

## SOIL PHYSICAL PROPERTIES AND PRODUCTION OF UPLAND Ultisol SOIL AS INFLUENCED BY MANURE APPLICATION AND P FERTILIZATION

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### **ABSTRACT**

Acid upland soil in Indonesia has a great potential for agricultural development but the soil physical properties have been degraded. The use of manure and direct application of Gresik phosphate rock (PR) was an alternative to improve land productivity and crop yields. The objective of the study was to evaluate the effects of manure and P sources on soil physical properties and yield of food crops, which was arranged on intensive cropping systems of upland rice + maize -/- cassava- mungbean. The experiment was carried out in Tamanbogo Research Farm, East Lampung from 2007 to 2009 using randomized complete block design with 3 replications. The treatments were (1). 10 t ha<sup>-1</sup> manures+1 ton per ha of PR, (2). Without manure + 1 ton per ha of PR, (3). 10 ton per ha manures+100 kg per ha of SP 36, and (4). Without manure+100 kg per ha of SP 36. The results showed that the application of manure along with PR improved soil physical characteristics of ultisol soil and gave the highest yield of food crops with B/C in year 3<sup>th</sup> was 3.60.

**Keywords:** soil physical property, manure, P fertilization, upland ultisol, Lampung

### **INTRODUCTION**

Acid, upland soil in Indonesia reached 122,289 million hectares, covered about 67.5% of the total agricultural land (Dierolf *et al.*, 2001), and most of them were widely distributed outside the island of Java. The land was dominated by ultisol soil of about 45.80 million hectares and classified as marginal land (Subagyo *et al.*, 2000). The content of N, K<sub>2</sub>O

and P<sub>2</sub>O<sub>5</sub> nutrients was low. Beside the nutrient deficiencies, the upland ultisols soil contains low organic matter, high soil bulk density (BD), low total pores space and soil permeability, and low available water (Soelaeman *et al.*, 2003).

Ultisol soil had high contents of Al oxide, it was binding P nutrient into unavailable forms (Singh *et al.*, 2003), and so that P deficiency in acid upland soil was a factor limiting crops production. Animal manure (cow-dung) has important function to improve soil fertility, soil physical properties, and soil biology. FAO (2005) mentioned that the active and some of the resistant soil organic components, together with micro-organisms (especially fungi), were involved in binding soil particles into larger aggregates. Aggregation is important for good soil structure, aeration, water infiltration and resistance to erosion and crusting. Higher contents of soil organic matter have positive impact on soil bulk density, pore volume and maximum water capacity as well as on yield and yield components of cereals (Raupp, 2001). Dierolf *et al.* (2001) mentioned that direct application of indigenous PR as a source of P nutrient at once was more appropriate in acid soil.

Multiple cropping practices have been spreading in upland ultisol soil in Indonesia in the forms of inter cropping, sequential cropping, and relay cropping; each of which has purposes to increase plant production per unit of area and time (Sullivan, 2003). Organic manure has played the most prominent role in maintaining soil fertility and increasing plant production.

The present study was to evaluate the application of manure and phosphorus fertilization to the physical properties of the soil and crops yield.

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## MATERIALS AND METHODS

A field experiment was conducted from November 2007 to December 2009 (3 years) at the Tamanbogo Research Farm, East Lampung, Lampung Province; the site had 3-4 of dry months and 7-8 of wet months. The mean annual rainfall of more than 100 mm per month occurred during the rainy season (October to May) while the rest months (June to September) were less than 100 mm month<sup>-1</sup>. The soils of the area were typic kanhapludult, ultisol order, that had been degraded, very acid (pH 4.2), contained low organic matter (0.8%) and very low available P (0.92 ppm P).

The experiment was designed as a randomized complete block design with four treatments and four replications. The treatments were (1) 10 ton manures per ha + 1 ton PR per ha, (2) Without manure + 1 ton PR per ha, (3) 10 ton manures per ha + 100 kg SP per 36 ha, and (4) Without manure + 100 kg SP 36 per ha. The crops were arranged in intensive cropping pattern of Upland Rice + Maize -/-Cassava – Mungbean.

