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Quality of Soil and Yield of Food Crops in Ultisols Due to Application of Manure and Source of Phosphate Fertilizer

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ABSTRACT

Acid upland soil in Indonesia has a potential for agricultural development but it has constraints low of organic C and available P as well as the soil physical properties have been degraded. The use of manure and direct application phosphate rock (PR) was an alternative to improve land productivity and crop yields. The objective of the study was to examine the effects of manure and the sources of P on soil physical and chemical properties and yield of foods crop that was arranged on intensive cropping systems of upland rice + maize -/- cassava- mungbean. The experiment was carried out at Tamanbogo Station Farm, East Lampung since 2007 until 2009 using randomized completely block design with 3 replications. The treatments were (1) 10 Mg ha^{-1} manures + 1 Mg ha^{-1} of RP, (2) without manure + 1 Mg ha^{-1} of PR, (3) 10 Mg ha^{-1} manures + 100 kg ha^{-1} SP 36, and (4) without manure + 100 kg ha^{-1} SP 36. The results showed that the application of manure along with PR improved soil chemical and physical characteristics. Its improvement affected the yield of foods crops, hence the profit increased with B/C ratio between 2.88-3.60.

Keywords: Food crops, manure, soil quality, source of P, upland ultisols

INTRODUCTION

Acid upland soil in Indonesia reaches 122,289 million hectares that cover about 67.5% of total agricultural land (Dierolf *et al.* 2001), most of them is widely distributed in the outside of Java Island. The agriculture land is dominated by ultisols soil that occupy an areas of about 45.80 million hectares and are classified as marginal land (Subagyo *et al.* 2000). Upland ultisols soil have a potential and opportunity for agricultural development, eventhough they have some physical and chemical soil constraints (Kang 1989).

Multiple cropping practices has been spreading in upland agriculture in Indonesia in the forms of inter cropping, sequential cropping, and relay cropping; each of them has purposed to increase plant production per unit of area and time. However, the intensive food crops cropping systems become necessary in many upland agricultural systems in Indonesia due to the limitation of arable land. Organic manure has played a most prominent in maintaining soil fertility and increasing plant production in sustainable manners.

Ultisols is a very acid soil with soil pH ranges from 4.2 to 4.3. Due to the relatively high rainfall (> 2,000 mm year^{-1}), the soil bases such as Ca, Mg, K and Na cations are released and quickly leached from the soil, thereby the soil becomes acid (Subagyo *et al.* 2000). The contents of N, K_2O and P_2O_5 nutrients in ultisols soil are low that are between 0.06 to 0.48% of N; 0.51 to 0.76 mg 100 g^{-1} of K_2O; and 0.92 to 0.95 mg kg^{-1}of P (Soelaeman *et al.* 2003).

Ultisols soil with high contents of Al oxide will retain P into the unavailable forms for plant growth, so that the P deficiency in acid upland soil is the most limiting factor crop for production. A possible strategy to solve the problem of P deficiency is by direct application of indigenous phosphate rock (PR). Use of PR as a source of P nutrient at once in high dosage (P recapitalization) is more appropriate in acid soil because the P nutrient will not be lost by leaching, except on very sandy soil (Dierolf *et al*. 2001). The use of PR with the dosage of 1 Mg ha^{-1} directly will reduce the cost of acidification processes required in SP36, TSP, and others kind of P fertilizers production. Phosphate rock has a nature of slow release of P (Zapata and Zaharah 2002) and contains Ca nutrient and other micro nutrients to support plant growth, so that the

PR is more appropriate to eliminate the unavailable P in the soil.

Beside of nutrient deficiencies, the upland ultisols soil contains low organic matter, high soil bulk density (BD), low of total pores space, soil permeability and available water (Soelaeman *et al.* 2003). Animal manures (cow-dung) are most widely used to improved soil fertility and physical properties. The general effect of manure is to improve soil physical properties that is closed relation to the increasing of soil productivity.

To reduce the problems of P deficiency for plant and poor of soil fertility and soil physical conditions in acid upland soil, the application of manure and PR is necessary. The purposes of study were to examine the management of soil productivity through the use of manure and sources of P on soil physical and chemical properties, and crop yields.

MATERIALS AND METHODS

Study Site and Experimental Design

The experiment was conducted at the Experimental Farm of Tamanbogo, located in East Lampung. The experiment was carried out since 2007 until 2009 (3 years) using food crops that was arranged in intensive cropping pattern of Upland Rice + Maize -/-Cassava – Mungbean.

