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Response of Maize Grown on Overburden Soil in a Coal Mining Area without Top Soil to Various Compost Sources

Erry Purnomo

Centre of Tropical Coal Agriculture
Faculty of Agriculture, Borneo Tarakan University, Jalan Amal Lama No. 1, Tarakan, North Kalimantan (77123), Indonesia. e-mail: erry_purnomo@borneo.ac.id

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ABSTRACT

Soil in Kalimantan Island is considered infertile. To obtain a reasonable crop yield a high input fertilizer package should be applied. The situation will be worsening when an open pit system of coal mining adopted. Failure in re-arranging the soil layers can result in decreasing soil fertility compared to original soil prior to mining. This study aimed to determine the improvement of soil fertility of a disposal without top soil by using composts from various sources, namely, the public garbage pile, commercial compost, and compost from kitchen waste. The experiment was conducted in a disposal area of a coal mining of PT AI. A series of application rate of compost was set. This was 0, 5, 10, and 20 tonne compost ha^{-1}. A plot with top soil was involved for another control. Maize was selected as the plant indicator to evaluate the effect of treatments applied. It can be concluded that application of composts to reclamation area without top soil significantly improve soil fertility. Among the composts used, K-compost (compost from kitchen waste) was the best in improving soil fertility. There were some characters of the compost that had not enough to support maize yield. These were P, K, and pH. Addition of P and K fertilizers and lime material are needed. Of the equation coefficients obtained, the b coefficient of equation belong to K-compost was higher than of the others.

Keywords: coal mining, composts, infertile soil, mineral fertilizers, overburden soil, response curve, top soil

INTRODUCTION

Most of soils in Kalimantan Island are infertile. So, to grow and to obtain the optimum yield plant a heavy fertilization is necessary. The condition is worsening if soil is disturbed by coal mining activity. The arrangement of disposal after mining operation is very important for the success of reclamation and mine closure plan.

When the coal mining operation is a single pit and slopped coal seam, the ratio of top soil and soil layer underneath become smaller and smaller. The amount of top soil for covering disposal becomes less and less.

However, the Minister of Forestry Republic of Indonesia (2011) released a guide regarding forest reclamation. It was mentioned that top soil was the key of successful reclamation. Generally speaking, top soil is characterized by a better soil condition for growing plant than the sub-surface soil (mainly over burden [OB] soil).

Therefore, the shortage of top soil in the single pit coal mine operation may become an obstacle for the reclamation program in such areas. An opportunity was taken to determine the use of several composts in improving the properties of OB soil.

MATERIALS AND METHODS

Study Site

The experiment was carried out in a coal mining area of PT AI (2.226096 South, 115.478528 East). The soil in the experimental plot was developed from OB soil. OB soil is a soil lies above an area of a coal seam.

Treatments

The treatments of the experiment are shown in Table 1. The treatments were arranged in a Randomised Block Design.

Paddock Preparation

Based on treatments applied there were three (composts) x four (rates) + one (top soil) = 13 plots. These plots were used for applying the treatments. The size of each plot was 5×5 m^2. Each set of the treatments were applied into three blocks.

Table 1. The treatments applied in the experiment.

Treatments	Rate of compost ($Mg\ ha^{-1}$)	Note
Top soil only*)		Spread on the overburden soil plot 25 cm thick
PG (Public garbage) Compost	0, 5, 10, and 20	Furrowed into 10 cm depth
C (Commercial) Compost	0, 5, 10, and 20	Furrowed into 10 cm depth
K (Kitchen waste) Compost	0, 5, 10, and 20	Furrowed into 10 cm depth

*) Only top soil plot received Urea, SP36 and KCl of 200, 200 and 100 $kg\ ha^{-1}$, respectively

Table 2. The selected chemical properties of the composts used in the experiment.

