Palm oil compost reduces aluminum toxicity thereby increases phosphate fertilizer use efficiency in Ultisols

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Abstract
Ultisols are widespread in many countries including Indonesia and the main problem of the Ultisols is low soil fertility due to the high aluminum (Al) solubility and low phosphorus (P) availability. Aluminum toxicity in these soils can be mitigated by applying liming materials such as lime and dolomite and/or organic materials such as compost and manure. Large quantities of palm oil compost are produced in Malaysia and Indonesia which can be used to overcome Al toxicity in Ultisols. This study examines the distribution of Al species in Ultisols and the effect of palm oil compost on Al solubility and P uptake at different levels of P fertilizer application in an Ultisol. The uptake of P by soybean was examined at various levels of palm oil compost application using a pot experiment. The results showed that exchangeable Al in soils decreased with increasing levels of compost application and the growth of soybean was improved by application of compost as indicated by increases in dry matter (50% over control) and P uptake (198% over control). In addition, the soil fertility was also improved by the application of compost through the decreasing of Al solubility by 40.57% and increasing P availability by 73.82% at the highest rate of compost.

Key Words
Compost, palm oil waste, soybean, soil fertility, and Ultisol.

Introduction
Ultisols are acidic and are widely distributed in Indonesia occupying about 47.5 million ha (Budianta 1999). In this regard, Ultisols provide a potential opportunity to increase food crop production; however the main constraints of Ultisols for crop production are low soil fertility due to low availability of essential macronutrients for plant growth, low soil organic matter content, low pH and high aluminum content (Hardjowigeno 1995; Budianta 1999). Moreover, acidic tropical soils are mostly characterized by a poor fertilization history, resulting in low total nutrient content, for example P availability. Thus, an adequate supply of P in these marginal soils is required to enhance and to sustain food crop production (Friesen *et al.* 1997; Budianta and Vanderdeelen 2001). Soybean crop is classified as a sensitive crop to Al solubility compared to other food crop plant species. Highly acidic condition with a pH value below 4.38, coupled with high Al level, reduces growth of soybean (Ritchey and Carter 1993). The principal factor that is responsible for the inhibition of seed germination due to high Al content in acidic soils is not delayed radicle initiation, but delayed initiation of hypocotyl elongation. The later has been shown to be highly associated with the rate of tap root growth of soybean (Ritchey and Carter 1993). One of the management strategies suggested to increase P availability in acidic mineral soils such as Ultisols is by adding P fertilizer combined with organic matter (Bettina *et al.* 2007). In this case, the organic matter can be used to immobilise Al solubility, thereby enhancing the availability of P. Large quantities of palm oil compost is produced in Indonesia which can be used a source of organic matter in improving the fertility of Ultisols (Adeoluwa and Adeoye 2008). The objective of this study is to examine the potential value of palm oil compost in reducing Al toxicity in Ultisols and thereby enhancing the uptake of P from P fertilizer addition.

Material and method
A pot experiment was conducted using Ultisol to evaluate the effect of compost derived from palm oil waste and P fertilizer (Superphosphate-36) on Al solubility and P uptake of soybean. The Ultisol was sampled from Sembawa Rubber Research Station, South Sumatra, Indonesia. The Ultisol with pH of 4.04 was amended with compost at a rate of 0, 7, 14 and 21 tons/ha and SP-36 at the rate of 36, 72 and 108 kg P/ha. Three replications were used per treatment (total 36 pots). Commercial N and K fertilizers at the rate of 50 kg N/ha as urea and 45 kg K/ha as KCl as basic fertilizers were applied.

The compost was mixed thoroughly with the soil and after one week of incubation, P fertilizer was also incorporated to the amended soils. After 2 weeks of soil P treatments, three seeds of soybean were sown per pot and 2 healthy seedlings were left per pot. After six weeks of sowing, shoots were harvested to determine the dry matter production. Shoots were washed with water, oven-dried at 70^{o}C for 48 h and dry weights were determined. Oven-dried shoots were ground, digested using strong acid of Sulfate and Chloride and filtered into a 50 ml flask after digestion. The plant digests were analyzed for P. The soil samples were analyzed for exchangeable Al, pH and P availability. The compost was also analyzed to characterize the chemical properties such as lignin, organic-C, total-N, pH and carboxylic and phenol functional groups.

Result and discussion

Soil and compost characterization

From Table 1, it is apparent that the soil is characterized by low cationic exchange capacity (CEC) in combination with high exchangeable Al. The pH (H_2O) of the soil was 4.04, and the soil also showed low available P as measured by Bray–I P (Olsen and Sommers 1982). The compost derived from palm oil waste has high content of CEC and functional groups of carboxylic and phenol, indicating that the compost is effective in the immobilization of Al. According to Senese *et al.* (1994) phenol and carboxylic groups are able to immobile Al solubility, consequently, decreasing Al-P fractions and increasing P availability in acidic soils.