The experiment was arranged in a randomized completely block design with 3 replications. Gresik RP that contains of 18% P_2O_5 and manure were applied at once with the dosages of 1 Mg ha^{-1} years^{-1} and 10 Mg ha^{-1} year^{-1}, respectively in the rainy season, and SP36 was applied in every planting season. The treatments were (1) 10 Mg manures ha^{-1} + 1 Mg PR ha^{-1}, (2) without manure + 1 Mg PR ha^{-1}, (3) 10 Mg manure ha^{-1} + 100 kg SP36 ha^{-1}, and (4) without manure + 100 kg SP36 ha^{-1}.

Field Plot and Cropping Pattern

The upland rice (*Oriza sativa* L.) namely Limboto cultivar was planted in the rainy season with plant spacing of 25 × 25 cm, and 3 to 5 grains per hole. The Pioneer 21 hybrid variety of maize (*Zea may* L.) was intercropped in upland rice with plant spacing of 2 m × 0.25 m, 1 plant/hole, while cassava (*Manihot utilisima* L.) Namely Kasesart cultivar was relayed between maize plants with plant spacing of 4 m × 0.5 m. Local cultivar of mungbean (*Phaseolus radiatus* L.) was planted in dry season (after the upland rice and maize have been harvested)with plant spacing of 30 cm × 20 cm, 1-2 grains hole^{-1}.

The manure was applied by evenly broadcasting according to the treatment, and then mixed with soil in 15-20 cm depth using hand hoes. Upland rice was fertilized with the dosage of 90 kg N ha^{-1} and 30 kg K_2O ha^{-1}, broadcasted 3 times, namely 1/3 dosage of N and all dosages of P and K were applied at 7 days old after planting (DAP), 1/3 dosage of N was applied at 30 DAP and the remaining of 1/3 dosage of N was applied at primordial phase (45 DAP).

Maize fertilization was carried out in 2 times at the dosage of 90 kg N ha^{-1}, 36 kg P_2O_5 ha^{-1} and 30 kg K_2O ha^{-1}. The first fertilization was 1/3 dosage of N and all dosages of P and K were applied at 7 DAP and the remaining 2/3 dosage of N applied at 30 DAP. Mungbean was fertilized by 22.5 kg N ha^{-1} at 7 DAP, while cassava did not fertilize.

Soil Analysis

Parameter observed were chemical of manure, soil chemical and physical properties before planting and after harvest, and crops yield. The variables of soil chemical were soil pH, organic C, cation ion exchange capacity (CEC), N, P (Bray-I), K, Mg, Fe and Al. The variables of soil physical variables were bulk density (BD), total soil pores space, available water and soil permeability.

Data Analysis

Soil data's were analyzed descriptively while the crop data's were analyzed using the SAS Systems for Linier Models, v.6.12 for windows (Ramon *et al*. 1992). Data were analyzed by analysis of variance and followed by Duncan Multiple Range Test (DMRT) at 5% significance level. The financial effectiveness of each treatment was calculated by input-output farming and B/C ratio.

RESULTS AND DISCUSSION

Manure Quality

The results of manure analysis (Table 1) showed that the nutrients content in the manure were very low but the organic C content was relatively high (9.50%) and the water contents was characterized at moderate level (34.30%). In addition, the manure contained some micro elements required by plant. Therefore, the quality of manure used in this study was high.

Manure could improve soil chemical and physical properties effectively, and the plant growth was affected by the maturity of manure. Hartatik and Widowati (2009) suggested that the microbes

Tabel 1. Chemical characteristics of manure used in upland rice+maize-/-cassava-mungbean at Tamanbogo Experimental Farm, East Lampung.

Chemical Variable	Value
N (g kg^{-1})	5.8
P (g kg^{-1})	1.1
K (g kg^{-1})	2.9
Ca (g kg^{-1})	4.8
Mg (g kg^{-1})	4.2
Organic C (g kg^{-1})	95.0
Mn (g kg^{-1})	724
Cu (g kg^{-1})	9.5
Zn (g kg^{-1})	64
Water contents (%)	34.30

Description: Analyzed at the Chemical Laboratory of Indonesian Soil Research Institute (ISRI)

will use the available N to decompose organic materials if the manures decomposition processes were not finished yet, so that the absorption of N by the crops was limited.

