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Utilizing Coal Ash and Humic Substances as Soil Ameliorant on Reclaimed Post-Mining Land

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ABSTRACT

Coal ash and humic substances can be used as soil ameliorant in the reclamation of formerly mined land. Due to its high pH and nutrients content, coal ash can be used to improve the chemical properties of the soil, such as increasing of pH, and increasing the levels of nutrients availability in the soil. Humic substances may also be used to complement, as they can increase the release of nutrients from the coal ash. Thus, the objective of this study was to assess the influence of coal ash and humic substances on soil chemical characteristics, nutrient absorption, and plant growth. This study was conducted in two locations - in a nursery area, involving two treatment factors: coal ash at different dosages (0, 200, and 400 g polybag^{-1}), and humic material also at varying dosages (0, 0.04, and 0.08 g C polybag^{-1}); and in a post-mining field using similar treatments: coal ash dosage (0, 2.5, and 5.0 kg planting^{-1} hole) and humic material dosage (0, 0.56, and 1.12 g C planting hole^{-1}). The results showed that coal ash and humic materials significantly increased the soil pH, available P, and exchangeable K, Ca and Mg. Coal ash also contained a number of heavy metals but in quantities that are far below the limits set by both Indonesian Government Regulation and the US Environmental Protection Agency (USEPA). The above soil amelioration effects mean that. applicaton of coal ash and humic substances can significantly increase the growth of *Jabon* trees in the reclaimed post-mining land.

Keywords: Coal ash, ex-mined land, humic substances, *Jabon (Anthocephalus chinensis)*, soil ameliorant

INTRODUCTION

Coal is one of the primary natural resources in Indonesia that has been increasingly utilized as fuel for electricity-generating thermal power plants. In the process of burning coal, among the resulting by-products are bottom ash and fly ash, or collectively referred to simply as coal ash. In 2006, the total production of coal ash from the all thermal power plants in Indonesia amounted to over 2 million tons; this volume nearly doubled (3.3 million tons) in 2009 (Aziz *et al.* 2006). Such large quantities of coal ash generated annually in Indonesia continue to accumulate as solid landfill waste, and its utilization potential remains to be tapped to optimum benefit. To cite an example, PT Newmont Nusa Tenggara (PTNNT), one of the largest companies in Indonesia that is engaged in open mining of gold and copper, operates a coal-fired power plant. PTNNT's power plant produced 21672.87 tons of coal ash in 2011-2012 which has not been fully taken advantage yet (PTNNT 2012).

One promising prospect for coal ash utilization is in the reclamation of post mining land. Reclamation is necessary towards reclaiming the functional qualities of post-mined areas as such lands need to be remediated for example, by reforestation, but which is constrained by their generally low soil fertility condition, especially in terms of nutrient content essential for plant growth. Hence, the soil need to be improved first, and one way is by the application of soil ameliorants, such as coal ash. Aside from the fact that coal ash is already abundantly available *in situ*, it possesses a high pH (11-12) (Singh *et al.* 2011) and contains considerable amounts of chemical compounds: 52.00% SiO_2, 31.86% Al_2O_3, 11.85% SO_3, 4.89% Fe_2O_3, 2.68% CaO, and 4.66% MgO (Wasim 2005).

Recent studies have demonstrated that coal ash can play a vital role in soil amelioration, which can lead eventually to successful resforestation of exhausted and degraded wastelands, particularly ex-mining land. For instance, McCarty *et al.* (1994) Singh *et al.* (2011) Sharma *et al.* (2006) found that applying coal fly ash substantially raised mineral soil pH. Iskandar *et al*. (2008) also reported that coal fly ash applied into peat soil increased pH, Available-

P, and exchangeable K, Na, Ca, and Mg. It has also been shown that fly ash from spent coal can adsorb such metals as Zn^{2+}, Cd^{2+}, Ni^{2+}, $Cu^{2+}$and Cr^{6+} from liquid wastes as effectively as active carbon (Bayat 2002).

Ironically, in Indonesia, the utilization of coal ash is still very limited, and it is partly because of the existence of Government Regulation No. 85/ 1999 which categorizes it as *hazardous and toxic substance* (Category B3) and imposes rigid restrictions in its handling. Hence, before it can be legally utilized, burned coal residues must undergo a Toxicity Characteristic Leaching Procedure (TCLP) in order to determine its toxicity properties. In contrast, other countries like Finland (Korpijärvi 2012), Australia (ADAA 2009) and Pathan *et al*. (2002), along with Israel (Cohen *et al*. 2001) have already been widely utilizing coal ash in various ways of economically viable and environmentally friendly application.