The upland rice (*Oriza sativa* L.) used Limboto cultivar that was planted in the rainy season with plant spacing of 25 x 25 cm, 3 to 5 grains per hole. The maize hybrid of Pioneer 21 (*Zea mays* L.) was intercropped with upland rice using plant spacing of 200 cm x 25 cm, 1 plant/hole. Cassava (*Manihot utilisima* Crantz.) using Kasesart cultivar was inserted/relayed between maize plants with plant spacing of 400 cm x 50 cm. Local cultivar of mungbean (*Phaseolus radiatus* L.) was planted in dry season after the upland rice and maize were harvested with plant spacing of 30 cm x 20 cm, 1-2 grain(s)/hole.

Gresik phosphate rock (18% P<sub>2</sub>O<sub>5</sub>) was applied once with the rates of 1 ton per ha, manure was applied yearly at the rates of 10 ton per ha per year and SP 36 was applied in each planting season. Manure and PR were spread evenly onto the soil surface before planting, followed by evenly mixing them with soil at a depth of 15-20 cm using a hand hoe. Upland rice was fertilized with the rates of 90 kg N per ha and 30 kg K<sub>2</sub>O per ha, spreaded 3 times, i.e. 1/3 dose of N and all doses of P and K were applied when the plant had been 7 days old after planting (DAP), 1/3 dose of N was applied when the plant had been 30 DAP and the remaining of

1/3 dose of N was applied at primordium phase (45 DAP).

Maize fertilization was carried out twice at the rates of 90 kg N per ha, 36 kg P<sub>2</sub>O<sub>5</sub> per ha and 30 kg K<sub>2</sub>O per ha. The first fertilization was 1/3 dose of N and all doses of P and K were filled to the hole when the plants had been 7 DAP, and the remaining 2/3 dose of N was applied at 30 DAP. Mungbean was fertilized with 22.5 kg N per ha when the plants had been 7 DAP, while cassava was not fertilized.

Soil samples from the depths of 0-15 cm before application of manure and fertilizers, and after harvest were taken from each plot at random using ring samplers. The sampler was pressed vertically at the soil surface up to 15 cm in depth. The soil extending beyond each end of the ring sampler was trimmed with a straight edged knife/cutter. The sampler and its contents were carefully taken and maintained, so that the natural soil structure as best as possible was not damaged, and transported safely for analyses in the laboratory.

Observations were conducted to some chemical variable of manure, soil physical properties before planting and after harvest, and crops yield. The soil physical variables observed were bulk density (BD), total soil pores space, available water and soil permeability.

Soil data were analyzed descriptively, while the crops data were analyzed using the SAS Systems for Linier Models, v.6.12 for windows (Ramon et al., 1992). The data was analyzed using the analysis of variance, continued to the Duncan Multiple Range Test (DMRT) at 5% significance level. To determine the financial profit of each treatment, the calculation of input-output and B/C ratio was applied.

## RESULTS AND DISCUSSION

### Manure Quality

The result of manure analysis indicated that the nutrient content was very low but the organic C content was relatively high (9.50%) and the water content was in moderate level (34.30%). Fiber part of manure can improve granulation/aggregate formation of the soil that plays an important role to improve soil permeability and air circulation (aeration). Based on the Regulation of the Ministry of Agriculture of Indonesia No. 28/Permentan/SR.130/5/2009

(Departemen Pertanian, 2009) showed that the quality of manure used in this study was relatively good.

### **Effect of Manure and P Fertilizer on Soil Physical Properties**

#### **Soil Bulk Density**

Considerable influence of manure and P fertilization on soil bulk density was observed as shown in Figure 1.

