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Effects of plant residue and compost extracts on phosphorus solubilization of rock phosphate and soil

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ABSTRACT

Phosphor is an essential nutrients needed by plant for growth and production. Treating the plant with organic matter such as plant residue or compost will improve soil quality, especially increasing P-availability. Both plant residue and compost contain of organic compounds which mobilize phosphate in the soil. This research attempts to evaluate the influence of organic compounds extracted from plant residue and compost on P-available in rock phosphate and soil. Result indicates that organic compounds extracted from plant residue and compost may influence the dissolution of P from rock phosphate. The influence of organic compounds from compost is better than its compost extract in improving P-availability in soil.

Key words: plant residue, compost, organic compound, P-available

INTRODUCTION

In Indonesia, Ultisols which are characterized by low pH, low base saturation, and low content of available P, are mostly found in Kalimantan, Sumatera, Sulawesi and Papua covering about 48.3 ha [15,21]. The low content of available P has been the major constraint for agricultural production on these soils [24,30,34]. The low content of available P in theses soils is because of P fixation by Fe and Al as well as adsorption of Fe oxides [24], which in turn reduces uptake of P by plants. This problem can be alleviated by application of P fertilizers to the soil. However, because the limited economic conditions of most farmers in Indonesia, they usually use natural rock phosphate as a source of P, yet this material is known to have low content of available P. Most of organic wastes or plant residues applied to the soil is generally in the form of compost that contains organic compounds, particularly humic acid [13,8,36]. Plant residues and decomposed organic materials (or compost) have different amounts of organic acids which can be released to soil, after deposition [26,5],

Many other researchers suggested that availability of soil P can be enhanced by application of organic matters as organic compounds released from decomposition of the organic matters react with Al to form organo-Al complexes or Al-chelate [32,6]. However, the organic acids produced from organic matter decomposition are generally degraded or complexed in soil rapidly [5]. In rhizosphere, organic compounds containing low molecular weight organic acids may be able to increase nutrient availability depending on the characteristics of organic compounds and their interactions with the soil [14]. According to Van Hees *et al.* [31], low molecular weight organic acids that normally ranges from 1 to 10 mM in the soil, plays a significant role in mobilizing various soil phosphates. The ability of these organic acids to increase P availability in soils is because of the ability of carboxylate functional groups in the organic acids to occupy anion adsorption sites in the soils and thus competing with

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phosphate. Organic acids are also significantly potential in increasing weathering rate of primary minerals in the soil [9]. The objective of this study was to evaluate the effects of organic compounds extracted from plant residues and compost on phosphorus solubilization of natural rock phosphate and soils

Materials and Methods

A two series of experiments were conducted in a laboratory and in a glasshouse of the Faculty of Agriculture, Brawijaya University from June to December 2013. Materials used for this study were, natural rock phosphate (NRP), an Ultisol top soil (0-30 cm), rice straw, maize residues and groundnut residues.

Preparation of plant and compost extracts:

Fresh crop residues (rice, maize and groundnut) were collected from the farmer's field. Parts of the fresh residues were composted for 4 weeks. Both fresh and composted crop residues were oven dried at 65^0C for 8 hours following the methods developed by [2,12,19]. The dried fresh and composted crop residues were then sieved to pass through 2 mm sieve for extractions. The fresh and composted crop residues extracts were prepared following the method of Pavinato *et al*., [19]. Eight g of dried organic materials was mixed with 200 mL distilled water with a proportion of 1:25. This was equivalent to 20 t/ha. The organic material and water mixture was then horizontally shaken for 8 hours [2]. The solution was then filtered out to get extract materials. Characterization of organic acids in the extracts was performed using HPLC (High Performance Liquid Chromatography) following the method of AOAC (Association of Official Agriculture Chemistry, 2006). Ten grams of each of the extracts was mixed with 10 mL asetonitril (CH_3CN), blended at 4^oC and filtered using Whatman 42. Ten milliliter of the supernatant was eluted in a silica column of 10 u diameter for 10 minutes and was then eluted with 10 mL asentronil. Organic acids that remained in the column were then eluted twice using 10 mL methanol. The methanol extracted materials was than freeze dried at -50^oC. Results of chromatograms were compared with a standard solution.