Fibers part of organic materials improved on the granulation/aggregate formation of the soil that played an important role to improve soil permeability and air circulation (aeration). As a function of soil chemistry, organic manure could provide some of soil CEC that was important to hold a given inorganic fertilizers and soil buffering capacity, so that the crops could avoid from the pressure of soil acidity. The use of organic materials increased the availability of some nutrients and improved the efficiency of P absorption by crops because in the process of organic matters decomposition humic acid and fulfat acid (polyelectrolite) were produced that had an ability to bind Al and Fe in the soil. To eliminate P fixation in the soil, the active anion of organic manure formed a chelate bond with Si-Al-OOCR (Alofan). The higher the carboxyl and fenolic compounds in organic matters the higher the ability of organic matters to realease $AlHPO_4$ bonds so the P nutrient became more available for plant (Mengel dan Kirkby 1987). By increasing of organic matter contents in the soil, the N total and N mineralization, soluble P, exchangeable K, N uptake by plants and soil water content could be increased (Stanford *et al.* 1973).

The Effect of Manure and P Sources to the Soil Chemical Properties

Table 2 showes that the initial soil pH (before planting) was very acid (4.2), soil organic C contents, available P (Bray-1) and CEC were very low. Residues of 1 Mg ha^{-1} yr^{-1} of PR combining with 10 Mg ha^{-1} yr^{-1} of manures increased soil pH by 0.3 points in the year II and III, respectively. The content of soil organic C increased by 25% in the year I, and 37.5% and 50.0% in the year II and year III, respectively. The use of PR without manure increased soil pH by 0.2 points in year I and II, and 0.25 points in the year III, while the soil pH relatively did not change it using SP36 only. The use of PR along with manure was likely to increase soil organic C higher than the use of SP36, both with manure and without manure.

Rochayati *et al.* (2009) suggested that the PR contained Ca equivalent to 40% CaO. Phosphate rock application in acid upland soil increased soil pH due to the presence of Ca. Soil pH affected plant growth and weight of harvested biomass (Chien and Friessen 1992), thereby, the quantity of organic materials that were returned back to the soil was higher compared to the biomass produced by SP36. Sutriadi *et al.* (2005) argued that the application of organic matter in acid upland soil had positive effect on the solubility of PR. Chien *et al.* (2010) reported that the dissolution of PR increased with an increase of soil P-fixing capacity.

The available P before planting was very low (0.92 mg kg^{-1} P) and tended to increase in the year II and III. The effect of PR residues combined with manure application increased the availability of P (Bray 1) in year II and III up to the high level (1.0 to 1.1 mg kg^{-1} P). The PR or SP36 fertilizers without manure reduced the availability of P in the soil, so that the values of available P in year I up to year III was very low. The application of PR or SP36 fertilizers with manure increased CEC values from 4 $cmol_{(+)}$ kg^{-1} to between 4.56 to 7.30 $cmol_{(+)}$ kg^{-1}, whereas in the other treatments were very low. The nutrient added to the soil with low CEC could not be held and easily lost. This condition was reflected to the increasing of soil organic C contents in the treatment with manure application and it did not increase significantly in the treatment without manure application, *vice versa*.

The Effect of Manure and P Sources on the Soil Physical Properties

Tabel 3 showes that the application of manures with PR or SP36 decreased soil BD from 1.5 Mg m^{-3} (before planting) to between 1.2-1.3 Mg m^{-3} in the year II and to 1.0 Mg m^{-3} in the year III. Agus *et al.* (2006) suggested that the soil BD was one of the soil physical characteristic that was usually measured because its had closely relationship with root penetration into the soil, soil drainage and soil

Table 2. Soil chemical characteristics before planting and after harvest in upland rice +Maize-/-cassava-mungbean cropping pattern at Tamanbogo Experimental Farm, East Lampung.