Another potential soil ameliorant is humic substances, which comes as a result of organic matter decomposition. According to Suganya and Sivasamy (2006), humic substances can maintain soil humidity, improve efficiency of water uptake, and increase the nutrient potential of sandy soils. It also has the capacity to form complex bonds with metallic ions (Stevenson 1982; Santos 2007).

This study was conducted to look into the technical suitability of utilizing coal ash and humic substances as soil amelioration agents, and to examine their relative influences on the soil properties of previously mined land. Further, this study would evaluate the effects of coal ash and humic substances application on the growth of *Jabon* seedlings in the forest nursery, and trees planted in the reclaimed post-mining land.

MATERIALS AND METHODS

Site Description

This study was conducted over a period of one year (December 2012-December 2013) in the forest nursery and land reclamation site (with geographic coordinates 116°44’0" – 116°57’0" East longitude and 8°30’0"– 9°3’0" South latitude) within the mining concession area of PTNNT in Sumbawa Barat Regency, Nusa Tenggara Barat Province in eastern Indonesia.

The materials used in this study consisted of coal ash obtained from the landfill of the PTNNT coal-fired power plant, humic substances, seedlings of *Jabon*, soil media, and various chemical reagents for laboratory analysis. Field equipment included planting tools and measuring devices, while the main laboratory instrument that was used was an Atomic Absorption Spectrophotometer (AAS).

Experimental Procedure

Nursery Trial (NT)

For the nursery (greenhouse) portion of this study, a 2-factorial Completely Randomized Design was used with factor 1 being coal ash at different dosages (0, 200, and 400 g polybag^{-1}, which can correspondingly be scaled up to 0, 40, and 80 Mg ha^{-1}); and factor 2 being humic substances at varying dosages (0, 0.04, and 0.08 g C polybag^{-1}), or corresponding to 0, 15, and 30 liter ha^{-1}. Each treatment was replicated three times (3 × 3 × 3 = 27 polybags). The potting medium consisted of 10-kg air-dried soil for each polybag. Humic substances was diluted 100 times prior to application. For this study, *Jabon* seedlings were used as indicator plant.

Field Trial (FT)

A 2-factorial Randomized Block Design was used in the field part of this study, with factor 1 being coal ash at different dosages (0, 2.5, and 5.0 kg/planting hole, or by extrapolation, corresponding to 0, 40, and 80 Mg ha^{-1}; and factor 2 being humic substances at varying dosages (0, 0.56, and 1.12 g C/planting hole, or corresponding to 0, 15, and 30 L ha^{-1}). Field blocking was randomized following east-west sunlight exposure. Each treatment was 3 replicated (3 × 3 × 3 = 27 polybags), and each treatment replication consisted of 4 plants (27 × 4 = 108 plants) with plant spacing of 2 × 3 m. Thus, the total study land area covered in this study was 648 m^2 (108 plants × 6 m^2). The soil ameliorant (material) was applied in the field into each planting hole measuring 0.5 × 0.5 m × 0.5 m. The concentrated humic substances contained 3.23% C, was first diluted 100 times before field application. Again, *Jabon* was used as indicator plant.

Statistical Analysis

The measurement parameters and their respective method of data analysis that were used in this study are summarized in Table 1. The statistical analysis employed a significance level of 5%, and the iterative paired tests used DMRT (Duncan’s Multiple Range Test).

Analysis of Chemical Properties of Coal Ash and Humic substances

The chemical composition and total metal content of coal ash are summarized in Table 2, while

Table 1. Measurement of soil and plant parameters and means of analysis.

