

Effect of Poultry Manure and Vertisols Matter on Availability and Leaching of Macronutrients in Coastal Sandy Soil

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ABSTRACT

The poultry manure and vertisols matter have potency for reclaiming a soil. The research objectives was to study the effect of poultry manure (PM) and vertisols matter (VM) on availability and leaching of macro nutrient in coastal sandy soil treated by rainfall simulation. A laboratory experiment was conducted with lysimeters to measure nutrient leaching. The factorial 4×4 treatment applied was arranged by randomized completely block design with three replications. The first factor was level of PM consisted of 0, 20, 40, and 60 Mg ha⁻¹. The second one was the level of VM consisted of 0, 5, 10, and 15%. Variables observed were soil physical and chemical properties such as bulk density (BD), particle density (PD), porosity, pF 2.54, pF 4.2, available water capacity (AWC), permeability, cation exchange capacity (CEC), available macro nutrients (N, P, K, Ca, Mg, and S) by Morgan Wolf extraction, and the rate of macro nutrient leaching measured by Spectrophotometry and Atomic Absorption Spectrophotometry. Result of the research showed that application of PM and VM in the sandy soil decreased soil PD and BD, increased soil porosity and AWC, decreased soil permeability, and slightly increased soil CEC. Application of PM and VM increased soil available nutrient in the sandy soil. Up to 60 Mg ha⁻¹ dose PM increased soil available nutrient, while 10 to 15% dose, VM did not increased it. The rank of nutrient leaching from high to low by rain simulation was $N-NO_3^- > SO_4^{2-} > K^+ > Ca^{2+}$. Leaching of K and $N-NH_4^+$ could be reduced by soil amendment. Combination of PM 60 Mg ha⁻¹ and VM 10% was the best soil amendment for increasing nutrient availability and decreasing nutrient leaching in the sandy soil.

Keywords: available nutrient, coastal sandy soil, leaching, poultry manure, vertisols matter

INTRODUCTION

Indonesia chile pepper production is not stable along the year but it is fluctuative, a chile pepper was rarely found in the rainy season and abundantly found in the dry one. When the production decrease, its price is relatively high so that this gives impact to society life. The chile pepper cultivation, therefore, is needed during the rainy season to keep the production stability along the year with benefit to the farmer and available to the consumer.

The use of coastal sandy soil to cultivate the chile pepper in the rainy season has comparatively superior compared to rice field. In the rainy season, the sandy soil preparation for chile pepper cultivation is easier due to low flooding risk than the rice field. Therefore, farmers prefer to use the rice field to cultivate chile pepper in the rainy

season, so that the rice production will decrease. The main problem for developing horticultural plants in the sandy soil, however, is that the soil physical, chemical, and biological characteristics do not support the growth of the crop.

A fine material content such as dust, clay and organic matter in the sandy soil is less than 1% which causing a highly fast permeability (> 150 cm hr⁻¹), while the water storage ability is very low as only 1.6 - 3% from the available water total (Tim FP-UGM 2002), and nutrient buffer characteristic and water holding capacity are low with CEC 4.0 – 5.0 cmol (+) kg⁻¹ (Tim FP-UGM 2001). Cation exchange capacity (CEC) value of the sandy soil is low causing ability of soil nutrient buffer is very low while water leaching ability is very fast and potentially nutrient intensively leaching during the rainy season is happened.

Excessive rain and irrigation resulted in water flows down through soil profile and leach as soluble nutrient mainly nitrate, sulphate, and boron (FAO

1984). The leaching number and degree of soluble nutrient in the wet tropical soil has very widely range as reflection of various factors controlling the leaching. The potency of soil leaching increases with high annual rain (2,750 mm) and soil effective CEC is low (Dierolf *et al.* 1997). According to Plucknett and Sprague (1989), leaching of nutrient depends on high rainfall as well. Rainfall intensity and application of farmyard manure were the main determinants of K losses by leaching (Alfaro *et al.* 2004).

