivity,

due to 90% of photosynthesis product was found in the dry weight form (Gardner *et al.*, 1991). Table 2 showed that the best treatments to support the growth of total dry weight of *A. dammara* in the tailing medium were A₀B₁, A₁B₃, and A₁B₂. It indicated that the addition of coconut shell charcoal from 0 g to 25 g and the addition of compost about 20 g, 40 g, to 60 g could support the growth of *A. dammara* seedling as well in the tailing medium. The interaction treatments (coconut shell charcoal and compost) gave significant influence toward TDW of *A. dammara* (Table 2). Based on this study, it was known that the treatment with 0 g coconut shell charcoal and 20 g compost increment (A₀B₁) gave the raising of the TDW (12.44% toward the control). Beside that, the treatment of 25 g coconut shell charcoal and 0 g compost (A₁B₀) were showing the lowest growth of total dry weight (-41.45% toward control).

Charcoal is a porous material which produced through out pyrolysis process or organic matter (containing carbon) burning process. Charcoal contain dust, water, nitrogen, and sulfur. The benefits of charcoal were to increasing organic matter (C/N) in the soil, improving water and air circulation in the soil. Thus it will stimulate the growth of the root (Gusmailina *et al.*, 2002). Beside that, charcoal also is able to hold soil nutrient, and support the soil biology's life. Charcoal will release nutrient for the plant slowly appropriate to the plant necessary. Thus charcoal can support plant to growing up in the marginal soil, such as tailing. Charcoal has function as a soil amendment material such as improving the soil characteristics (soil physic, soil chemical, and soil biology), absorbing toxic substance in the tailing, and also stimulating the root growth (Darwo and Sugiari, 2008; Wasis and Noviani, 2010; Wasis and Istantini, 2013).

Wasis and Istantini (2013) said that root-shoot ratio is needed to know the growth parity between shoot as a location for photosynthesis and root as a location for water and nutrient absorption. Figure 3 showed root-shoot ratio of *A. dammara* in several treatments of coconut shell charcoal and compost increment which planted in the tailing.

Figure 3 showed the average of root-shoot ratio of *A. dammara*. The highest root-shoot ratio was shown by the A₀B₁ treatment (8.34). It means that the addition of 0 g coconut shell charcoal and 20 g compost could support the shoot growth of the *A. dammara*. A₀B₁ treatment caused the shoot growth of the *A. dammara* higher than the root growth. This phenomenon perhaps due to the compost increment. In other hand, the lowest root-shoot ratio was shown by the A₁B₀ treatment (2.98). A₁B₀ treatment was the addition of 25 g coconut shell charcoal and 0

g compost. Without compost, the root-shoot ratio of *A. dammara* was decrease. The low value of root-shoot ratio was showing that the root growth of the *A. dammara* lower than the shoot root. Without compost, *A. dammara*'s root might be growing up more than there was a compost in the soil. This phenomenon probably due to *A. dammara*'s root was stimulated by the lack of nutrient. These facts indicated that compost played an important role toward the *A. dammara* growth, which planted in the tailing. At least, compost is one of organic matter that contain essential components for the plant (Munawar, 2011). This study shows that charcoal giving has caused excess nutrients to be absorbed. The existing nutrients are absorbed in the charcoal so that they become unavailable to the plant.

Soil nutrient analysis

Soil nutrient analysis as a supporting data was conducted in the end of the research. The soil samples taken for the analysis process were the soil (medium) which given A₀B₀ treatment (control) and A₁B₂ (treatment that gave the best growth of the height and the diameter) (Table 3).

Charcoal (25 g) and compost (40 g) or A₁B₂ treatment could increase soil pH as 0.63 to be 7.40. Beside that these treatment also increased cation exchange capacity (CEC) from 2.39 me/100 g to 4.83 me/100 g. The existence of organic matter and clay in the soil were rewarding to the CEC, and it would increase the soil fertility (Hardjowigeno, 2003; Tan 1994; Phillip *et al.*, 2015). Coconut shell charcoal and compost increment (A₁B₂) also could increase the soil nutrient availability. The soil analysis showed that these treatments increased several elements, such as C (1.62 %), N (0.04%), P (3.84 ppm), K (0.65 me/100g) Ca (8.89 me/100 g), and Mg (0.10 me/100 g). This study showed that the coconut shell charcoal and compost increment could increased soil characteristics, such as improved soil pH, CEC, soil organic, also soil nutrient which all of those were very important to support the growth of plant. In other hand, in this study showed that the increment of coconut shell charcoal and compost was not significantly toward the growth of *A. dammara*, except the TDW parameter. This phenomenon might cause of (1). the doses of the treatments were to low, or (2). *A. dammara* was an adaptive species which had good performance and adaptability to growth in the tailing (marginal medium). However, basically organic fertilizer such as charcoal and compost have low nutrient content relatively, but this fertilizer has a special role to improve the soil characteristics (Hardjowigeno, 2003, Munawar, 2011; Wasis dan Fathia, 2011).