Experiment 1:

Two hundreds milliliter of each of the organic material extracts was poured into a 250 mL plastic bottle containing 0.4g NRP (equivalent to 100 kg P_2O_5/ha), and incubated for 56 days in a dark room at 25^0-27^0C. For comparison, each of 200 mL of distilled water, 1% commercial humic acid, 1 mM citric acid, 1 mM malic acid, and 1 mL lactic acid was also mixed with 0.46 NRP. The chemical characteristics of the NRP were, 25% (250000mg/kg) total P, 5.58% (55800 mg/kg) available P, 1.88% (18800 mg/kg) soluble P, 16,63% Ca, 1,36% Mg, 1,12% Fe, 0,17% Mn, 0,16 % Na, 0,012% K, 0,013% Zn, and 0,003% Cu. Eleven treatments (three plan extracts, three compost extracts, one humic acid, one lactic acid, one citric acid, one malic acid and one distilled water) were arranged in a completely randomized bloc design with three replicates. Soluble P and pH were measured at 1, 3, 7, `4, 28 and 56 days. Data obtained were then subjected to analysis of variance using Microsoft Excel 2007

Experiment 2:

A glasshouse experiment was conducted following the incubation experiment (experiment 1). Five grams of each organic material extracts was mixed with 500g an Ultisol top soil and placed in a 1 kg plastic pot. The top soil (0-30 cm depth) was collected from Moncongloe, Maros District of South Sulawesi (05^0 08' 55,13'' S and 119^0 33' 51,02'' E). The mixtures were then incubated for 63 days. The characteristics of the soil were: pH 4.9, organic C 0.32%, total N 0.16%, total P 348.5 mg/kg, available P 1.18 mg/kg, CEC 26.77 me/100 g, exchangeable Al 6.59 me/100 g and exchangeable H 1.34 me/100g, loamy clay texture. Seven treatments (three plant extract, three compos extracts and one control) were arranged in a completely randomized block design with three replicates. At 0, 7, 14, 28, 42 and 63 days of incubation, pH (pH meter), total P (HCl 25%), available P (Bray II), P fractions of Al-P, Fe-P, Ca-P [20], and exchangeable Al (KCl 1M), were measured.

Results and Discussion

Characteristics of organic acids in plant and compost extracts:

Results of organic characterization are presented in Fig. 1. The types of organic acids found in pant and compost extracts varied considerably. Plant extracts was dominated by low molecular weight organic acids, i.e. citric acid, while compos extracts contained low molecular weight organic acids (lactic, malic, acetic), and high molecular weight organic acids (humic and fulvic). Groundnut compost extracts contained high concentrations of lactic, malic, acetic, and fulvic acids, while the highest concentration of humic acid was observed in the rice compost extract followed by maize compost and groundnut compost extracts. These results indicate that extracts generated from residues of rice, maize and groundnut composts play a significant role in improving soil nutrient availability because the extract contained low and high molecular weight of organic acids. Although plant extracts with high concentration of malic, lactic and citric acid can affect availability of soil nutrients, these organic compounds can also reduced soil nutrient availability depending the characteristics of each organic acids and their interactions [5,14].