Based on field observation of Ultisol in Indonesia, a number of K, Ca, and Mg applied through fertilization was accumulated into soil in depth of 30–90 cm as 1, 5, and 24%, respectively; while average of K, Ca and Mg found in soil or crop biomass and possibly leached in soil under 90 cm were 33, 26, and 8%, respectively (Dierolf *et al.* 1997). In Rajasthan loamy sandy soil, loss of soluble water and nutrient was mainly high enough potassium (Majumdar *et al.* 2000). The number of Ca, Mg, and K leached was in the range of 27 and 34%, 29 and 37%, and 8 and 10%, respectively, from initial Ca, Mg, and K content in soil without lime and accumulated in the depth of 1,35 m (Fillery 1999). Applying N rates in excess of standard recommendations increased N leaching by 64, 59, and 32%, respectively for a pepper, tomato, and zucchini crops (Zotarelli *et al.* 2007).

A research on the use of coastal sandy soil marginal land for developing food and horticultural crops has been done, especially in the south coastal of Yogyakarta. Technology of soil amendments application for chile pepper cultivation in the rainy season on coastal sandy soil is not revealed yet. The main aim of this research was to gain a local specific technological package of the chile pepper cultivation in the sandy soil at rainy season. In this stage, the research aimed (1) to study the effect of poultry manure and vertisols matter as soil amendments on the availability and leaching of nutrients in the sandy soil treated by rain simulation, and (2) to find the best combination between the manure and the vertisols matter for applying in the cultivation on the sandy soil at rainy season.

MATERIALS AND METHODS

Simulation and Experimental Designs

The research was carried out by experimental method with simulation experiment of nutrient leaching at the laboratory by using glass tube lysimeters. The research was conducted at the Soil Science Laboratory, Sudirman University, Purwokerto. A completely Randomized Block

Design arranged in a 4 × 4 factorial with three replications was used in this experiment. The first factor was the dosages of poultry manures in which consisted of four levels, *i.e.*, K₀ (without the manure), K₁ (20 Mg ha⁻¹), K₂ (40 Mg ha⁻¹) and K₃ (60 Mg ha⁻¹). The second factors were the dosage of vertisols matter in which consisted of four levels, *i.e.*, L₀ (0%), L₁ (5%), L₂ (10%), and L₃ (15%).

Soils and Manures

The properties of sandy soils used for this study were following: total-N 0.07%, available-N 0.02%, organic carbon 0.53%, total-P 47.6 mg 100g⁻¹, available-P 19.10 ppm, available-K 0.105 cmol kg⁻¹, Ca 34.96 cmol kg⁻¹, Mg 0.718 cmol kg⁻¹, Mg 0.762 cmol kg⁻¹, CEC 20.50 cmol kg⁻¹, and soil pH 6.6. The properties of amendment treatment of Vertisols matter were: total-N 0.065%, available-N 0.01%, organic carbon 0.57%, total-P 159.95 mg 100g⁻¹, available-P 53.03 ppm, available-K 0.068 cmol kg⁻¹, Ca 1.962 cmol kg⁻¹, Mg 0.165 cmol kg⁻¹, Mg 0.733 cmol kg⁻¹, CEC 4.8 cmol kg⁻¹, and soil pH 5.98. The properties of amendment treatment of poultry manure were: total-N 1.74%, available-N 0.16%, organic carbon 9.94%, total-P 3.90 mg 100g⁻¹, available-K 0.0017 cmol kg⁻¹, Ca 0.025 cmol kg⁻¹, Mg 0.0078 cmol kg⁻¹, Mg 0.0003 cmol kg⁻¹, and soil pH 6.6.

Application of Fertilizers

Sandy soils as much as 300 gram was put in the lysimeter in which the soil volume as high as 20 cm-times its bulk density (BD). The soil was fertilized according to the farmer applications, *i.e.*, equal to ZA 25 g, NPK 25 g, KCl 15 g, SP-36 15 g, and Boric 1 g per crop. The use of fertilizer was to know the nutrient status dynamic for the next research for chili pepper cultivation in sandy soils. Variation of the manure and the Vertisols matter combination were given in the sandy soil in lysimeter after two weeks incubation. Water content was maintained around field capacity by watering in the equal number of rain (450 mm with 12 days of rain per month).