Parameter	Unit	Analytical Method / Device Used
Soil Analysis		
pH H_2O (1 : 1)	-	pH meter
Organic-C	%	Kurmish
N total	%	Kjeldahl
Available-P	%	Bray 1
Exch.-Ca, exch.-Mg	$cmol^+ kg^{-1}$	NH_4OAc 1 *N* extract measured with AAS
Exch.-K	$cmol^+ kg^{-1}$	NH_4OAc 1 *N* extract measured with Flame photometer
CEC	$cmol^+ kg^{-1}$	NH_4OAc 1 *N* extract percolated with NaCl 10% and then distilled
Available-Fe and Cu	$mg kg^{-1}$	Morgan Wolf measured with AAS
Plant Growth Analysis		
Plant height	cm	Measured with meter, from stem collar/ground level to tip of erect plant
Stem diameter	cm	Measured with clipper meter or diameter tape

Note: exch denotes "exchangeable"

Table 3 shows the results of the coal ash toxicity test (TCLP), and humic substances composition. The results of the TCLP test on coal ash, as summarized in Table 3, indicate that the levels of heavy metals present in the coal ash are all far below the standard tolerance limits set under Indonesian Government Regulation (PP No. 85/ 1999), which are more stringent than that of the United States Environmental Protection Agency (USEPA). This finding has an important implication which is that the PTNNT coal ash is environmentally suitable for use as soil ameliorant.

On the other hand, the humic substances material that was used in this study was extracted from lignite coal. By its nature, humic substances possesses a highly functional group that can influence the degree of nutrient release from coal ash or mineral soil. Earlier, Ahmad (2011) highlighted that humic substances from lignite humic acid and peat humic acid can accelerate the release of elements from diorite porphyry, basalt porphyry, and trachite porphyry rocks. The properties of the humic substances solution in this study are shown in Table 4.

Table 2. Chemical composition of the PTNNT thermal power plant coal ash.

Parameter	Method[a]	Coal ash from Landfill (in % except pH)
pH	pH meter	11.70
C	CNS	0.97
N	CNS	0.13
SiO_2	XRF	27.4
Al_2O_3	XRF	7.36
CaO	XRF	10.7
Fe_2O_3	XRF	11.5
MgO	XRF	4.85
K_2O	XRF	0.85
Loss on Ignition	Gravimetric	35.3

[a] Notation: CNS: C, N and S analyzer; XRF: X-ray Fluorescence.

RESULTS AND DISCUSSION

Suitability of Coal ash as Soil Ameliorant

Shown in Table 2, coal ash is highly alkaline and contains a number of nutrient elements which can be utilized as ameliorant to improve the chemical properties of soil. At the same time, although the TCLP test results in Table 3 suggest that coal ash contained several heavy metals, they occurred in levels which were far below the limits set by both Indonesian Government Regulation (PP No.85/ 1999) and the US *Environmental Protection Agency* (USEPA) and therefore, it could be safely utilized as soil ameliorant.

Effect of Coal ash and Humic substances Application on Chemical Properties of Soil with *Jabon* Indicator Plant

Soil pH

As depicted in Figure 1, the application of different dosage levels of coal ash (F) and humic substances (B) significantly raised soil pH in both nursery trial (NT) and field trial (FT) using *Jabon* tree seedlings.

Table 3. Results of Toxicity Characteristic Leaching Procedure (TCLP) test on PTNNT coal ash.

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Parameter	Methods	Coal ash from Landfill	Reference/Standard	
			PP No. 85/ 1999 [a]	USEPA[b]
		.... mg L^{-1}	....	
As	HVAAS	0.078	0.2	5
Ba	FAAS	<1	5	100
B	ICP-AES	12	100	-
Cd	FAAS	<0.05	0.05	1
Cr	FAAS	<0.5	5	5
Cu	FAAS	<0.1	0.19	-
Pb	FAAS	<0.5	2.5	5
Hg	CVAAS	<0.0005	0.01	0.2
Se	HVAAS	<0.005	0.05	1
Ag	FAAS	<0.2	2	5
Zn	FAAS	0.19	2.5	-

[a] Indonesian Government Regulation (PP No. 85/1999 amending PP No.18/1999 regarding environmental standard limits for TCLP results; [b] Maximum Concentration of Contaminants for Toxicity Characterictics, United States Environmental Protection Agency (USEPA). Note: HVAAS : Hydride Vapour Atomic Absorption Spectrophotometry, FAAS : Furnace Atomic Absorption Spectrophotometry, ICP-AES: Inductively Coupled Plasma-Atomic Emission Spectrophotometry, CVAAS : Cold Vapor Atomic Absorption Spectrophotometry.

Table 4. Properties of concentrated humic substances solution.

