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Research Article

Effects of application of groundnut biomass compost on uptake of phosphorus by maize grown on an Ultisol of South Sulawesi

Kasifah[1*], Syekhfani[2], Y. Nuraini[2,3,] E. Handayanto[3]

[1] Postgraduate Program, Faculty of Agriculture, Brawijaya University, Jl. Veteran, Malang 65145, Indonesia
[2] Department of Soil Science, Faculty of Agriculture, Brawijaya University, Jl. Veteran, Malang 65145, Indonesia
[3] IRC-MEDMIND, Soil Science Building, Brawijaya University, Jl. Veteran, Malang 65145, Indonesia

* corresponding author: kasifah.unismuh@yahoo.co.id

Abstract: Low crop production is acid dryland area of South Sulawesi is due to low availability of P in the soils. One of alternatives that can be performed to overcome the problems of acid soils having high level of exchangeable Al, is through the addition of organic material. In the upland areas in South Sulawesi, crop rice, maize and groundnut crop residues are readily available, but the crop residues are generally only used as animal feed or even burned. This study was aimed to elucidate the effects of groundnut compost on P uptake by maize in Ultisol of Moncongloe, South Sulawesi. Eight kilograms of air dried soil was mixed with compost according to the following treatments; 0, 10, 15, 20, 25, 30, 35 and 40 t compost/ha. All pots received 200 kg/ha KCl and 300 kg Urea/ha as basal fertilizers. Two maize seeds were planted in each pot and thinned to one plant per pot after one week. At harvest maize shoot dry weight and maize root dry weight, length of maize cop, cob weight, cob diameter, weight grains per cob, P uptake by maize, P content in maize grain, soil available P were measured. Results of the study showed that groundnut compost has the ability to improve the availability of P in the soil and increase P uptake by maize grown on an Ultisol of South Sulawesi. Application of 25 t groundnut compost/ha was the optimal rate that can be used to increase P availability in an Ultisol of South Sulawesi.

Keywords: *available soil P, acid soil, crop residues, ground nut*

Introduction

In South Sulawesi, the dry land area that covers 9,521,651 ha is dominated by Ultisols (1,529,242 ha) (Mulyani et al., 2004). Ultisols often associated with poor soil. Plants that are commonly cultivated in the area are cassava, ginger, elephant grass, and some other food crops. However, crop production is very low. This is related to the nature of Ultisols that have high acidity, and high exchangeable Al, low cationic exchange capacity (less than 24 me/100g soil), low nitrogen, phosphorus and potassium contents, and very susceptible to erosion (Mulyani et al., 2004). The high content of exchangeable Al limits root growth and decrease crop production due to Al toxicity (Watanabe et al., 2006a). In addition to Al toxicity, deficiency of P is one of the important obstacles to farming acid dry land (Thao et al. 2008; Setiawati et al., 2009; Vitousek et al., 2010). In acid soils, the majority of P added to the soil will be transformed into forms of Al - P and Fe - P (Trevisan et al., 2010). The forms are relatively insoluble in the soil, thus the availability of P in acid soils is relatively low (Setiawati et al., 2009). Therefore, efforts to improve availability of soil P for plant growth are important for the management of acid soils.

One of alternatives that can be performed to overcome the problems of acid soils having high level of exchangeable Al, is through the addition of organic material (Minardi et al., 2007; Wahyudi et al., 2010). The addition of organic matter can improve soil P availability through the release of P through mineralization, and the release of P sorption complex through the chelating mechanism between Al and Fe with organic matter through functional groups and organic acids (Stevenson, 1982). Organic acids produced during the decomposition of organic matter (Verlinden et al., 2009), can react with Al to form compounds or organo-Al or Al - chelate complexes (Hiradate et al., 2007). Results of a study previously conducted by Minardi et al. (2007), showed that organic material containing high humic and fulvic, contributed very significantly to the availability of P. *Gliricidia sepium* pruning as organic matter was capable to increase 53.61 % P available in the soil studied.