Variables observed were particle density (PD), bulk density (BD), porosity, pF 2.54, pF 4.2, available water capacity (AWC), permeability, soil cation exchange capacity (CEC), N, P, K, Ca, Mg, and S contents before and after rain treatment with Morgan Wolf extraction; and nutrient leached (Balai Penelitian Tanah 2005).

Data Analysis

Means were compared by analysis of variance (ANOVA) of data for significance difference ($P <$

0.05). When ANOVA results indicated a significant treatment effect, Duncan test at $P < 0.05$ were used to separate treatment means for all properties.

RESULTS AND DISCUSSION

Characteristic of Soil Physic and Cation Exchange Capacity

Result of laboratory analysis showed that the PD, BD, AWC and permeability of sandy soil used were 2.89 g cm^{-3} , 1.62 g cm^{-3} , 8.7% (low) and 20.8 cm hr^{-1} (fast), respectively. Application of the poultry manure (PM) and the Vertisols matter (VM) in the sandy soil decreased PD and BD, increased soil porosity, increased AWC, and decreased soil permeability (Table 1). However, there was no interaction between PM and VM on each variable. PD and BD had a negative correlation on porosity ($r = -0.62$ and $r = -0.96$, respectively) and AWC ($r = -0.76$ and $r = -0.86$, respectively), but they had positive interaction on permeability. It means that decreasing PD and BD values due to soil amendments application increased porosity and AWC, but they decreased the sandy soil permeability.

Organic matter is one of strong factors in changing soil BD (Ruehlmann and Korschens, 2009). Application of cow manure could increase soil organic matter so it had a negative correlation ($r = -0.87$) or decrease soil PD (Blanco-Canqui *et al.* 2006). Increasing sandy soil organic matter

decreased soil BD and increased AWC (Morlat and Chaussod 2008). Addition of clay sediment as high as 5% into sandy soil could be able to decrease water infiltration velocity, and decreasing of water infiltration will be faster when clay content in the sediment is higher (Al-Omran *et al.* 2004). At the wide scale, soil permeability variation related to clay and soil organic matter (Zekele and Si 2005). Because a very low content of sandy soil fine matter such as dust and clay as well as organic matter addition of many soil amendments were needed. Table 1 shows that PM and VM could affect soil physical characteristic if they were added in the sandy soil at high level, *i.e.*, 40 and 60 Mg ha^{-1} for PM and 10% and 15% for VM.

The sandy soil used had CEC value of $4.8 \text{ cmol (+) kg}^{-1}$. According to Landon (1984), the sandy soil had a very low rate of CEC value. Figure 1 shows that PM and VM increased the CEC of sandy soil, but the average of CEC only increased from very low to low rate. The cation exchange capacity of soils depends on the amount and compositions of clay minerals and soil organic matter (Stewart and Hossner 2001; Kaiser *et al.* 2008).

Soil organic matter has high of specific surface ($800 - 900 \text{ m}^2\text{g}^{-1}$) and CEC ($150 - 300 \text{ cmol kg}^{-1}$) where it is predicted that more than 80% of soil CEC value determined by the organic matter (Stevenson 1982 *in* Sparks 1995). However, addition of PM in the sandy soil until 60 Mg ha^{-1} dosage was not able to increase soil CEC rate. This

Table 1. Physical characteristic of the sandy soil treated with in the poultry manure and the Vertisols matter.