Description	Method	Unit	Value
pH	pH meter	-	8.71
Electric Conductivity	EC meter	mS/cm	13.89
Carbon (C) content	CNS	%	3.23
Nitrogen (N) content	CNS	%	1.17
Ash content	Gravimetric	%	2.96
Solids content	Gravimetric	%	7.42

Data analysis (Figure 1) reveals that the application of coal ash significantly altered soil alkalinity in both nursery and field trials using *Jabon* plants. However, the addition of humic substances did not exhibit any significant effect. In the nursery trial (NT), coal ash application raised soil pH from 6.30 (moderately acidic) into 7.97 (neutral), reaching up to 8.21 (moderately alkaline). The same pattern was observed in the field trial (FT): soil pH went up from 5.49 (acidic) into 7.54 (neutral), until 7.97 (moderately alkaline). Further, application of both coal ash and humic substances did not show any significant combinations on soil pH in the nursery trial (NT), but turned out to be significantly interactive in the field trial (FT). In short, the application of soil ameliorants can significantly improve the chemical properties of the recipient soil.

The resulting changes in soil pH (*i.e.*, from acidic into neutral, and even into moderately alkaline) due to the application of coal ash (Table 2) appear consistent with the findings of earlier studies: in mineral soil (McCarty *et al.* (1994), and peat soil (Iskandar *et al*. 2008).

Levels of Organic-C, Total-N, and Available-P

Table 5 shows that the levels of organic-C, total-N and available-P in the soil were not significantly influenced by the addition of the soil ameliorants in the nursery trial (NT), but coal ash did increase both organic-C and total-N levels in the field trial (FT), although not high enough to alter the chemical properties of the soil and facilitate nutrient availability for plant growth. Interactively, the addition of both coal ash and humic substances did not influence organic-C and total-N levels in either nursery or field trial. In other words, it can be summed up that the total of the organic-C and total-N levels originally present in the soil, plus those contained in the soil ameliorants that were applied at given dosages in this study, were way too low to manifest any significant effect.

Table 5 discloses that the application of coal ash and humic substances significantly increased the level of soil available-P in the nursery trial (NT): coal ash increased available-P from 2.47 mg kg^{-1} (F0B0: no coal ash applied, no humic substances

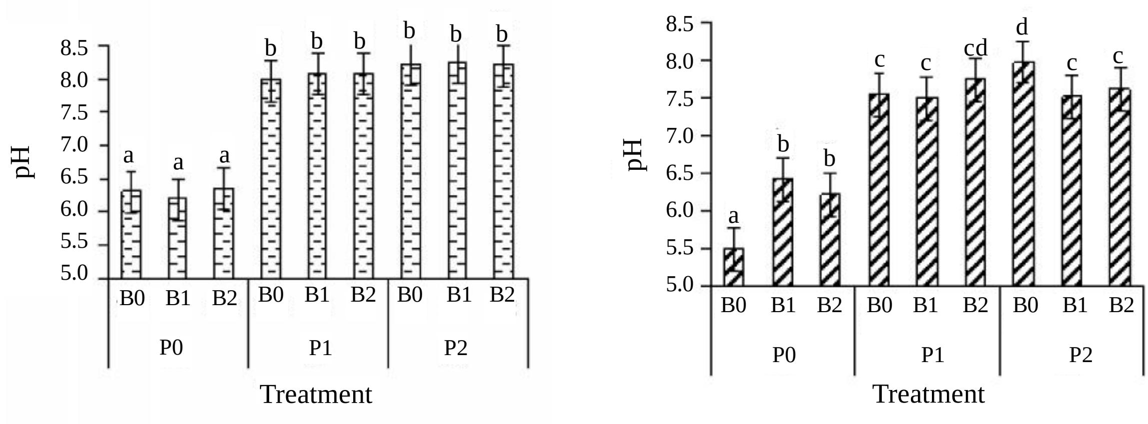

Figure 1. Effect of ameliorant application on soil pH: nursery trial (NT), and field trial (FT). The vertical lines above each bar graph show comparative treatment results based on DMRT at 5% level of statistical significance.

applied), or "very low level", into 7.08 mg kg^{-1} (F1B1 – 200 g coal ash $polybag^{-1}$, 0.04 g C humic substances $polybag^{-1}$ applied), or "low level", reaching up to 9.55 mg kg^{-1} (F2B2: 400 g/polybag coal ash, 0.08 g C humic substances $polybag^{-1}$ applied). In contrast, in the field trial (FT), the effect was not significant enough, although, in absolute terms, the resulting available-P level came out to be somewhat higher than that of Control (no soil ameliorant applied).