Table 1. The effect of coconut shell charcoal and compost increment on *A. dammara* seedling growth.

Parameter	Treatment		
	Charcoal	Compost	Charcoal×Compost
Height	0.765 ^{tn}	0.864 ^{tn}	0.052 ^{tn}
Diameter	0.297 ^{tn}	0.941 ^{tn}	0.409 ^{tn}
Total wet weight	0.376 ^{tn}	0.890 ^{tn}	0.057 ^{tn}
Total dry weight	0.173 ^{tn}	0.984 ^{tn}	0.026 [*]
Root-shoot ratio	0.750 ^{tn}	0.071 ^{tn}	0.534 ^{tn}

Numbers in the table were significant value. * = treatment significantly affect, on confidence interval 95% (Pr<F). tn = treatment no significant affect, on confidence interval 95% (Pr>F).

Table 2. Duncan test result of coconut shell charcoal and compost increment toward the total dry weight of *A. dammara*.

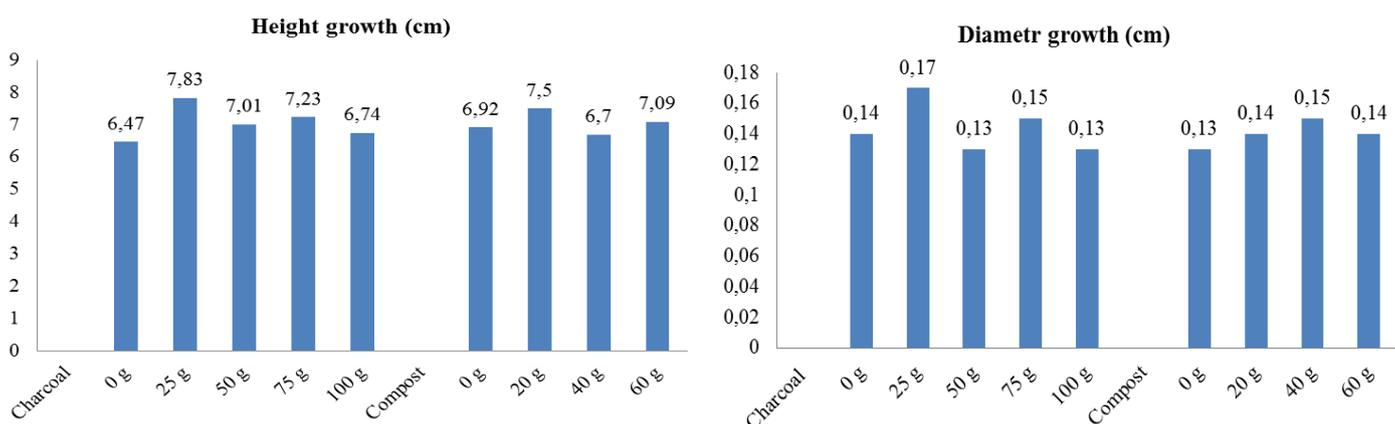
Treatment	Average of total dry weight (g)	Increasing toward control (%)
A ₀ B ₀	3.86 ab	0.00
A ₀ B ₁	4.34 c	12.44
A ₀ B ₂	2.30 bc	-40.41
A ₀ B ₃	3.06 abc	-20.73
A ₁ B ₀	2.26 a	-41.45
A ₁ B ₁	2.97 abc	-23.06
A ₁ B ₂	3.59 abc	-6.99
A ₁ B ₃	3.65 abc	-5.44
A ₂ B ₀	3.14 abc	-18.65
A ₂ B ₁	2.93 abc	-24.09
A ₂ B ₂	2.95 abc	-23.58
A ₂ B ₃	2.35 bc	-39.12
A ₃ B ₀	2.81 abc	-27.20
A ₃ B ₁	2.76 bc	-28.50
A ₃ B ₂	3.51 abc	-9.07
A ₃ B ₃	3.47 abc	-10.10
A ₄ B ₀	2.86 abc	-25.91
A ₄ B ₁	2.38 bc	-38.34
A ₄ B ₂	2.87 abc	-25.65
A ₄ B ₃	2.39 bc	-38.08

Number followed by the same letter showing treatment significant difference at 95% confidence level. Charcoal doses: A₀ = 0 g, A₁ = 25 g, A₂ = 50 g, A₃ = 75 g, and A₄ = 100 g. Compost doses: B₀ = 0 g, B₁ = 20 g, B₂ = 40 g, and B₃ = 60 g.