Parameter and Treatment	Before Planting (2006)	Year I (2007)	Year II (2008)	Year III (2009)
pH	4.20(va)			
10 Mg ha^{-1} manure + 1 Mg ha^{-1} PR		4.40(va)	4.50(a)	4.50(a)
Without manure + 1 Mg ha^{-1} PR		4.40(va)	4.40(va)	4.45(va)
10 Mg ha^{-1} manure +100 kgha^{-1} SP36		4.40(va)	4.35(va)	4.40(va)
Without manure +100 kg ha^{-1} SP36		4.30(va)	4.25(va)	4.30(va)
C-organic (g kg^{-1})	8.0(vl)			
10 Mg ha^{-1} manure + 1 Mg ha^{-1} PR		10.0(l)	11.0(l)	12.0(l)
Without manure + 1 Mg ha^{-1} PR		8.0(vl)	8.5(vl)	9.0(vl)
10 Mg ha^{-1} manure +100 kg ha^{-1} SP36		9.5(vl)	10.0(vl)	11.0(vl)
Without manure +100 kg ha^{-1} SP36		9.0(vl)	9.0(vl)	8.5(vl)
P_2O_5 Bray 1 (mg kg^{-1} P)	0.92(vl)			
10 Mg ha^{-1} manure + 1 Mg ha^{-1} PR		12.92(h)	12.78(h)	11.18(h)
Without manure + 1 Mg ha^{-1} PR		7.00(m)	7.10(m)	7.05(m)
10 Mg ha^{-1} manure +100 kg ha^{-1} SP36		10.92(h)	10.64(h)	9.97(m)
Without manure +100 kg ha^{-1} SP36		6.50(l)	6.53(l)	6.61(l)
CEC (cmol $_{(+)}$ kg^{-1})	4.00(vl)			
10 Mg ha^{-1} manure + 1 Mg ha^{-1} of PR		6.44(l)	7.32(l)	7.30(l)
Without manure + 1 Mg ha^{-1} of PR		4.44(vl)	4.24(vl)	4.10(vl)
10 Mg ha^{-1} manure +100 kg ha^{-1} of SP36		4.86(vl)	4.51(vl)	4.56(vl)
Without manure +100 kg ha^{-1} of SP36		4.24(vl)	4.16(vl)	4.00(vl)

Description: (a) = acid, (va) = very acid, (l) = low, (vl) = very low, (m) = medium, (h) = high + = intercropping, -/- = relay cropping, - = continous cropping.

aeration and others soil characteristics. 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 (Hsieh and Hsieh 1990). Soelaeman *et al*. (2011) found out that low soil BD had caused to the low of soil particle density (PD), so that the crop roots developed normally.

The use of PR and SP36 without addition of manures did not affect to soil BD. This condition showed by the soil BD at initial study of 1.5 Mg m^{-3} was relatively fix in the year II and year III (Table 3).

Pore space is that portion of the soil volume which is not occupied by soil solid but by air and/or water. Pore space in soil is of two kinds: the macro pore space which has a diameter of more than 60 mm stores exchangeable air and the micro pore space which has a diameter of less than 30 mm stores capillary water. Physical properties of soil type depend on the size of particles in it. Soil particles occupy roughly more than half the space in the soil. The remaining space between the particles, called the pore space, is occupied by water and air. Total soil pores space is the pores which will be filled by air/oxygen when the soil is in the state of field capacity (pF 2.54% by volume).

The use of manure with PR increased total soil pores from 40.7% by volume to 58.4% by volume in the year III, the availale water and soil permeability also increased by the amounts of 8.6% and 57.9%, respectively in the year III. Application of manure along with SP36 increased total soil pores, available water and soil permeability but it did not increase as high as PR. The different improvement of some soil physical characteristics between PR and SP36 were estimated due to the differences of plant biomass returned back into the soil. The texture, organic matter present in soil, nature of crops cultivated and the soil depth had a great influence over the soil pore space, available water and soil permeability.

The pore size or porosity of soils together with bulk density determines the structure of soils. The stability of soil aggregates depends on the organic matter content of individual soils and the nature of microbial products which binds particles together.

Table 3. Soil physical properties before planting and after harvest in upland rice+maize -/-cassava-mungbean cropping pattern at Tamanbogo Experimental Farm, East Lampung.

Parameter and Treatment	Before Planting (2006)	Year I (2007)	Year II (2008)	Year III (2009)
BD (Mg m^{-3})	1.5			
10 Mg ha^{-1} manure + 1 Mg ha^{-1} PR		1.5	1.2	1.0
Without manure + 1 Mg ha^{-1} PR		1.4	1.4	1.5
10 Mg ha^{-1} manure +100 $kgha^{-1}$ SP36		1.4	1.3	1.0
Without manure +100 kg ha^{-1} SP36		1.5	1.4	1.5
Total Soil Pores (% vol.)	40.7			
10 Mg ha^{-1} manure + 1 Mg ha^{-1} PR		53.7	56.2	58.4
Without manure + 1 Mg ha^{-1} PR		43.4	43.3	43.6
10 Mg ha^{-1} manure +100 kg ha^{-1} SP36		50.8	53.9	54.0
Without manure +100 kg ha^{-1} SP36		42.4	43.6	43.2
Available Water (% vol.)	7.6			
10 Mg ha^{-1} manure + 1 Mg ha^{-1} PR		9.3	9.6	10.1
Without manure + 1 Mg ha^{-1} PR		8.0	8.2	8.8
10 Mg ha^{-1} manure +100 kg ha^{-1} SP36		9.2	9.1	9.8
Without manure +100 kg ha^{-1} SP36		8.0	7.9	8.6
Permeability (cm hr^{-1})	5.7			
10 Mg ha^{-1} manure + 1 Mg ha^{-1} PR		7.5	8.5	9.6
Without manure + 1 Mg ha^{-1} PR		6.4	6.2	6.0
10 Mg ha^{-1} manure +100 kg ha^{-1} SP36		7.3	8.1	9.2
Without manure +100 kg ha^{-1} SP36		6.5	6.3	6.4