Exchangeable Cation (Exch.-K, Exch.-Ca and Exch.-Mg), Cation Exchange Capacity (CEC), and Micro-Element (Fe and Cu) Content

Shown in Tables 6 and 7, the application of coal ash significantly increased the level of exch.-K in both nursery (NT) and field (FT) trials, and that the two soil ameliorants brought about interacting effect in raising exch.-K in the field trial. The soil ameliorants likewise significantly raised exch.-Ca in the nursery (NT) and field (FT) trials, but there was no observed interaction between the two ameliorants in the nursery trial (NT). Both ameliorants did not significantly affect exch.-Mglevel in the nursery trial (NT), but they exhibited significant interaction effect in the field trial (FT).

In the nursery trial (NT), base cations levels of the exch.-K, exch.-Ca and exch.-Mg in the *Jabon* seedlings rose in direct proportions with higher additions of soil ameliorants. To illustrate, the level of exch.-K went up from 0.09 cmol^{+} kg^{-1} to 0.12 cmol^{+} kg^{-1}; similarly, exch.-Ca increased from 1.82 cmol^{+} kg^{-1} to 2.21 cmol^{+} kg^{-1}, and reached up to 3.62 cmol^{+} kg^{-1}. However, the soil ameliorants did not significantly affect the exch.-Mg level in the soil. In the same manner, the soil ameliorants significantly influenced soil CEC: rising from 7.80 cmol^{+} kg^{-1} F0B0 (no coal ash applied, no humic substances

Table 5. Effect of coal ash (F) and humat substances (B) application at various combinations of dosage levels on organic-C, total-N, and available-P content of the soil.

Treatment	Nursery trial (NT)			Field trial (FT)		
	Organic-C (%)	Total-N (%)	Available-P (mg kg^{-1})	Organic-C (%)	Total-N (%)	Available-P (mg kg^{-1})
F0B0	0.11 a	0.05 a	2.47 a	0.29 a	0.04 ab	0.27 a
F0B1	0.16 a	0.06 a	1.86 a	0.32 ab	0.03 a	0.55 a
F0B2	0.23 a	0.06 a	3.09 a	0.33 ab	0.05 ab	1.24 a
F1B0	0.25 a	0.05 a	3.02 a	0.37 ab	0.05 ab	0.96 a
F1B1	0.26 a	0.03 a	7.08 bc	0.43 ab	0.07 b	0.69 a
F1B2	0.19 a	0.03 a	2.47 a	0.43 ab	0.06 b	0.48 a
F2B0	0.22 a	0.03 a	2.44 a	0.47 ab	0.06 b	1.51 a
F2B1	0.24 a	0.05 a	4.05 ab	0.58 ab	0.06 b	0.76 a
F2B2	0.35 a	0.04 a	9.55 c	0.63 b	0.06 b	0.82 a

Notes: 0 refers to Control (no ameliorant applied). Numerical values under the same column which are followed by similar letters denote "not significant difference" at 5% level of significance (DMRT).

Table 6. Effect of coal ash and humic substances application at various combinations of dosage levels on the level of exchangeable cation, cation exchange capacity (CEC), and micro-element content of the soil in the Nursery Trial (NT).

Treatment	Exch.K	Exch.Ca	Exch.Mg	CEC	available Fe	available Cu
	.... $cmol^+ kg^{-1}$	....			....................mg kg^{-1}..................	
F0B0	0.09 a	1.82 a	9.8 a	7.80 a	74 a	1.44 a
F0B1	0.10 a	2.04 ab	7.7 a	8.60 a	117 ab	1.88 a
F0B2	0.10 a	2.16 ab	8.9 a	8.60 a	101 ab	1.71 a
F1B0	0.10 a	2.21 b	8.7 a	8.20 a	301 abc	1.42 a
F1B1	0.12 b	2.38 bc	9.7 a	8.30 a	549 c	1.30 a
F1B2	0.12 b	2.61 c	8.0 a	9.80 a	463 c	1.78 a
F2B0	0.12 b	2.72 c	8.9 a	15.60 a	380 bc	1.64 a
F2B1	0.12 b	3.62 d	8.9 a	25.30 b	493 c	1.23 a
F2B2	0.13 b	3.63 d	9.1 a	30.60 b	545 c	1.43 a