Although there have been many studies on the important role of organic matter in increasing the availability of P in acid soils, this technology has not been widely used for the improvement of productivity in acid dryland dominated by Ultisols in South Sulawesi. This is because of the limited information about organic materials, the characteristics of organic acids from plant residues and compost that can be used to increase the availability of P in Ultisols of South Sulawesi. In the upland areas in South Sulawesi, crop rice, maize and groundnut crop residues peanuts are always available. However, the crop residues are generally only used as animal feed or even burned. Results of previous studies showed that application of compost from groundnut residues for incubation of 28 days significantly improved P-available in an Ultisol from 1:18 mg/kg to 42.57 mg/kg. This value was greater than the application of composts from maize and rice residues (Kasifah et al., 2014). This study was aimed to elucidate the effects of groundnut compost on P uptake by maize in Ultisol of Moncongloe, South Sulawesi.

Materials and Methods

The study was conducted at the experimental station of the Centre for Agricultural Extension, Batangkaluku, Gowa, South Sulawesi, from 27 September 2013 until December 25, 2013. Material used in this study is Ultisol soil, compost of groundnut residue and maize seeds of Gumarang variety. The maize seeds were obtained from Maros Cereal Research Institute. Top soil (0-30 cm) collected from Moncongloe, Maros, South Sulawesi (050 08 ' 55.13 " S and 1190 33 ' 51.02 " E), was air dried for 3 days and sieved to pass through a 2 mm sieve. The characteristics of the soil are as follows: pH 4.9, 0.32% organic C, 0:16 % total N, 348.5 mg/kg total P, 1:18 mg/kg available P, CEC 26.77 me/100 g, 6.59 me/100 g exchangeable Al and 1.34 me/100g exchangeable H, loamy clay texture (Kasifah et al., 2014).

Thirty kilograms of fresh groundnut residues was composted for 2 months (December 2012 - January 2013) at the Compost Unit of the Faculty of Agriculture, Brawijaya University. Analysis of chemical composition of the compost included: pH (pH meter), organic-C (Walkey and Black), N - total (Kjedhal), P, K, Na, Ca, and Mg (wet ashing method, HNO_3 + $HClO_4$). Methods of analysis were in accordance with the technical instructions of Soil Research Institute (2005). The chemical composition of the groundnut compost were as follows: pH H_2O (1:2,5) 7.2, 1.98 % total N, 14.3 % organic C, C/N ratio 7.22, 0.41% total P total, 2.47% C, 1.39 % Ca, 0.83% Mg, 4.33% Na, 193 mg/kg humic acid, and 2104 mg/kg fulvic acid.

Eight kilograms of the air dried soil was placed in a 10 kg plastic pot having a diameter of 28 cm, and then mixed with compost according to the following treatments: 0 t compost/ha (K0), 10 t compost/ha (K10), 15 t compost/ha (K15), 20 kg of compost/ha (K20), 25 kg of compost/ha (K25), 30 kg of compost/ha (K30), 35 t compost/ha (K35), and 40 t compost/ha (K40). All pots received 200 kg/ha KCl and 300 kg Urea/ha as basal fertilizers. Half rate of each basal fertilizer was applied at the time of planting and the remaining half rate was applied at 6 weeks after planting. The eight treatments were arranged in a randomized block design with three replicates. Two maize seeds were planted in each pot and thinned to one plant per pot after one week. Water was periodically supplied to maintain the approximate value of field capacity. Maize plant height was observed at 3, 4, 5, 7, 8 and 9 weeks after planting. Parameters measured at harvest (9 weeks) were maize shoot dry weight and maize root dry weight, length of maize cop, cob weight, cob diameter, weight grains per cob, P uptake by maize, P content in maize grain, soil available P. The data obtained were subjected to analyses of mean, standard error, regression analysis and analysis of variance at 95% confidence level (α 5 %) and Duncan's Multiple Range Test using Microsoft Office Excel 2007.