Treatments	PD (g cm^{-3})	BD (g cm^{-3})	Porosity (% vol)	pF 2.54 (% vol)	pF 4.2 (% vol)	AWC (% vol)	Permeability (cm hr^{-1})
Poultry manure (Mg ha^{-1})							
0	2.77 a	1.61 a	42.08 b	16.50 c	7.89 c	8.61 c	16.18 a
20	2.76 a	1.58 b	42.85 b	16.90 c	8.05 bc	8.85 bc	15.68 ab
40	2.75 ab	1.53 c	44.49 a	17.40 b	8.25 ab	9.15 b	14.52 bc
60	2.73 b	1.50 c	44.97 a	18.40 a	8.49 a	9.91 a	14.02 c
CV (%)	1.06	2.09	2.75	3.05	4.10	6.70	12.62
Vertisols matter (%)							
0	2.78 a	1.59 a	43.01 b	16.68 c	7.91 b	8.77 c	18.07 a
5	2.76 ab	1.57 a	43.12 b	16.82 c	8.18 ab	8.63 c	16.52 bc
10	2.75 bc	1.53 b	44.21 a	17.55 b	8.25 a	9.30 b	14.30 c
15	2.72 c	1.52 b	44.04 a	18.16 a	8.34 a	9.82 a	11.51 d
CV (%)	1.06	2.09	2.75	3.05	4.10	6.70	12.62
Interaction	(-)	(-)	(-)	(-)	(-)	(-)	(+)

Note: (-) no interaction, value followed by same word in the same column and treatment group did not significantly different by Duncan test at 5%.

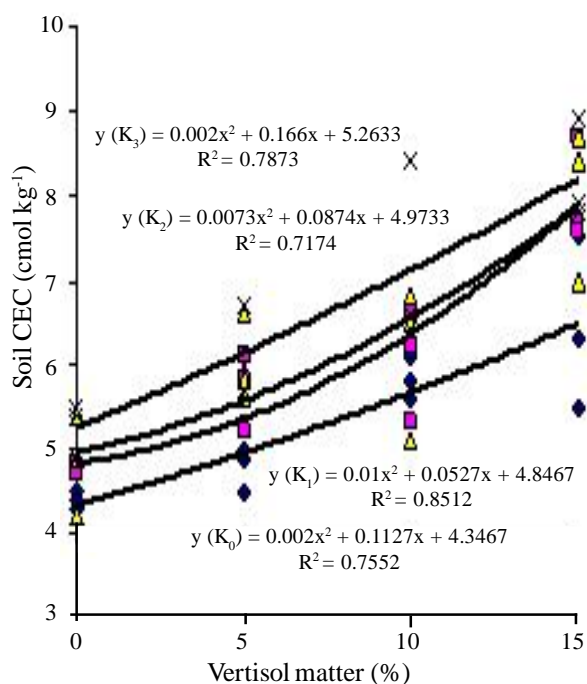


Figure 1. Effect of poultry manure and vertisols matter on soil CEC. \blacklozenge = without manure, \blacktriangle = 20 Mg ha⁻¹ manure, \blacksquare = 40 Mg ha⁻¹ manure, and \times = 60 Mg ha⁻¹ manure.

was due to addition of manure was not perfectly degraded to be humus so it did not play a big role in increasing the sandy soil CEC. Figure 1 shows that VM with dosage up to 15% in every dosage of PM increased the sandy soil CEC quadratically positively. It means that VM with low dosage slightly increased soil CEC. Furthermore, the

the addition of high dosage of VM (more than 15%) could highly increase soil CEC. Vertisols is soil in which clay fraction is dominated by monmorillonite, which has CEC of 80 – 100 cmol kg⁻¹ at pH 7.0 (Landon 1984). Thus the addition of vertisol matter with high dosage into the sandy soil could increase soil CEC.

Soil Nutrient Content

The PM and VM could increase N-NO₃⁻, P, K, Ca, Mg, and SO₄⁼ contents of soil which were available for crops growth in the soil but they did not affect soil N-NH₄⁺ content (Table 2). The higher PM and VM level added, the bigger soil nutrient content. Furthermore there was an interaction between PM and VM on soil K, Ca, Mg, and SO₄⁼ content.