Compost properties*)	Commercial Compost**)	Kitchen Waste Compost	Public Garbage Compost	SNI for Compost
Total C (%)[1]	-	18.3	10.1	32.0
Total N (%)[2]	-	1.3	0.6	0.4
C/N	-	14.1	19.7	20.0
Total P (%)[3]	-	0.3	0.4	0.1
Total K (%)[4]	-	0.7	0.5	0.2

Note: *) Procedure of measurements are described in [1]Yeomans and Bremner (1988); [2]Bremner and Mulvaney (1982); [3]Olsen and Sommers (1982); [4]Knudsen and Peterson (1982)
**) the commercial compost owner did not allow to characterize the product.

Table 3. Selected soil properties of the OB soil.

Soil properties*)	Value	Category**)	Land suitability for maize***)
Texture[1]		Silt loam	S2
Total C (%)[2]	7.09 ± 0.36	Very high	S1
Total N (%)[3]	0.17 ± 0.05	Low	S2
C/N	52 ± 17	Very high	
Bray P ($mg\ kg^{-1}$)[4]	0.90 ± 0.15	Very low	S3
pH H_2O[5]	4.07 ± 0.06	Very acidic	S3
Exch. Ca (cmol[+] kg^{-1})[6]	1.35 ± 0.11	Very low	
Exch. Mg (cmol[+] kg^{-1})[6]	0.52 ± 0.08	Low	
Exch. Na (cmol[+] kg^{-1})[6]	0.44 ± 0.02	Moderate	
Exch. K (cmol[+] kg^{-1})[6]	0.15 ± 0.03	Low	
CEC (cmol[+] kg^{-1})[7]	19 ± 4.6	Low	
EC (mS/cm)[8]	0.35 ± 0.02	Very low	S1
Base saturation (%)	15.59 ± 2.96	Very low	
Al saturation (%)[9]	3.48 ± 0.23	Very low	

Notes: *) Procedure of measurements are described in [1]Gee and Boulder (1986); [2]Yeomans and Bremner (1988); [3]Bremner and Mulvaney (1982); [4]John (1970); [5]McLean (1982); [6]Thomas (1982); [7]Rhoades (1982a); [8]Rhoades (1982b) ;[9]Dougan and Wilson (1974). **) and ***) The values obtained were categorized and classed their suitability as described in Djaenuddin *et al.* (1994).

Selected Compost and Soil Properties

The chemical properties of composts used for the experiment are shown in Table 2.

Selected OB soil properties are shown in Table 2. There were two main problems in growing maize on OB soil. These were very low P availability and soil pH.

Experimental Procedures

The maize was grown till produced grain. The composts were furrowed in approximately 15 cm depth. Two seeds were sown at 25 x 75 cm planting distance. At the harvest time, the maize grains were weighted. Some chemical properties changes due to composts application were determined. These were total-P, $P_{Bray 1}$, mineral-N, exchangeable-K, pH, and EC.

Data Analyses

Data variations were shown using standard error of three means. A regression analysis was used to compare the response of the three composts. The response curve differences were carried out by comparing the standard error of the equation constants. The standard errors were obtained by the SigmaPlot software (SigmaPlot 2011).

RESULTS AND DISCUSSION

Over Burden Soil properties

The soil suitability wise, the suitability of OB soil for growing ranged from very- to less suitable (Table 3). The C content and the EC of soil were classed as very suitable. The soil texture and soil total N were classed as suitable. The contents of soil total-P and P_{Bray1}, however, were classed as less suitable for growing maize.

Response of maize to various composts applied

Figure 1 shows the response of maize to various composts applied. It was observed that the kitchen composts (K Compost) consistently had the highest effect on maize yield, followed by commercial and public garbage composts (C Compost and PG Compost, respectively). In agricultural areas, a similar response of composts with different quality to canola and wheat (Nkoa *et al*. 2014), wheat (Mahli 2012) and other crops (D'Hose *et al*. 2012) yields were also recorded. The superiority effect of K Compost on maize yield was due to its higher effect in improving soil properties to support corn production (Figure 3) and its lower C-N ratio than that of other composts (Table 2). The low C-N ratio is an insurance the release of nutrients from the compost (Barral *et al*. 2011; Duong 2013).