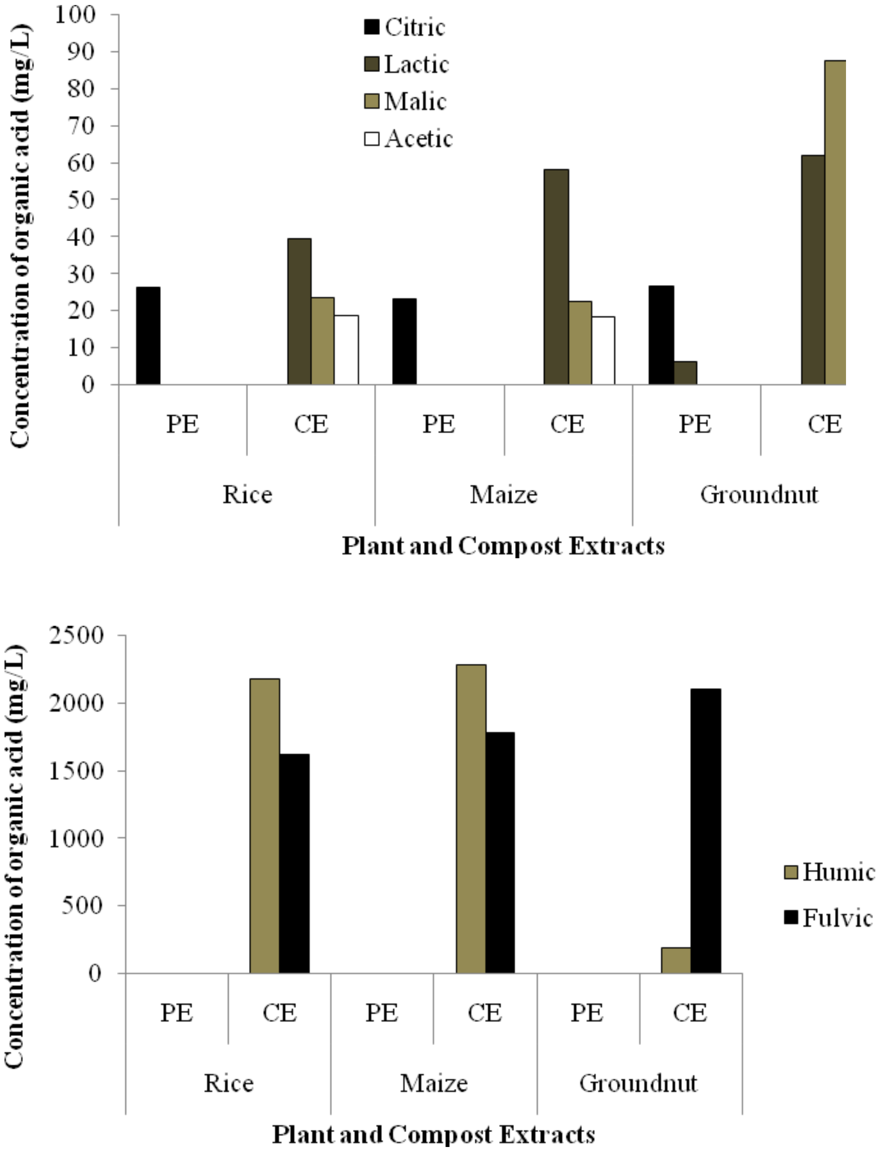

Fig. 1: Characteristics of organic acids from plant and compost extracts of rice, maize and groundnut. Insert: low molecular weight of organic acids. R-rice, M-maize, G=groundnut, PE=plant extract, CE=compost extract.

P solubilized from natural rock phosphate:

Ability of low molecular weight organic acids such as citric, lactic and malic in solubilizing P from NRP was relatively low (Figure 2). This is probably due to low concentration of organic acids used in this experiment (1mM). However, ability of citric acid in solubilized P from NRI was higher than that of lactic and malic acids. Palomo *et al* [18] reported that concentration of citric acid of >100 umol L^{-1} and > 1 mmol L^{-1} compared to tartaric and oxalic acids is needed to release P from solid phase and will significantly increase P in the soil solution. According to Wang *et al*. [35], the order of P mobilization by organic acid was citric acid> tartaric acid> oxalic acid.

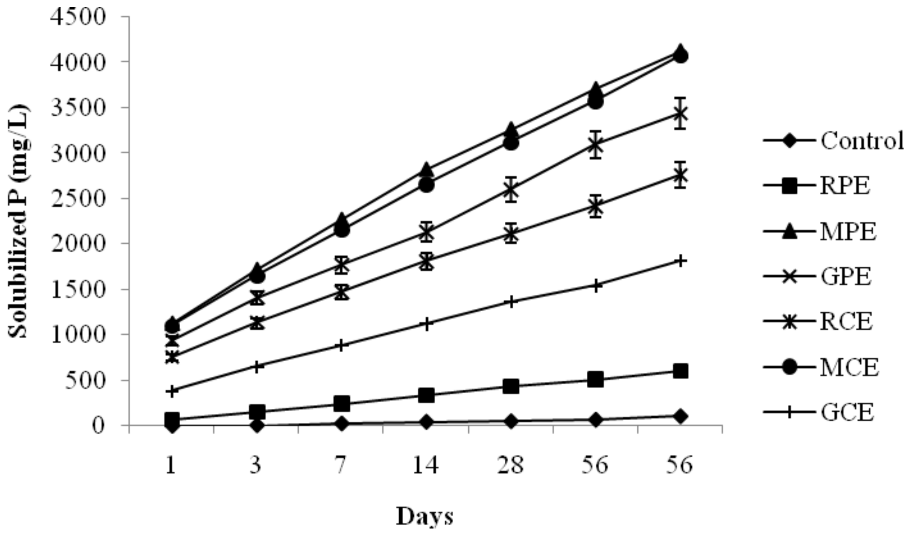

Fig. 2: P solubilized from natural rock phosphate

Results of this study were in line with previous studies reported by Ström *et al*., [27] and Van Hees *et al*. [31] who stated that each type of organic acid interacts differently with solid phase of the soils. Extracts of rice, maize and groundnut compost did not only contain low molecular weight organic acids but also contained high molecular weight organic acids. The concentrations of low molecular weight organic acids and for humic and fulvic acids in water extract of compost were higher than those of plant extracts. This may explain the linier increase of P solubility during incubation for 56 days (Fig. 2).