Increasing soil nutrient content was either from PM or VM application. Besides as negative charge sources, PM could also increase soil nutrient contents that become available for crops growth. Organic acids resulted from PM decomposition could increase soil soluble phosphate and micronutrient so that they could be available for crop growth (FAO 1984). Compost in soil increases P availability, soluble salt, and decreases toxic elements (Bar-Tal *et al.* 2004). Organic matter (OM) is responsible for increasing soil P phytoavailability when P fertilizer and OM are applied together (Guppy *et al.* 2005). After application of the chicken manure in the soil, hydrolyzation,

Table 2. Soil nutrient content at the poultry manure and the vertisols matter treatments after 14 days incubation.

Treatments	Macronutrient content (mg kg ⁻¹)						
	N-NH ₄ ⁺	N-NO ₃ ⁻	P	K	Ca	Mg	SO ₄ ⁼
Poultry manure (Mg ha ⁻¹)							
0	12.75 a	36.51 c	15.57 d	113.20 d	124.86 d	17.50 d	245.37 d
20	13.59 a	40.03 b	19.74 c	189.42 c	173.22 c	33.98 c	280.20 c
40	13.63 a	43.65 a	23.83 b	255.89 b	196.74 b	45.83 b	294.66 b
60	14.63 a	45.68 a	32.91 a	297.66 a	229.66 a	56.67 a	312.75 a
CV (%)	13.60	6.94	8.69	2.99	3.54	3.52	2.94
Vertisols matter (%)							
0	12.95 a	39.42 c	21.53 c	172.26 d	141.47 d	33.32 d	250.33 d
5	13.93 a	40.35 bc	22.36 bc	195.61 c	167.53 c	37.15 c	277.05 c
10	14.13 a	42.19 ab	23.55 ab	233.50 b	199.75 b	40.74 b	292.63 b
15	13.59 a	43.90 a	24.61 a	254.80 a	215.74 a	42.78 a	312.97 a
CV (%)	13.60	6.94	8.69	2.99	3.54	3.52	2.94
Interaction	(-)	(-)	(-)	(+)	(+)	(+)	(+)

Note: (-/+) no/with interaction, value followed by same word in the same column and treatment group did not significantly different according to Duncan test for 5%.

mineralization, and nitrification were taking place fast, accumulation of N-NO₃⁻ maximum was reached after incubation for 14 days (Diaz *et al.* 2008). Table 2 shows that available N was more in the form of N-NO₃⁻ than N-NH₄⁺. According to Uebler (1984), changing N-NH₄⁺ into N-NO₃⁻ is increased by soil amendments as a result of increasing soil aeration. Data analyses showed that there was significant correlation (r = 0.96) between soil porosity and N-NO₃⁻ resulted from addition of PM and VM in the soil.

Beside as nutrient source in soil, PM and VM were also as soil organic and anorganic colloid, so that they could also increase both soil available nutrient as well as its nutrient adsorption capability. Nutrient in soil is adsorped by soil colloids in the form of cation (NH₄⁺, K⁺, Ca²⁺, Mg²⁺) and anion (NO₃⁻, SO₄⁼, PO₄⁼). Table 2 shows that increasing of soil nutrient content by PM treatment was higher than VM treatment. This showed that the role of PM was higher than VM in the soil in case of nutrient availability. Beside as nutrient source, PM has also a role as fertilizer salt solvent and as buffer of available nutrient in the soil. Soluble potassium accumulation in soil was equal to number of manures added (Pratt and Laag 1977). The manure increased soil available K and P (Meek *et al.* 1982). K in manure was mainly found as soluble anorganic K so that it could supply available K for crop growth (Havlin *et al.* 2005).

In soil with organic matter as the main content component variable, Ca was adsorped through ligan exchange mechanisms (Bolan *et al.* 1993), so that

the high available Ca was equal to addition of organic matter. Adsorption of Ca will increase adsorption of SO₄⁼ if they are added together where Ca and SO₄⁼ are adsorped through ion pair adsorption mechanism (Chicota *et al.* 2007). One of factors affecting adsorption of SO₄⁼ in soil is organic matter; thus increasing the organic matter content in soil will increase the adsorption potency of SO₄⁼ (Havlin *et al.* 2005).