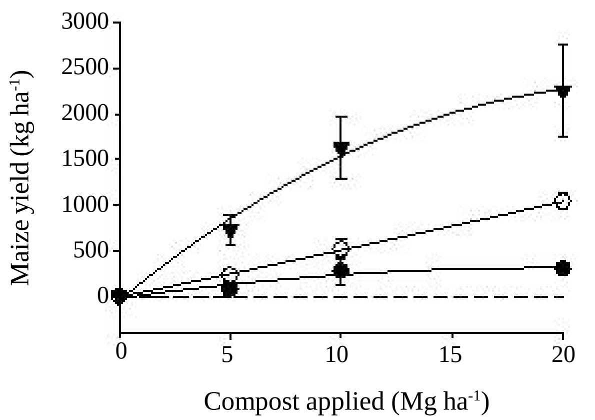

Figure 1. The response of maize to various composts applied. Bars indicate standard error. Ï% PG Compost, Ë% C Compost, and ¼% K Compost. ●: PG Compost, ○: C Compost, ▼: K Compost, - - -: Top Soil.

It was also observed that the top soil plot failed to perform well as expected by the regulation. This was a surprise, since top soil was the key of successful reclamation according to the policy of present regulation (Minister of Forestry Republic of Indonesia 2011). The performance of maize in the top soil plot was similar to OB soil plot without compost application. This reflects that at this experimental site, the top soil had no different compared with OB soil (Figure 1 dan 2).

It was also revealed that the *a* and *c* coefficients were the same for all quadratic equations (Figure 2). However, the *b* coefficient of quadratic equation belong to K Compost was consistently higher than the other composts. This indicates the response curve of K Compost differed from other composts and confirms that the quality of K compost was better than the other two composts.

The relationship between selected chemical properties due to various composts applied and maize yield

Figure 3 shows the effect of various compost applications on selected soil properties had influenced the maize yield. It is shown that the

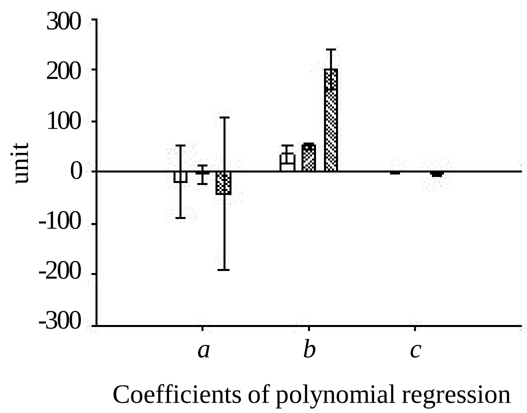

Figure 2. The coefficients response curve of various composts applied. Bars indicate standard error. ▭: PG Compost, ▨: C Compost, ▩: K Compost.