Notes: 0 refers to Control (no ameliorant applied). Numerical values under the same column which are followed by similar letters denote "not significant difference" at 5% level of significance (DMRT).

applied) to 8.20 $cmol^+ kg^{-1}$ at F1B0 (200 g $polybag^{-1}$ applied, no humic substances applied), up to 15.60 $cmol^+ kg^{-1}$ at F2B0 (400 g $polybag^{-1}$ applied, no humic substances applied). Moreover, the addition of coal ash raised available Fe in both nursery (NT) and field (FT) trials, with significant combinations effects. In contrast, the level of available Cu did not exhibit any significant reaction to the treatment in the nursery trial (NT).

Table 7 shows the positive influence of the soil ameliorants on the levels of exch.-K and exch.-Ca however, a reverse reaction was observed in the case of soil exch.-Mg level in the field trial (FT). Exch.-K went up a bit from 0.15 $cmol^+ kg^{-1}$ to 0.17 $cmol^+ kg^{-1}$, while exch.-Mg rose in much higher proportion from 5.27 $cmol^+ kg^{-1}$ at F0B0 (no coal ash applied, no humic substances applied) to 8.48 $cmol^+ kg^{-1}$ at F1B0 (2.5 kg planting $hole^{-1}$ applied, no humic substances applied). On the contrary, the exch.-Ca level exhibited a slight lowering from 3.79 $cmol^+ kg^{-1}$ at F0B0 to 3.57 $cmol^+ kg^{-1}$ at F1B0.

In the field trial (FT), similar favorable effects were observed on soil CEC: its value increased from 12.60 $cmol^+ kg^{-1}$ at F0B0 (no coal ash applied, no humic substances applied) to 15.80 $cmol^+ kg^{-1}$ at F1B0 (2.5 kg $planting^{-1}$ hole coal ash applied, no humic substances applied), which falls under the category of "moderate/average" under standard analytical result criteria (BPT 2005). Both independent and combinations positive effects of the two soil ameliorants were also recorded on available Fe levels in the soil, however, the reverse effect was found in the case of available Cu level.

Table 7. Effect of coal ash and humic substances application at various combinations of dosage levels on the level of exchangeable cation, cation exchange capacity (CEC), and micro-element content of the soil in the Field Trial (FT).

Treatment	Exch.-K	Exch.-Ca	Exch.-Mg	CEC	Available Fe	Available Cu
	.... $cmol^+ kg^{-1}$	....			.... mg kg^{-1}	
F0B0	0.15 a	3.79 bc	5.27 ab	12.60 a	94.74 cd	1.72 a
F0B1	0.17 b	3.79 bc	5.03 ab	17.07 ab	34.98 a	1.64 a
F0B2	0.17 b	3.91 c	5.94 ab	18.10 c	53.31 ab	3.03 a
F1B0	0.17 b	3.57 a	8.48 c	15.80 abc	105.24 cd	3.00 a
F1B1	0.17 b	3.62 ab	5.52 ab	12.60 a	73.04 bc	2.05 a
F1B2	0.17 b	3.79 ab	5.78 ab	15.80 abc	89.62 bcd	2.01 a
F2B0	0.17 b	3.79 ab	4.89 ab	14.00 ab	81.99 bcd	1.47 a
F2B1	0.17 b	3.57 a	4.06 a	13.10 a	112.08 d	1.78 a
F2B2	0.17 b	3.46 a	6.57 ab	19.12 c	75.92 bcd	1.37 a

Notes: 0 refers to Control. Numerical values under the same column which are followed by similar letters denote "not significant difference" at 5% level of significance (DMRT).