Table 2 shows that the higher application of PM and VM, the higher soil nutrient content. There was an interaction effect on soil K, Ca, Mg, and SO₄⁼ content, at application of the highest PM dose (60 Mg ha⁻¹), but addition of high VM dose (from 10% to 15%) did not affect them significantly. In the sandy soil, the role of PM in increasing soil available nutrient and CEC was higher than VM. Sparks (1995) reported that at sandy soil (*Psamment* with CEC 5.26), the contribution of organic matter on the soil CEC was 74.9%, while it was only 25 % at clay soil.

Soil Nutrient Content After Leaching

Table 3 shows that PM and VM increased soil nutrient content in leached soil. The higher application of PM dosages, the higher soil N-NH₄⁺, P, K, Ca and Mg content, while the higher application of VM, the higher soil N-NH₄⁺, K, Ca and SO₄⁼ content. There was an interaction effect between PM and VM on soil NH₄⁺, K, and Ca content at the highest PM dose (60 Mg ha⁻¹), while application of VM (10% to 15%) did not affect them significantly.

Table 3. Soil nutrient content after leaching at the poultry manure and vertisols matter treatments.

Treatments	Macronutrient content (mg kg ⁻¹)						
	N-NH ₄ ⁺	N-NO ₃ ⁻	P	K	Ca	Mg	SO ₄ ⁼
Poultry manure (Mg ha ⁻¹)							
0	14.92 d	9.84 c	17.31 d	109.40 d	76.89 d	12.04 d	121.97 c
20	16.37 c	10.91 b	22.30 c	150.33 c	101.58 c	23.48 c	135.31 b
40	17.66 b	11.58 ab	29.07 b	203.32 b	115.41 b	29.90 b	140.66 a
60	20.55 a	11.71 a	36.94 a	217.19 a	127.15 a	37.03 a	149.75 a
CV (%)	8.83	8.26	7.62	6.08	3.52	7.34	4.66
Vertisols matter (%)							
0	9.89 d	11.30 a	24.18 c	107.98 d	89.52 d	22.60 b	121.05 d
5	12.92 c	10.74 a	25.82 bc	138.76 c	99.74 c	24.99 b	132.10 c
10	21.28 b	11.05 a	27.17 ab	201.26 b	114.22 b	26.79 a	143.54 b
15	25.43 a	10.94 a	28.44 a	232.25 a	117.54 a	28.06 a	150.99 a
CV (%)	8.83	8.26	7.62	6.08	3.52	7.34	4.66
Interaction	(+)	(-)	(-)	(+)	(+)	(-)	(-)

Note: (-/+) no/with interaction, value followed by same word in the same column and treatment group did not significantly different according to Duncan test for 5%.

Available nutrient in soil is in the form of soil solution (intensity) and adsorbed by soil colloid (quantity). In the form of soil solution, the available nutrient will easily be moved either by leaching or crops uptake, while adsorbed nutrient will be released to the soil solution so that the balance of intensity and quantity will be happened. Sandy soil that has low nutrient buffer capacity is in the form of solution so that the nutrient is easier to loss by leaching. Soil buffer capacity increases with increasing CEC, clay, organic matter, and other solid elements in soil (Havlin *et al.* 2005).

Nutrient Content in Leachate Water

Total available nutrient after 14 days incubation did not reflect total available nutrient resulted from PM and VM treatments because during leaching process, solubility of anorganic fertilizer and PM hydrolysis were still going on. Total available nutrient resulted from PM and VM treatments was the number of adsorbed and leached nutrient. Therefore, to know the role of PM and VM application on nutrition leaching, it could be seen from percentages of leaching nutrient. It was formulated as leached nutrient divided by sum of adsorbed and leached nutrient. The adsorbed nutrient was predicted with the soil nutrient concentration extracted by Morgan Wolf, while the leached nutrient was predicted with the concentration of nutrient in leached water. Table 4 shows that the application of PM increased percentage of leaching nutrient except N-NH₄⁺. The