Application of manure with PR or SP36 reduced soil bulk density by 13.3-20.0% in year I and 33.3% in year III but the application of SP 36 and PR without manure showed mild/little positive effect in reducing soil bulk density. Sultani *et al.* (2007) found out that phosphorus fertilization did not show any significant effects on various soil physical properties. Soil BD was affected by the contents of soil organic C, soil texture and soil management. The higher the organic C contents in the soil, the lower the soil BD. Agus *et al.* (2006) suggested that soil BD had a close relationship with root penetration into the soil, soil drainage and soil aeration, and other soil characteristics.

Application of P without manure in this experiment did not contribute significantly in

reducing soil bulk density even though the soil bulk density tended to decrease, but it was caused by returning back of harvest residues from previous harvest. Min *et al.* (2003); Werner (1997) and Islam and Weil (2000) mentioned that soil bulk density was inversely related to total soil porosity, which provided a measure of the porous space left in the soil for air and water movement. Lower bulk density implied greater pores space and improved aeration, thus, developed a suitable environment for biological activity and plant growth.

#### **Total Soil Pores Space (TPS)**

Physical properties of soil type depend on the size of particles in it; soil particles occupy roughly more than half of the space in the soil. The remaining space between the particles, called the pores space, is occupied by water and air. Total soil pores space is the total pores which will be filled by air/oxygen when the soil is in the state of field capacity (pF 2.54% by vol.).

Figure 2 indicated that the use of manure with PR or SP 36 increased total soil pores by 25-43% in year I, II and III while the treatment without manure gave a small increase of soil pores space (4-7 %).