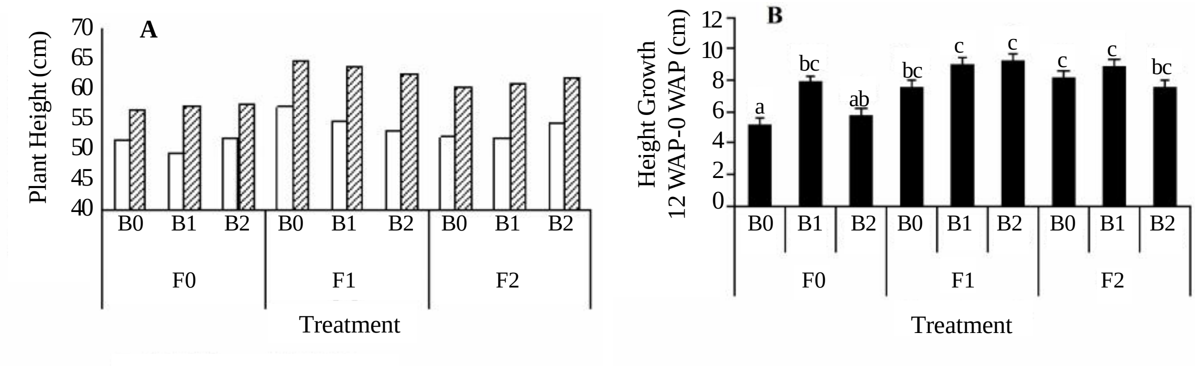

Figure 2. Effect of soil ameliorant application on plant height (A) and height growth (B) of *Jabon* seedlings in the nursery trial (NT) at 0 – 12 weeks after planting (WAP). □ = 0 WAP and ▨ = 12 WAP.

The analysis of data further demonstrated a distinguishable trend of exch.-Mg>exch.-Ca>exch.-K concentration in both nursery and field trials. According to Iskandar *et al*. (2008), the application of coal ash into peat soil could increase base cation availability including that of K, Na, Ca, and Mg. Other researchers, like Lee dan Bartlett (1976) and Reynolds *et al*. (1995) also found that the addition of lignite humic acid and lignite humic salt accelerated the release of phosphorous, potassium, and iron.

Response of *Jabon* Plant Growth to Coal Ash and Humic substances Application

The empirical consequence of the effects of the applied soil ameliorants particularly on the chemical properties of the soil was expected to be manifested by the response in the growth of the *Jabon* plants in this study. These effects are depicted in Figures 2 and 3. Plant growth observations in the nursery trial (NT) covered the duration of 0-12 weeks after planting (WAP), while