application of VM decreased percentage of leaching N-NH₄⁺, P, and K but increased percentage of leaching N-NO₃⁻, Ca, Mg, and SO₄⁻. Nutrient in form anion and cation in soil solution are adsorped by colloid surface in the outer-sphere and inner-sphere complexes. Adsorped form at outer-sphere complexes could be inversed while at inner-sphere complexes could not (Sparks 1995) so the adsorped nutrient at outer-sphere complexe was easier to be available in soil solution. In clay mineral type 2 : 1, K is adsorped at inner-sphere complexe, while Ca is at outer-sphere complexe (Sposito 1984 *in* Sparks 1995). Sulphate is adsorped at out-sphere complexe, while P is at inner-sphere complexes and NO₃⁻ in outer-sphere complexes (Sparks 1995). Therefore, in the sandy soil with low nutrient buffering capacity, Ca, SO₄⁻, and N-NO₃⁻ are easily leached so that it need soil amendmets matter. Leaching percentages of P and K increased with the application of PM shows that the PM plays an important role in dissolving fertilizer more than increasing buffer capacity of P and K. Phosphorus leaching from manure application on soils does not pose environmental concerns as long as soil P levels remain below the saturation level (Van-Es *et al.* 2004).

Anorganic soil amendmets decreased leaching of NH₄⁺ due to increasing of soil CEC. On the other hand, leaching of NO₃⁻ is constantly high either with or without soil amendment treatments (Bigelow *et al.* 2001). The anorganic soil amendment (gypsum) increases adsorption of P and decreases soluble P that depend on added soil

Table 4. Percentage of leached nutrient in sandy soil at poultry manure and vertisols matter treatments.

Treatments	Leached macronutrient (%)						
	N-NH ₄ ⁺	N-NO ₃ ⁻	P	K	Ca	Mg	SO ₄ ⁻
Poultry manure (Mg ha ⁻¹)							
0	14.00 a	73.86 b	2.18 c	24.24 c	44.24 b	32.14 c	53.77 c
20	13.51 a	74.80 b	6.49 b	28.21 b	44.55 b	34.73 b	54.25 bc
40	14.30 a	74.65 b	10.39 a	29.65 ab	45.16 b	36.09 ab	55.14 ab
60	14.91 a	76.12 a	10.55 a	31.44 a	46.94 a	36.97 a	55.35 a
CV (%)	17.80	2.03	20.54	11.66	2.90	4.68	2.40
Vertisols matter (%)							
L ₀	23.30 a	73.65 b	11.88 a	42.13 a	41.52 c	32.65 c	53.05 b
L ₁	17.33 b	75.03 a	8.32 b	32.81 b	44.38 b	34.43 bc	54.61 a
L ₂	9.02 c	75.15 a	5.09 c	22.20 c	47.03 a	36.07 ab	55.29 a
L ₃	7.07 c	75.61 a	4.33 c	16.40 d	47.96 a	36.79 a	55.55 a
CV (%)	17.80	2.03	20.54	11.66	2.90	4.68	2.40
Interaction	(-)	(-)	(+)	(+)	(-)	(-)	(-)

Note: (-/+) no/with interaction, value followed by same word in the same column and treatment group did not significantly different according to Duncan test for 5%.

amendment level (Coale *et al.* 1994). The highest retention of K is in soil containing monmorillonite and the smallest is in soil derived from volcanic dust (Bower 1975).

Based on Table 4, it could be known that nutrient relatively became problem in the sandy soil at rainy season was N-NO₃⁻, SO₄⁼, K, and Ca. Those leaching nutrients were relatively high at control which were 72.56, 52.1, 42.63, and 41.65%, respectively. Leaching of K could be minimized by soil amendments treatment, while leaching of N could be decrease by the amendment if it was in the N-NH₄⁺ form. Based on this observation, PM dose up to 60 Mg ha⁻¹ still increased nutrient adsorption in the sandy soil, while high dose of PM (10% to 15%) did not relatively give different effect on the adsorption. Therefore, the use of soil amendments with 60 Mg ha⁻¹ of PM and 10% of VM increased both availability of nutrient and decreased leaching of nutrient in the soil.