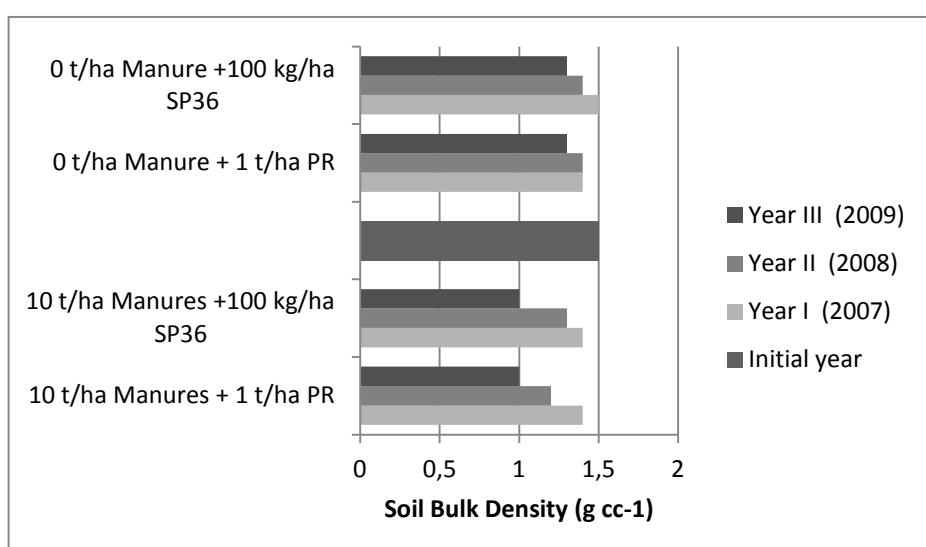


Figure 1. Effect of manure and P sources on bulk density of ultisol soil

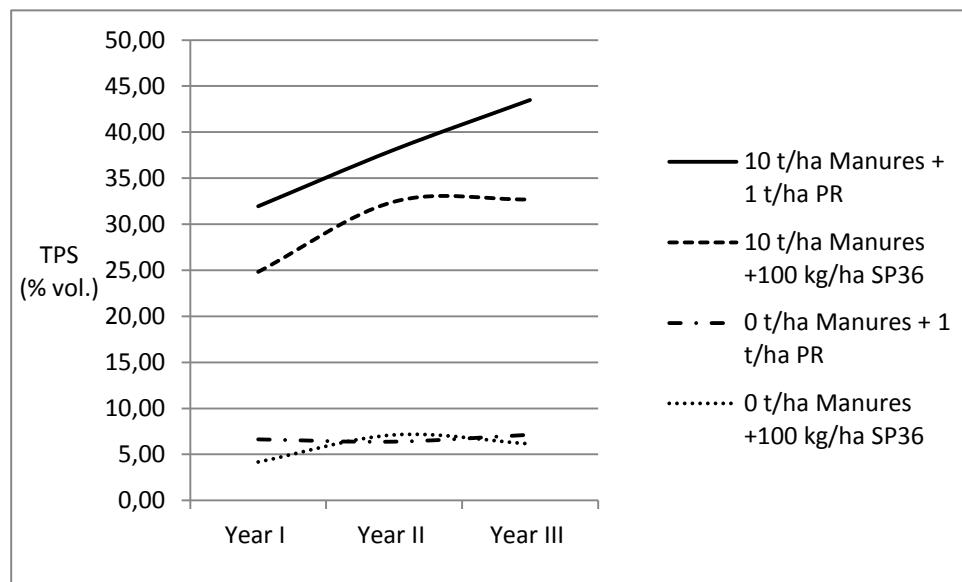


Figure 2. Effect of manure and P sources on total pores space of ultisol soil in tamanbogo experimental farm, Lampung

Phosphorus fertilization did not contribute significantly in increasing soil porosity but application of manure specifically influenced soil structural properties by binding soil primary particles and microaggregates into macroaggregation through production of cementing agents from enhanced microbial activities. These aggregation processes and properties may increase soil porosity with greater water retention and transmission capacities (Min *et al.*, 2003; Werner, 1997).

Significant differences in volume fraction of pores space suggested that manure amended soil pores space was much higher than the soil without manure. It means that there was an improvement of pore size in soil, which is very important for the air and water balance of soil since aeration critically depends upon pore size distribution (Aon *et al.*, 2001).

Increased total porosity of soils with manure application suggests that manure is able to increase larger pores and the soil is far more likely to be regulated by macropores over micropores. Pores with diameters between 0.1 and 15  $\mu\text{m}$  are assumed to retain more plant

available water than larger pores (Azooy *et al.*, 1996).

#### **Available Water and Soil Permeability**

Available water and soil permeability (Figure 3) increased by 22.4-32.9% and 31.4-68.0% with manure application along with PR, while its application with SP 36 did not increase as high as did PR. The different improvement of soil physical characteristics between PR and SP 36 was estimated due to the differences of plant biomass returning back into the soil.

Reicosky (2005) suggested that the organic matter and biological activity had a major influence on the physical properties of the soil. Soil aggregation and stability of soil structure increased with the increase of soil organic C, thus, increased the infiltration rate and water holding capacity.

Soil under manure with PR applications retained the greatest volume of water. Application of manure substantially increased the amount of available water to plants but phosphorus fertilization without manure showed no significant effect on available water.