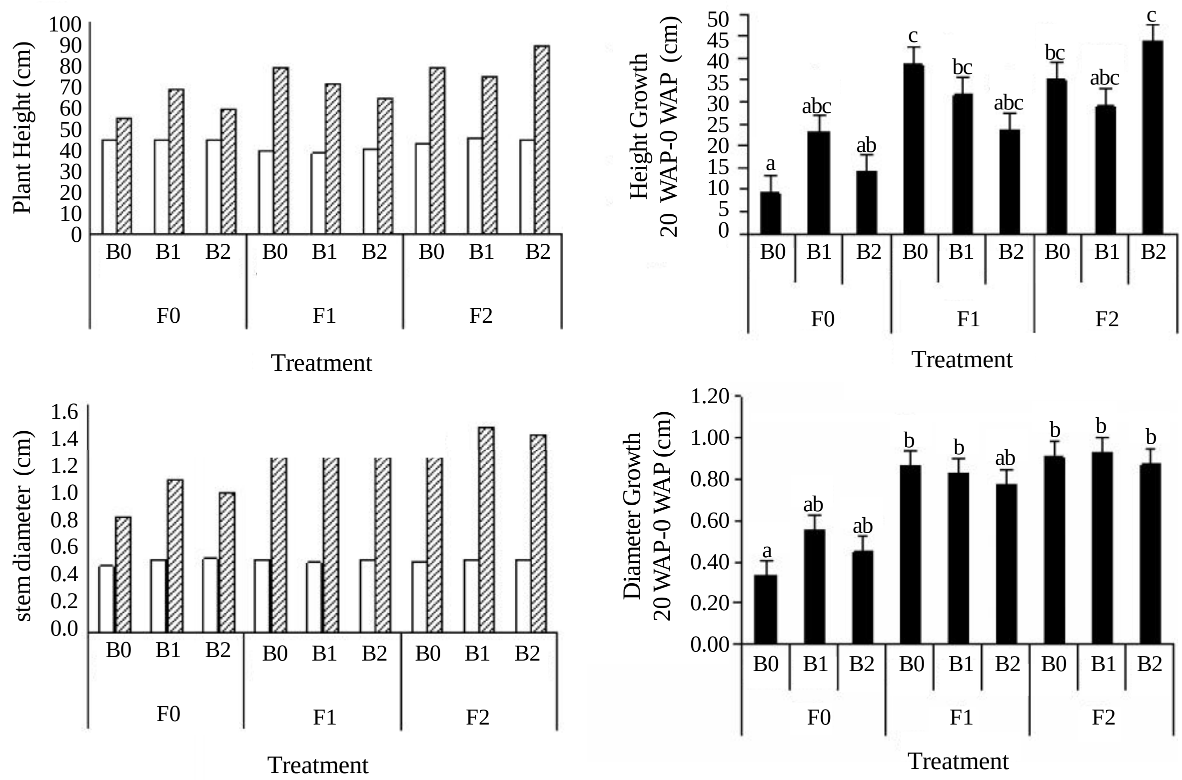

Figure 3. Effect of soil ameliorant application on plant height (A), height growth (B), stem diameter (C), and diameter growth (D) of *Jabon* plants at 0-20 weeks afer planting (WAP) in the field trial (FT). □ = 0 WAP and ▨ = 20 WAP.

in the field trial (FT), the monitoring period covered 0-20 WAP. Plant response parameters that were monitored were height and diameter growth rates.

As shown in Figure 2, the addition of the two soil ameliorants (coal ash and humic substances) significantly increased the height growth of the *Jabon* seedlings in the nursery trial (NT), meaning the plants became appreciably taller and grew faster in height. However, as can be expected during this very early stage of physiological tree growth, the ameliorants did not pose any significant effect on the girth growth of the *Jabon* seedlings.

Figure 3 depicts the impact of soil ameliorant application on the height and diameter growth of the beneficiary *Jabon* plants in the field trial (FT). As clearly shown, the *Jabon* trees were much taller and bigger in girth, and they continued to grow at much faster rates compared to the untreated (Control) group of plants in this study. In addition, and more importantly, it can also be noted that even without using humic substances, the sole application of coal ash, which is otherwise considered a hazardous and toxic waste material on mining landfills, could increasingly hasten *Jabon* tree growth, more so at higher ameliorant dosages.

CONCLUSIONS

This study has established fairly that the coal ash in the PTNNT mining landfill is highly alkaline and contains appreciable amounts of chemical elements that can favorably influence the chemical properties of the soil in reclaimed post-mining land. Although the coal ash also contains several heavy metals, they occur in levels which are far below the limits set by both Indonesian Government Regulation (PP No.85/1999) and the US *Environmental Protection Agency* (USEPA) and therefore, can be safely utilized as soil ameliorant.

In a nutshell, the following insights can be concluded from this study: Firstly, coal ash significantly raised field soil pH - from 5.49 (acidic) to 7.97 (moderately alkaline). However, by itself alone, humic substances did not exhibit any significant effect. Secondly, in this study, the sum of the organic-C and total-N levels originally present in the soil, and those contained in the soil ameliorants that were applied were way too low to manifest any significant effect. Thirdly, the application of coal ash and humic substances increased the level of available-P in the nursery - from 2.47 mg kg^{-1} (very low level) to 9.55 mg kg^{-1} (low level). In contrast, their effect in the field trial did not turn out to be significant enough. Fourthly, the application of coal ash significantly increased the level of exch.-K and exch.-Ca, but not exch.-Mg. The soil ameliorants also significantly influenced soil CEC: rising from 7.80 up to 15.60 $cmol^{+}$ kg^{-1}. Moreover, the addition of coal ash raised available Fe. In contrast, the level of available Cu did not exhibit any significant reaction to the treatment.

The practical consequence of the effects of the applied soil ameliorants particularly on the chemical properties of the soil would be manifested by the growth response in the beneficiary *Jabon* (*Anthocephalus chinensis*) plants. Thus, the addition of the two soil ameliorants (coal ash and humic substances) significantly increased the height growth of the *Jabon* seedlings in the nursery. However, the ameliorants did not pose any effect on the girth growth of the *Jabon* seedlings. In the field, due to the soil ameliorant application, the beneficiary *Jabon* trees grew much taller and bigger in girth, and continued to grow at much faster rate. More importantly, even without using humic substances, the sole application of coal ash, which is otherwise considered a hazardous and toxic waste material on mining landfills, can increasingly hasten *Jabon* tree growth, more so with higher dosages.

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