Available Soil P:

Application of plant and compost extracts significantly increased availability of P in the soil studied from 28 days to 42 days of incubation (Fig. 3). The amount available P in the soil with application of compost extract, however, was greater than that added with plant extract. The ability of plant and compost extracts in increasing availability P in the soil was in the order of maize compost extract > groundnut compost extract > rice compost extract > maize plant extract > groundnut plant extract > rice plant extract.

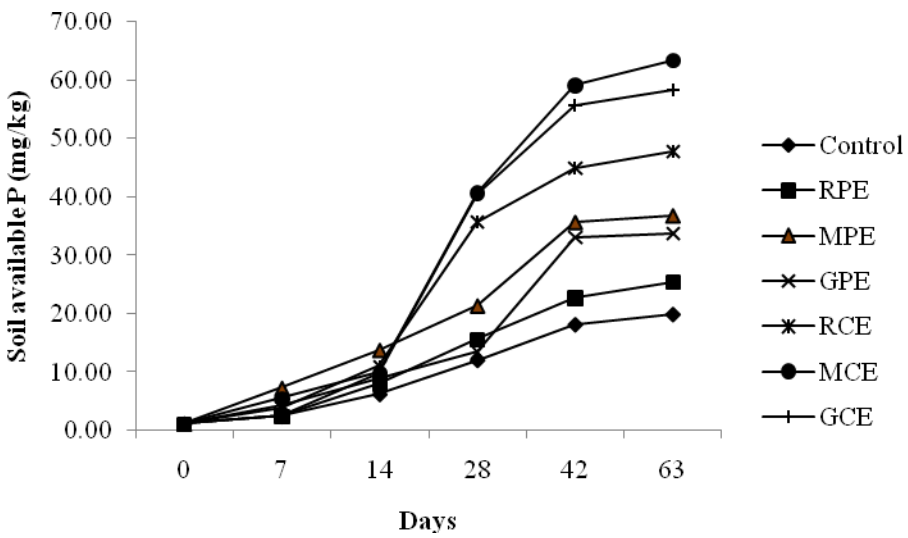

Fig. 3: Soil available P due to application of plant and compost extracts containing organic acids

Figure 3 shows that P-available increases with the length of incubation. The increase of P-available occurs since 7 to 14 days of incubation. However, the increase of P-available is very obvious in 28 days of incubation. The application of peanut compost in 28 days after incubation has improved P-available of soil for 35.08 times (42.57 mg/kg) compared to first day of incubation (1.18 mg/kg), while in treatment with corn compost, P-available increases for 33.53 times (1.18 mg/kg). The application of compost extract shows lower P-available increase than the application of compost. The application of corn compost extract for 28 days of incubation only increases P-available for 17.14 times (21.41 mg/kg) than first day of incubation. Straw compost extract can increase P-available for 11.35 times while peanut compost extract provides increase for 10.47 times.

The increase of P-available from compost application for 42 days of incubation is quite high (Figure 3). Similar findings are also observed in the application of corn compost which increases P-available to 59.12 mg/kg, so are peanut compost with 57.71 mg/kg and straw compost with 45.10 mg/kg. The increase of P-available still occurs in 63 days of incubation, but the increase of P-available is not bigger than before, but it tends to decline. Result of this research is consistent to Hu *et al* [7]which states that in acid soil, the treatment of organic acid after 14 days of incubation has produced bigger P-available than one day of incubation. Indeed, P-available has increased with the incubation length of organic acid into soil. Wang *et al* [35] have reported that organic acid application into Ultisol Yujiang, Jiangxi Province, China, can increase P-available in soil.

Adequate quantity of organic compounds in compost will allow the occurrence of chelation. Metal chelate will reduce P-adherence by substances of organic compounds such that P will be available to plant [33]. Tan [29] admits that humate and fulvate play important role than organic acid that is less humified. Previously, Tan [28] also says that humate and fulvate have high affinity on Fe, Al and Ca, and therefore, both will bind these substances from phosphate compound. Hu *et al* [7] assert that some phenolic acids are more effective than citrate acid in increasing P-availability. The number of phenolic hydroxyl cluster plays a key role to control the mobilization of P in the lime soil (calcareous), but in acid soil, the number of carboxyl cluster in ligand is more important than hydroxyl cluster to mobilize P.

Conclusion:

The study shows that organic compounds extracted from plant residue and compost have influenced P-dissolution from rock phosphate. The influence of organic compounds from compost is better in providing P-availability in soil than its compost extract.

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