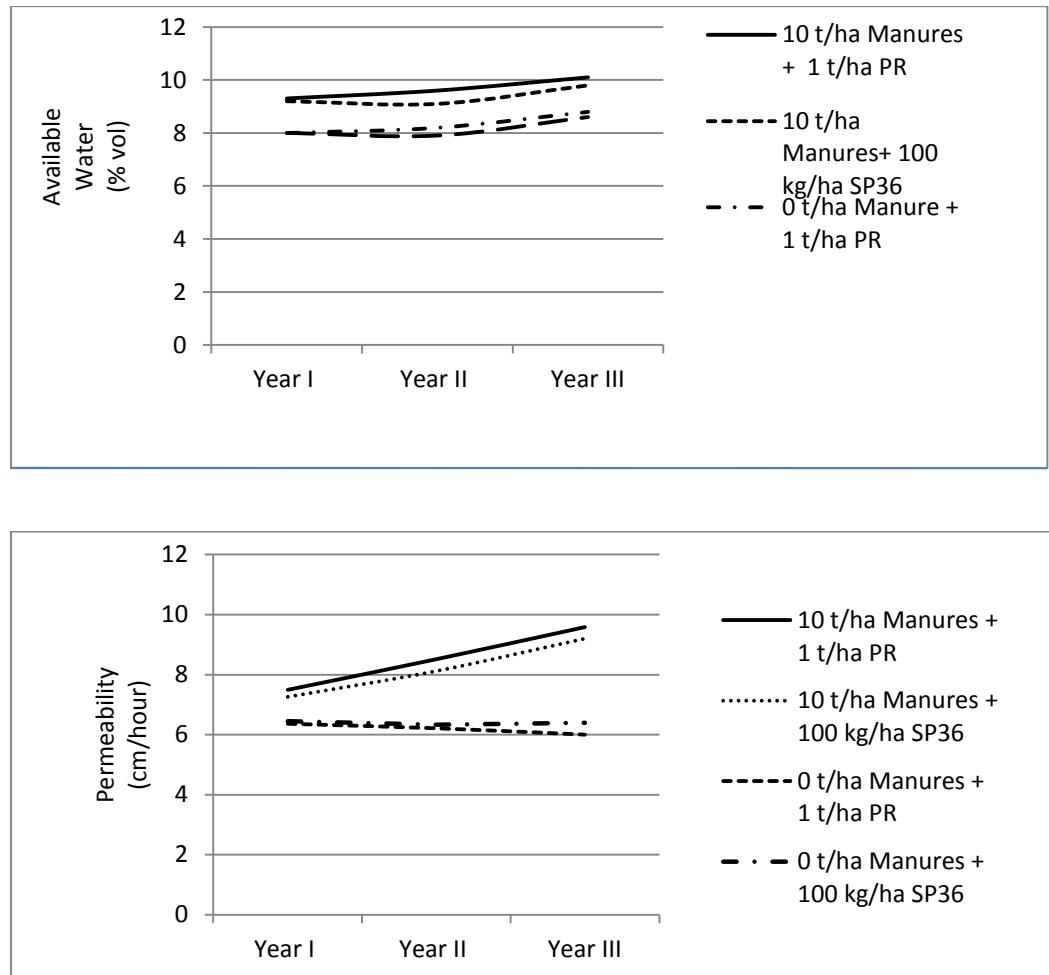


Figure 3. Effect of manure and P sources on available water and soil permeability of ultisol soil in tamanbogo experimental farm, Lampung

#### Effect of Manure and P on Yield of Food Crops

##### Planting Season I (Upland Rice + Maize +/- Cassava)

The treatment of  $10 \text{ t manures ha}^{-1}$  along with  $1 \text{ t PR ha}^{-1}$  significantly gave the highest dry

grain weight of upland rice and maize in the year I, II and III compared to the other treatments. The yield of upland rice was  $1.66 \text{ t ha}^{-1}$  in the year I (2007), increasing by 30.4% and 33.1% in the year II and III, respectively. Furthermore, the yield of maize was the highest compared to the other treatments tested (Table 1).

Table 1. The weight of dry grain rice and maize in intercropping of upland rice+maize/-cassava-mung bean in tamanbogo research farm, East Lampung

Treatments	Dry Grain Rice ( $t \text{ ha}^{-1}$ )			Dry Grain Maize ( $t \text{ ha}^{-1}$ )		
	Year I (2007)	Year II (2008)	Year III (2009)	Year I (2007)	Year II (2008)	Year III (2009)
10 $t \text{ ha}^{-1}$ manure + 1 $t \text{ ha}^{-1}$ of PR	1.661	a	2.166	a	2.21	a
Without manure + 1 $t \text{ ha}^{-1}$ PR	1.424	b	1.594	b	1.53	bc
10 $t \text{ ha}^{-1}$ manure + 100 kg $\text{ha}^{-1}$ of SP 36	1.296	c	1.722	b	1.96	ab
Without manure + 100 kg $\text{ha}^{-1}$ of SP 36	1.312	c	1.223	c	1.16	c
					2.88	a
					3.365	b
					2.60	a
					1.43	c
					1.548	c
					1.63	b

Remarks: Numbers followed by the same letter in the same columns are not significantly different by DMRT at 0.05,  
+ : intercropping, -/- : relay cropping, - : continuous cropping

This condition indicated that the use of manure improved the physical properties of soil, so that the effectiveness of PR increased and the yield was higher compared to treatment without manure. The PR and SP 36 without application of manure did not show significantly different yields of upland rice and maize in year II and III (Table 1). It was probably due to less improvement of soil physical properties as shown in Figures 1, 2 and 3.