Results and Discussion

Soil available P

Availability of soil P increased significantly with the increasing rate of compost applied. Application of 30 t compost/ha (K30), resulted in the higher concentration of soil available P compared to the other treatments (Figure 1). The highest increase of available soil P was observed at the K30 treatment (30 t compost/ha). Application of 40 t compost/ha reduced availability of soil P (Figure 1). The increase of soil available in line with increasing rate of compost applied to 30 t/ha because the high content of fulvic acid in the groundnut compost as reported earlier by Kasifah et al. (2014). Fulvic acid that is actually a product derived from humic compounds can dissolve minerals in the soil. The increase of available P in the soil is because of ligand exchange from Fe and Al oxides with organic acids. Complex bonding that occurs between organic acids with Fe and Al is in anticipation of the bonds between P with Al and Fe, so that the P can be optimally absorbed by plants (Johnson and Loeppert, 2006). Minardi et al. (2007) reported that the ability of the fulvic compound to release adsorbed P was greater than that of humic compounds. This is because of the higher mobility of fulvic acid that has low molecular weight than humic acid that has high molecular weight (Stevenson, 1982). Fulvic acid has a high total acidity that ranges from 10 to 12 me/g, about twice that of humic acid (5-6 me/g); the high total acidity in fulvic acid was possibly because of the high level of carboxyl (Watanabe et al., 2006). These characteristics lead to the ability to form complexes with cations, and minerals behave as cations in the soil become very large. The increase of soil available P led to the improvement of P uptake by maize which in turn improved maize growth, in terms of improved cob length, cob diameter, cob dry weight, and seed weight per cob (Table 1).

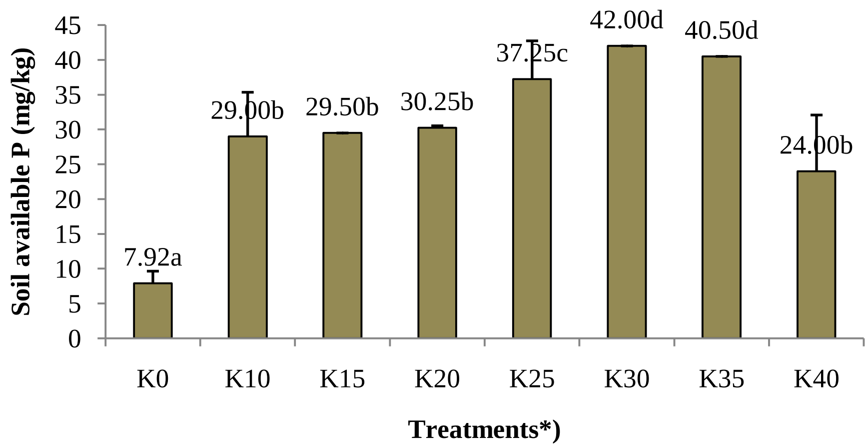

Figure 1. Effect of application peanut compost of soil P availability at maize harvest (9 weeks)

* Treatments: K0: Control, K25: 25 t/ha of compost, K10: 10 t/ha of compost, K30: 30 t/ha of compost, K15: 15 t/ha compost, K35: 35 t/ha of compost, K20: 20 t/ha of compost, and K40: 40 t/ha compost

Growth and yield of maize

Application of groundnut compost significantly affected plant height (Figure 2). Data presented in Figure show that the highest plant height was observed for K25 treatment (K25). The significant effect of groundnut compost on plant height is thought because of the relatively high content low and high molecular weight of groundnut compost (Kasifah et al., 2014). The high respond of maize to application of groundnut compost may indicate the important role of organic acids in the compost in cell elongation. This characteristic is similar to that of hormone auxin. Therefore, the activity of humic compounds in plant tissues is similar to the auxin hormone (Trevisan et al., 2010). In addition, the effect of humic compounds on plant growth is indirectly through improvement of soil properties such as aggregation, aeration, permeability and water holding capacity, increase input (uptake) of nutrients through the conversion of nutrients into available forms (Verlinden et al., 2009). The increase of plant membrane permeability improves plant growth by accelerating respiration or by improving activity of growth hormone, and accelerating growth of young roots or shoots (Eyheraguibel,2004; Syarif et al., 2008; Verlinden et al., 2009). Application of groundnut compost did not significantly affect dry weight of maize shoot harvested at 90 days after planting, but it significantly affected root dry weight (Table 1). Application of 15 t compost /ha (treatment K15) to 25 t compost/ha (K25) resulted in the highest shoot dry weight. Again, the significant effect of groundnut compost of maize yield seems to be strongly related to the organic acids content in the compost.