Table 3. The characteristic of planting medium (tailing) of *A. Dammara*.

Parameter	Treatment (A ₀ B ₀)	Criteria*	Treatment (A ₁ B ₂)	Criteria*	Alteration
Sand (%)	78.16	-	52.32	-	
Dust (%)	18.00	-	41.63	-	
Clay (%)	3.84	-	6.05	-	
pH	6.77	Netral	7.40	Netral	+0.63
CEC (me/100g)	2.39	Very low	4.83	Very low	+2.44
C-org (%)	0.07	Very low	1.69	Low	+1.62
N-Total (%)	0.03	Very low	0.07	Very low	+0.04
P (ppm)	3.22	Very low	7.06	Very low	+ 3.84
Ca (me/100g)	22.05	Very high	30.94	Very high	+8.89
Mg (me/100g)	0.83	Low	0.93	Low	+ 0.10
K (me/100g)	0.24	Low	0.89	High	+0.65
Na (me/100g)	0.12	High	1.12	Very high	+1.00
Al (me/100g)	Tr	-	Tr	-	
Fe (ppm)	Tr	-	16.04	-	+16.04
Cu (ppm)	0.03	-	3.07	-	+3.04
Zn (ppm)	Tr	-	5.75	-	+5.75
Mn (ppm)	41.33	-	5.28	-	-36.05

* = Soil characteristic criteria assesment by Soil Research Center (Soil Research Center) (Pusat et al., 1983).

**Figure 1.** Effect of coconut shell charcoal and compost increment toward the growth of height and diameter of *A. dammara* seedling in tailing.

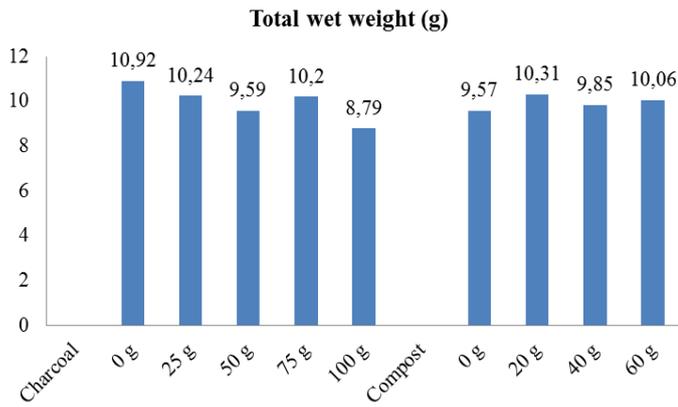


Figure 2. Effect of coconut shell charcoal and compost increment toward the growth of biomass of *A. dammara* seedling in tailing.

Conclusion

The addition of coconut shell charcoal and compost on the tailing gave significant influence toward TDW of *A. dammara* seedling, that was the treatment of the addition of 0 g coconut shell charcoal and 20 g compost). In other hand, the addition coconut shell charcoal and compost could improve the tailing characteristics, so this condition should support the growth of *A. dammara* as well, generally.

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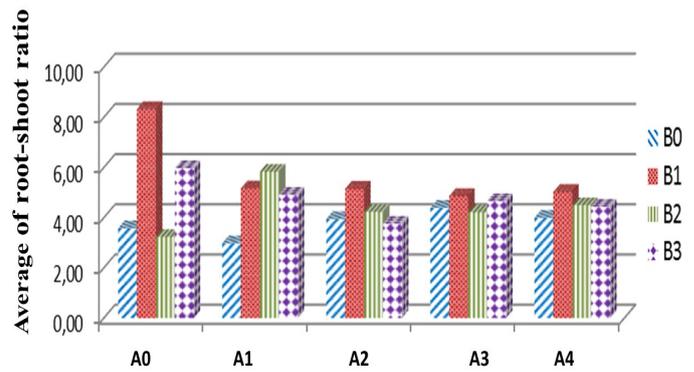


Figure 3. The average of root-shoot ratio of *A. dammara* seedling in the several treatment combinations of the increment of coconut shell charcoal (A) and compost (B).

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