Description: + = intercropping, -/- = relay cropping, - = continous cropping.

Crops Yields

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

Application 10 Mg manures ha^{-1} along with 1 Mg PR ha^{-1} had the highest dry grain weight of upland rice and maize significantly in the year I, II and III compared to other treatments. The yield of Limboto upland rice was 1.661 Mg ha^{-1} in the year I (2007), increased to 2.166 Mg ha^{-1} and 2.210 Mg ha^{-1} in the year II and III, respectively, and the yield of maize was higher than other treatments (Table 4). This condition indicated that the use of manure increased soil chemical and physical properties, so that the effectiveness of PR also increased and the yield was higher than without manures. The results indicated that manure increased soluble P in acidic soils (Alloush 2003). The PR and SP36 without application of manure did not show a significantly different of upland rice and maize yield in the year II and III (Table 4). It was due to less improvement of soil physical and chemical properties as shown in Table 2 and 3. Soil characterisation improvement can be detected by taking into account the physical and chemical properties of the soil.

Planting Season II (Mungbean -/-Cassava)

Application of PR along with manure showed significantly higher yields of mungbean in the year II (8% higher) and year III (28% higher) compared to the yield of SP36 with manure. Phosphate rock without manure gave a better yield of mungbean at 42.86% to 88.89% higher than the yield achieved by SP (Table 5).

The growth of cassava that were inserted between holes of maize plants was relatively slow and tended to stagnant and escalated because there were competition of space and light with upland rice and maize.

Tabel 5 indicates that the use of 10 Mg manures ha^{-1} along with PR provided yields of 11.2 Mg ha^{-1} and 12.6 Mg ha^{-1} fresh tuber in the year I and year III. This yield was significantly higher than SP36 with manure as well as SP 36 and PR without manure. The yields of cassava in the treatment of 10 Mg manures ha^{-1} along with PR in the year II

Table 4. The weight of dry grain rice and maize in intercropping of upland rice+maize-/-cassava-mungbean at Tamanbogo Experimental Farm, East Lampung.

Treatment	Dry grain rice (Mg ha^{-1})			Dry grain maize (Mg ha^{-1})		
	Year I (2007)	Year II (2008)	Year III (2009)	Year I (2007)	Year II (2008)	Year I (2009
10 Mg ha^{-1} manure + 1 Mg ha^{-1} PR	1.661 a	2.166 a	2.21 a	3.12 a	4.121 a	2.68 a
Without manure + 1 Mg ha^{-1} PR	1.424 b	1.594 bc	1.53 bc	2.31 b	2.648 b	1.69 b
10 Mg ha^{-1} manure + 100 kg ha^{-1} SP 36	1.296 c	1.722 b	1.96 ab	2.88 a	3.365 b	2.60 a
Without manure + 100 kg ha^{-1} SP 36	1.312 c	1.223 c	1.16 c	1.43 c	1.548 c	1.63 b

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

were relatively similar (11.50 Mg ha^{-1}) to the SP36 with manure (11.42 Mg ha^{-1}).

The effect of PR on soil quality improvement in the year II was varied because cassava did not specially fertilize but they utilized residual nutrients of previous fertilization of upland rice, maize and mungbean. The effect of PR was higher in the year III, such as mention by Chien *et al.* (2010) that the effectiveness of PR was higher for long-term than short-term. 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.

Application of manure and PR in acid upland soil showed significant effects to soil physical and chemical characteristics. Application of manures could improve soil organic C, CEC, and available P, and soil physical characteristic of soil BD, total soil pores space, available water and soil permeability such as showen in Table 2 and 3.