Table 1. Chemical properties of soil and compost.

Properties	Soil	Compost
pH	4.04	5.04
P-Bray-I (mg P/kg)	3.10	-
C-organic (g/kg)	14.7	23.5
N-total (g/kg)	1.3	2.2
C/N	-	11
CEC (cmol(+)/kg)	8.50	125
Al-exch. (cmol(+)/kg)	2.48	-
Al saturation (%)	59.62	-
Carboxylic group (cmol(+)/kg	-	294
Phenolic group (cmol(+)/kg	-	504
Lignin (g/kg)	-	223.3
Ash (g/kg)	-	15.2

Effect of compost on exchangeable Al and available P

Application of compost increased soil pH thereby decreasing exchangeable Al (Table 2). The exchangeable Al was decreased by 17.5%, 26.4% and 40.6% at 7, 14 and 21 ton/ha compost application, respectively. This indicates that the functional groups of organic matter replenished by compost application are able to immobile Al solubility.

Table 2. Effect of compost on pH, exchangeable Al and available P in soil.

Compost level (ton/ha)	pH	Exchangeable Al (cmol(+)/kg)	Available P (mg/kg)	Al-P (mg/kg)	Ca-P (mg/kg)
0	3.98 a	2.12 c	10.81 a	213.1 c	7.67 c
7	4.29 b	1.75 b	13.49 b	203.2 b	7.17 bc
14	4.32 bc	1.56 b	15.02 c	180.7 b	6.02 b
21	4.54 c	1.26 a	18.79 d	143.8 a	4.42 a
LSD 5%	0.23	0.21	1.29	21.5	1.57

Mean values followed by the same letter in a column are insignificantly different from each other at 0.05 level of LSD test

The data showed that application of compost increased P availability significantly by 24.79%, 38.95% and 73.82% at 7, 14 and 21 ton/ha compost application, respectively. Meanwhile P fraction represented by Al-P and Ca-P forms decreased by 4.65-32.51 % and 6.52-42.39 %, respectively. The decrease in these P-fractions is attributed to the immobilization of Al and Ca by functional groups of carboxylic and phenol derived from compost.

Effect of compost on soybean growth and P uptake

The effect of compost on soybean growth as measured by dry matter yield and P uptake at various levels of P application is given in Figure 1. The data indicate that soybean growth increased with increasing levels of compost application and the effect of compost on dry matter yield increased with increasing levels of P fertilizer application. At the highest rate of compost application the dry matter yield was increased by 20.3%, 50.4% and 50.4% for 36, 72 and 108 kg P/ha fertilizer application, respectively. However, in the presence of compost, there was no difference in dry matter yield and P uptake between two higher rates of P (72 and 108 kg P/ha) application. In general, the application of compost produced the positive interaction to increase dry matter and P uptake of soybean when combined with P fertilization (Figure 1). At highest rate of compost the dry matter and P uptake was increased by 50% and 198 % over control.

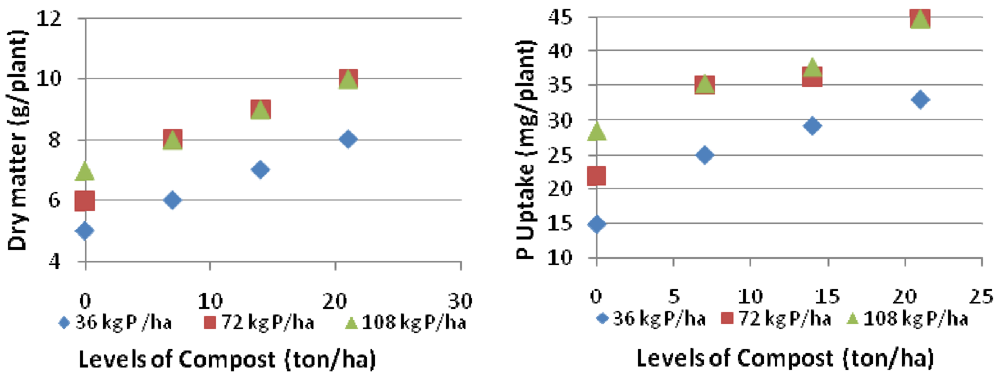

Figure 1. The effect of compost on soybean growth as measured by dry matter yield and P uptake at various levels of P application

Conclusions

Application of palm oil compost at the rate of 21 ton/ha decreased Al solubility in the soil by 40.6% and Al-P fraction by 32.5% and increased P availability by 73.8%. At the same rate of compost application the dry matter was increased by 20.3%, 50.4% and 50.4% for 36, 72 and 108 kg P/ha fertilizer application, respectively whereas in the presence of compost, there was no difference in dry matter yield and P uptake between two higher rates of P (72 and 108 kg P/ha) application. At highest rate of compost the dry matter and P uptake was increased by 50% and 198 % over control. In general, the application of compost produced the positive interaction to increase dry matter and P uptake of soybean when combined with P fertilization.

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