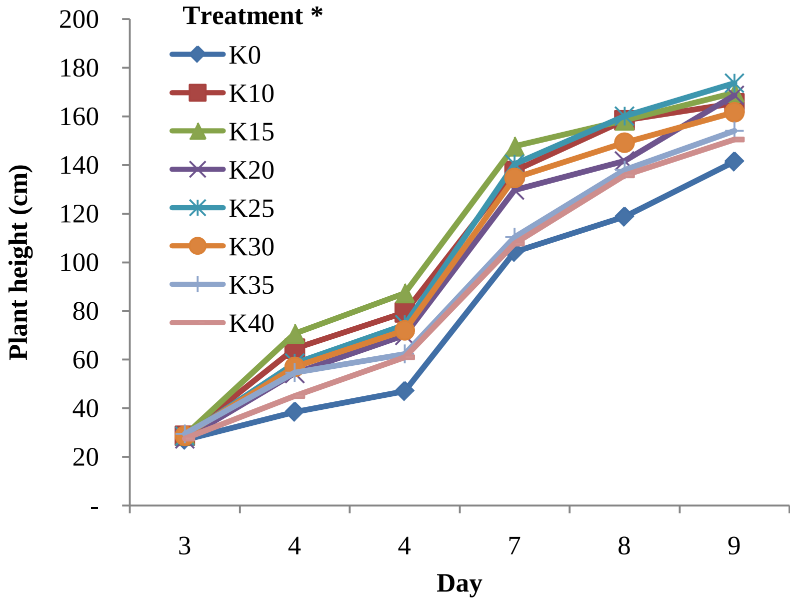

Figure 2. Effect of application of groundnut compost on height of maize grown on an Ultisol for 9 weeks.
*) see Figure 1

Table 1. Effects of application of groundnut compost of on yield of maize grown on an Ultisol of South Sulawesi.

Treatments *)	Shoot dry weight (g)	Root dry weight (g)	Cob length (cm)	Cob diameter (cm)	Cob dry weight (g)	Weight of grain per cob (g)
K0	22.87	7.20	10.00	3.57	19.90	15.19
K10	28.83	12.64	10.10	3.83	35.03	28.29
K15	42.80	19.90	10.83	4.07	41.03	32.49
K20	36.47	13.20	13.03	4.23	49.40	44.06
K25	43.40	14.40	14.04	4.30	58.50	42.72
K30	36.47	12.35	13.27	4.00	51.43	42.96
K35	33.65	11.60	12.35	4.03	48.75	35.53
K40	26.97	11.50	12.40	4.33	41.40	32.02

*) see Figure 1

The development plant root may be through the increase of plant cell energy that in turn will intensify exchange process (Eyheraguibel, 2004). The increase of plant absorption capability makes plant root easy to absorb nutrients into the cells and accelerate the process of plant respiration, and the formation of long and strong root system that makes plant root easy to access nutrients in the soil (Verlinden et al., 2009). Results of regression analyses presented in Figure 3 show that there were strong relationships between soil available P, cob dry weight and weight of grain per cob. According to Trevisan et al. (2010), the direct effect of organic acids of compost on crop production is through involvement in various metabolic processes including respiration, protein synthesis, enzyme activity, and photosynthesis. In the plant tissue, humic and fulvic compounds regulate a number of ions including nitrate and phosphate (Oburger et al., 2011). In response to P deficiency, plant has the ability to develop adaptive strategies to improve acquisition of P from the soil (Bais et al., 2006; Chen et al., 2008). This strategy includes organic acid anion exudation of low-molecular - weight, which can mobilize inorganic P.