Financial Analysis

Table 6 shows that the management of acid upland soil by using 10 Mg manure ha^{-1} year^{-1} along with PR provided greatest profit in the year I, II and III, that were Rp 8,546,250, Rp 15,077,350 and Rp 19,189,000, respectively. The biggest B/C of 3.66 was gained in the year III.

In many acid soils, soil fertility is a limited factor for crop production. These soils usually are low in plant-available P and often have a high P-fixing capacity that results in low efficiency of water-soluble P fertilizers such as SP36. Application of PR to soil can be an attractive alternative because PR contains Ca and releases P slowly.

Table 5. Mungbean and cassava yields after application of manure and PR fertilizers in upland rice + Maize -/- cassava–mungbean cropping pattern in Tamanbogo Experimental Farm, East Lampung.

Treatment	Weight of dry grain of mungbean (Mg ha$^{-1)}$			Weight of fresh cassava tuber (Mg ha^{-1})		
	Year I (2007)	Year II (2008)	Year III (2009)	Year I (2007)	Year II (2008)	Year III (2009)
10 Mg ha^{-1} manure + 1 Mg ha^{-1} PR	1.00 a	1.08 a	1.28 a	11.20 a	11.500 a	12.600 a
Wthout manure + 1 Mg ha^{-1} PR	0.65 b	0.50 c	0.85 c	9.55 c	10.233 b	10.120 c
10 Mg ha^{-1} manure + 100 kgha^{-1} SP36	0.98 a	1.00 b	1.10 b	10.04 b	11.417 a	11.523 b
Without manure + 100 kg ha^{-1} SP36	0.41 c	0.35 d	0.45 d	9.00 d	10.333 b	9.550 d

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

Table 6. Financial analysis of upland rice+ maize-/-cassava–mungbean cropping pattern at Tamanbogo Experimental Farm, East Lampung.

Treatment	Year I (2007)	Year II (2008)	Year III (2009)
Technology 1			
- Yield values	13,116,250	20,313,350	24,525,000
- Production cost	4,570,000	5,236,000	5,336,000
- Frofit	8,546,250	15,077,350	19,189,000
- B/C	1.87	2.88	3.60
Technology 2			
- Yield values	10,060,000	13,186,300	15,457,000
- Production cost	3,320,000	3,736,000	3,936,000
- Frofit	6,740,000	9,450,300	11,521,000
- B/C	2.03	2.53	2.93
Technology 3			
- Yield values	11,892,000	16,649,800	19,927,200
- Production cost	4,970,000	5,436,000	5,636,000
- Frofit	6,922,000	11,213,800	14,291,200
- B/C	1.39	2.06	2.54
Technology 4			
- Yield values	8,125,000	10,301,700	12,268,000
- Production cost	3,420,000	3,786,000	3,936,000
- Frofit	4,705,000	6,515,700	8,332,000
- B/C	1.38	1.72	2.12

Description: Technology 1=10 Mg ha^{-1} manure + 1 Mg ha^{-1} of RP. Technology 2 = Without manure + 1 Mg ha^{-1} RP. Technology 3 = 10 Mg ha^{-1} manure + 100 kg ha^{-1} SP 36. Technology 4 = Without manure + 100 kg ha^{-1} SP 36. + = intercropping, -/- = relay cropping, - = continuous cropping.

The yield values, profite and B/C ratio of treatments with application of PR, and SP36 along with manure increased with time (Table 6). There are in line with the experimental results reported by Chien (2003) that the Relative Agronomic Effectiveness (RAE) of PR increased from the first bean crop to the third crop grown on soil with a high P-fixing capacity. This is due to (1) the residual effect of P decreased rapidly in the soil with high P-fixing capacity, and (2) slow dissolution of PR in the soil with time. The smallest profit was achieved by using of SP36 without manure. The profit in the year I was Rp4,705,000 with B/C was 1.38. The profit and B/C increased in the year II (Rp6,515,700 with B/C was 1.72), and in the year III (Rp8,332,000 with B/C was 2.12).

CONCLUSIONS

The use of 10 Mg manure ha^{-1} along with PR improved the soil chemical properties (pH, C-organic content, available P, and cation exchange capacity) and soil physical properties (BD, total soil pores, available water and soil permeability) of acidic soil in the year II and year III. Except on soil pH, application of manure with SP36 gave better soil chemical and physical properties than PR treatment without manure.

Manure that was combined with PR gave highest food crops yield. Based on financial analysis showed that the highest benefits and B/C was achieved by the treatment of manure along with PR.

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