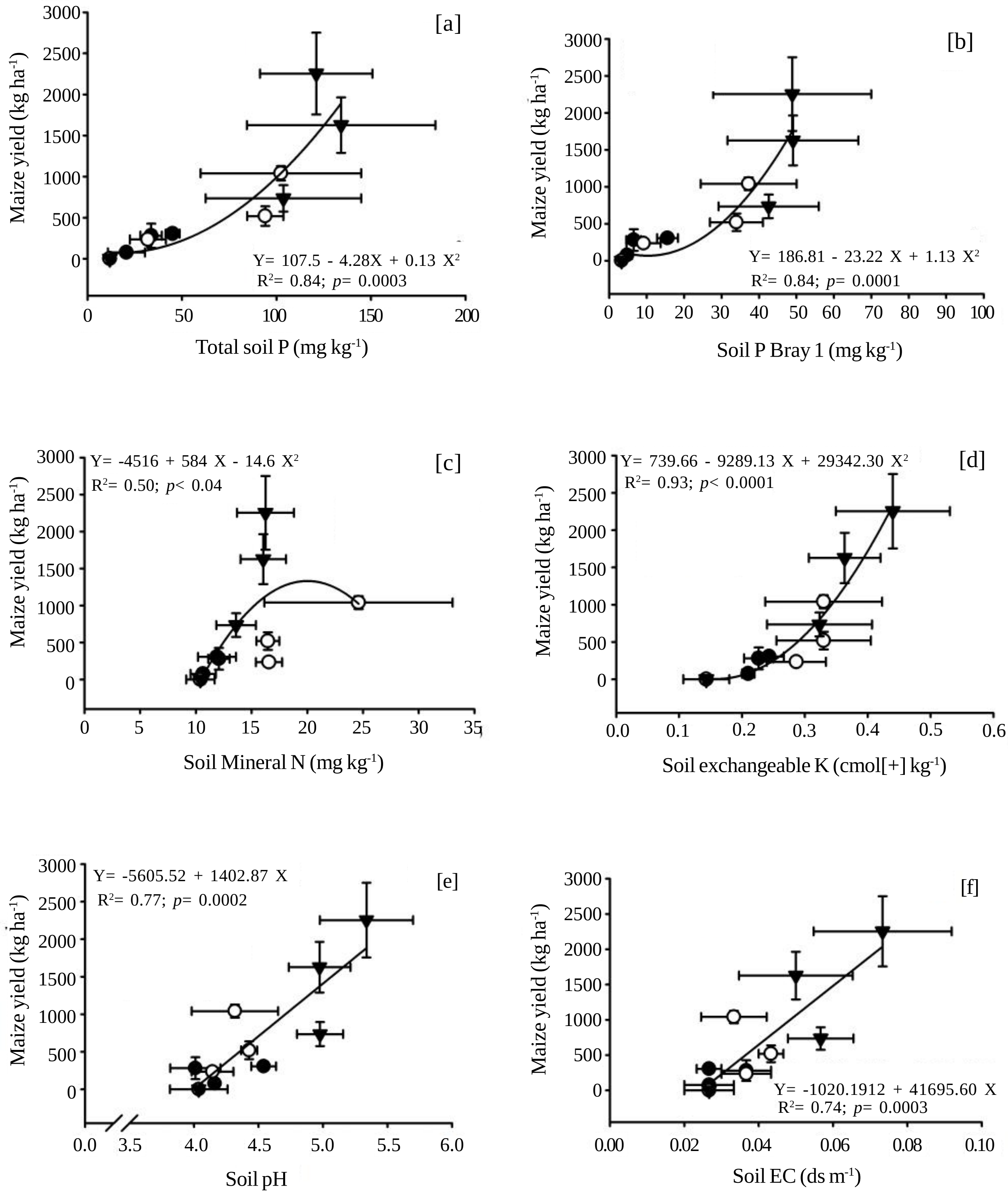

Figure 3. Relationship between selected soil chemical properties changes due to various composts and maize yield. Bars indicate standard error. ●: PG Compost, ○: Compost, ▼ : K Compost.

patterns relationships were varied depending soil chemical properties measured. As can be seen that the relationship patterns of total-P (Figure 3a), P_{Bray1} (Figure 3b) and exchangeable K (Figure 3d) and maize yield were similar. From the shape of the curve, the concentration of total-P, P_{Bray1} and exchangeable-K in the soil were in the deficient area of nutrient status for plant (Black *et al*. 1995). This shows that the amount of P and K from the composts were not enough to supply the maize need.

For N nutrient-wise, it was revealed that the relationship pattern was different (Figure 3c). It seems that there was enough amount of N came out from the composts to support maize yield.

Finally, the Figure 3e and 3f shows the relationship between pH or EC, respectively and maize yield. From the pattern of relationship, the compost application had created sinks for Ca and salt. The effect of compost application in reducing salt content was observed by Do and Scherer (2013). They found that salt content was reduced by the addition of peat compost. This was proved by the continue increasing of soil pH and EC readings.

CONCLUSION

It can be concluded that application of composts to the reclamation area without top soil significantly improve soil fertility. Among the composts used, K Compost (compost from kitchen waste) was the best in improving soil fertility. There were some characters of the compost had not enough nutrients to support maize yield. These were P, K, and pH. Addition of P and K fertilizers and lime material are recommended.

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