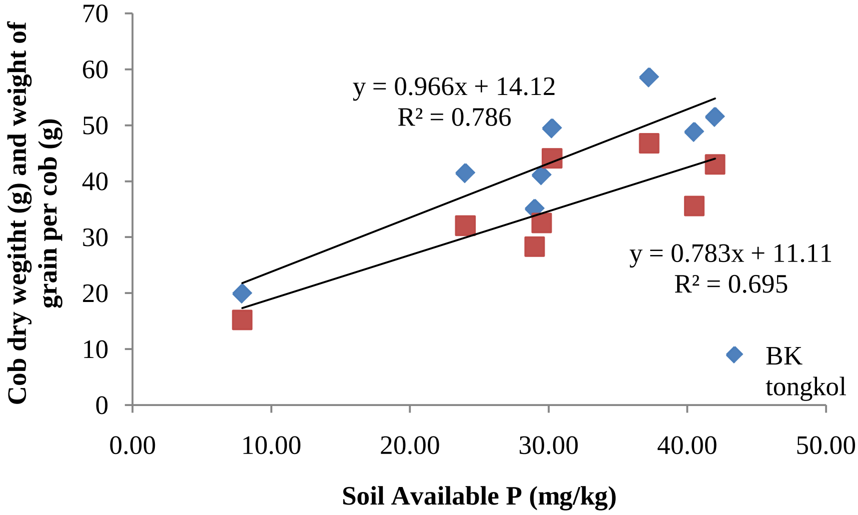

Figure 3. Relationship between available soil P, cob dry weight, and weight of grain per cob

P uptake by maize plants

Application of groundnut significantly affected P uptake by maize (Figure 4). Application of compost 25 t compost/ha (K25) resulted in the highest P uptake in maize shoot and grain which was not significantly different with P uptake of plants with compost application of 30 t/ha (K30). Application of 35 t and 40 t compost, however, resulted in the decrease of P uptake.

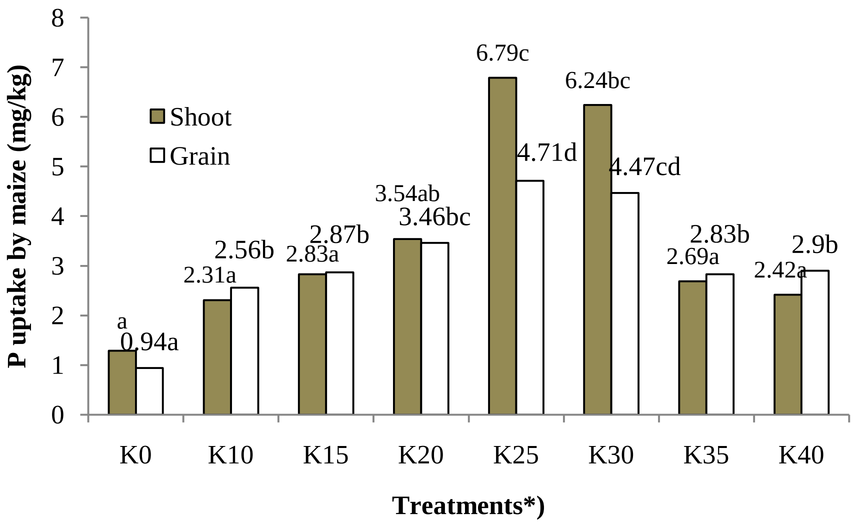

Figure 4. Effect of application of groundnut compost on P uptake by maize grown on an Ultisol for 9 weeks. *) see Figure 1

There was a negative quadratic relationship between rate of compost applied and total P uptake by maize (shoot + grain) ($y = -0.012x^2 + 0.601x + 1.144$; $R^2 = 0.626$). P uptake by maize shoot and grain, however, was linearly correlated with soil available P ($y = 0.216x + 0.101$; $R^2 = 0.583$). As explained earlier, humic and fulvic compounds directly or indirectly affected plant growth. The direct effects of humic and fulvic compounds are capable of altering the permeability of plant cell membrane and encourage the uptake of ions, either actively or passively into the roots. Humic and fulvic compounds of organic matter added to the soil are capable of improving the availability of phosphate by lowering the phosphate sorption (Winarso et al., 2009). Humic and fulvic compounds are also capable of binding heavy metals such as Fe and Al through forming of chelate compounds thereby reducing soil toxicity. The occurrence complex bonding between humic compounds with Fe and Al is in anticipation of the bonds between P with Al and Fe, so that plants can readily absorb the P.

Conclusion

Peanut compost has the ability to improve the availability of P in the soil and increase P uptake both in plants and in the seeds, especially maize grown on Ultisol South Sulawesi. Application of 25 t ground nut compost/ha was the optimal rate that can be used to increase P availability in an Ultisol of South Sulawesi.

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