#### Planting Season II (Mungbean /-Cassava)

Application of PR along with manure showed significantly higher yields of mungbean in year II (8 % higher) and III (28% higher) compared to the yield of SP36 with manure. Phosphate rock without manure gave better yield of mungbean (42.86 %-88.89 % higher) than the yield achieved by SP 36 (Table 2).

The growth of cassava inserted/relayed between the holes of maize was relatively slow and tended to be stagnant and escalate because there was competition of space and light with upland rice and maize. Table 2 indicates that the use of 10 t manure  $\text{ha}^{-1}$  along with PR provided yields of 11.2 ton per ha and 12.6 ton per ha fresh cassava tubers in year I and III. The yield was significantly higher compared to the fresh tuber yield achieved by SP 36 with manure, and SP 36 and PR without

manure. The yield of cassava with 10 t manures  $\text{ha}^{-1}$  along with PR in the year II was relatively similar (11.50 ton per ha) compared to the yield obtained by SP 36 with manure (11.42 ton per ha).

The effect of PR was higher in year III, as mentioned by Chien (2010) that the effectiveness of PR was higher for long-term than short-term.

#### Financial Analysis

Management of acid upland soil by using of 10 ton manure per ha per year along with PR provided greatest profit in year I, II and III, making Rp. 8,546,250, Rp. 15,077,350 and Rp. 19,189,000, respectively. The biggest B/C of 3.66 was gained in year III.

The yield values, profits and B/C ratio of treatments with application of PR, and SP 36 along with manure increased with time. Experimental results reported by Chien *et al.* (2003) stated that the Relative Agronomic Effectiveness (RAE) of RP increased from the first bean crop to the third crop grown on soil with a high P-fixing capacity. The smallest profit was achieved when using SP 36 without manure. The profit in the year I was Rp. 4,705,000 with B/C was 1.38. The profit and B/C increased in year II (Rp. 6,515,700 with B/C was 1.72), and in year III ( Rp. 8,332,000 with B/C was 2.12).

Table 2. Mungbean and cassava yields on manure and RP fertilizers in upland rice + maize -/- cassava-mungbean cropping pattern in tamanbogo research farm, East Lampung

Treatments	Weight of dry grain of mungbean (ton per ha)				Weight of fresh cassava tuber (ton per ha)			
	Year I (2007)	Year II (2008)	Year III (2009)	Year I (2007)	Year II (2008)	Year III (2009)		
10 t ha <sup>-1</sup> manure + 1 t ha <sup>-1</sup> of PR	1.00	a	1.08	a	1.28	a	11.20	a
Without manure + 1 t ha <sup>-1</sup> of PR	0.65	b	0.50	c	0.85	c	9.55	c
10 t ha <sup>-1</sup> manure + 100 kg ha <sup>-1</sup> of SP36	0.98	a	1.00	b	1.10	b	10.233	b
Without manure + 100 kg ha <sup>-1</sup> of SP36	0.41	c	0.35	d	0.45	d	9.00	d
							11.417	a
							10.333	b
							9.550	d
							12.600	a

Remarks: Numbers followed by the same letter in the same columns are not significantly different by DMRT at 0.05.  
+ : intercropping, -/- : relay cropping, - : continuous cropping

## CONCLUSIONS

The use of 10 t manure ha<sup>-1</sup> along with PR in ultisol soil improved soil physical properties (BD, total soil pores, available water and soil permeability) and gave highest crops yield in year II and III. Financial analysis showed that the highest benefits and B/C were achieved when the treatment of manure along with PR was applied.

Direct application of PR was to be a valuable source of nutrients in acid soil with low exchangeable Ca and thus provided favorable condition for PR dissolution.

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