CONCLUSIONS

Application of poultry manure and vertisols matter in the sandy soil decreased soil particle density and bulk density, increased soil porosity and available water capacity, decreased soil permeability, and slightly increased soil CEC.

Application of poultry manure and vertisols matter increased soil available nutrient in the sandy soil. Up to 60 Mg ha⁻¹ dose, poultry manure increased soil available nutrient, while 10 to 15% dose, vertisols matter did not increase it.

The rank of leached nutrient from high to low by rain simulation was N-NO₃⁻ > SO₄⁼ > K > Ca. Leaching of K and N-NH₄⁺ could be reduced by soil amendment treatment.

Combination of poultry manure 60 Mg ha⁻¹ and vertisols matter 10% was the best soil amendment treatment for increasing nutrient availability and decreasing nutrient leaching in the sandy soil.

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REFERENCES

- Alfaro MA, PJ Gregory and SC Jarvis. 2004. Dynamic of potassium leaching on a hillslope grassland soil. *J Environ Qual* 33(1): 192-200.
- Al-Omran AM, AM Falatah, AS Sheta and AR Al-Harbi. 2004. Clay deposits for water management of sandy soils. *Arid Land Res Manag* 18: 171-183.
- Balai Penelitian Tanah. 2005. *Analisis Kimia Tanah, Tanaman, Air dan Pupuk*. Balai Penelitian Tanah, Badan Penelitian dan Pengembangan Pertanian Departemen Pertanian, Bogor. 136 p (in Indonesian).
- Bar-Tal A, U Yermiyahu, J Beraud, M Keinan, R Rosenberg, D Zobar, V Rosen and P Vine. 2004. Nitrogen, phosphorus, and potassium uptake by wheat and their distribution in soil following successive, annual compost applications. *J Environ Qual* 33:1855-1865.
- Bigelow CA, DC Bowman and DK Cassel. 2001. Nitrogen leaching in sand-based rootzones amended with inorganik soil amendment and sphagnum peat. *J Am Soc Hort Sci* 126: 151-156.
- Blanco-Canqui H, R Lal, WM Post, RC Izaurralde and MJ Shipitalo. 2006. Organik carbon influences on soil particle density and rheological properties. *Soil Sci Soc Am J* 70: 1407-1414.
- Bolan NS, JK Syers and ME Sumner. 1993. Calcium-induced sulfate adsorption by soils. *Soil Sci Soc Am J* 57: 691-696.
- Bower CA. 1975. Leaching of absorbed potassium from humid tropical soils. *Soil Sci Soc Am J* 39: 594-596.
- Cichota R, I Vogeler, NS Bolan and BE Clothier. 2007. Simultaneous adsorption of calcium and sulfate and its effect on their movement. *Soil Sci Soc Am J* 71: 703-710.
- Coale FJ, PS Porter and W Davis. 1994. Soil amendments for reducing phosphorus concentration of drainage water from histosols. *Soil Sci Soc Am J* 58: 1470-475.
- Diaz DAR, JE Sawyer and AP Mallarino. 2008. Poultry manure supply of potentially nitrogen with soil incubation. *Agron J* 100: 1310-1317.
- Dierolf TS, LM Arya and RS Yost. 1997. Water and cation movement in an Indonesian Ultisol. *Agron J* 89: 572-579.
- FAO [Food and Agriculture Organization]. 1984. *Fertilizer and Plant Nutrient Guide*. United Nation, Rome. 176 p
- Fillery IRP. 1999. Monitoring water and nutrient fluxes down the profile: closing the nutrient budget. In: Z Rengel (ed). *Mineral Nutrient of Crops*, Food Product Press, New York, pp. 289-325.
- Guppy CN, NW Menzies, FPC Blamey and PW Moody. 2005. Do decomposing organic matter residues reduce phosphorus sorption in highly weathered soils?. *Soil Sci Soc Am J* 69 (5): 1405-1411.
- Havlin JL, JD Beaton, SL Tisdale and WL Nelson. 2005. *Soil Fertility and Fertilizers. An Introduction to Nutrient Management*. Pearson Education, Inc., Upper Saddle River, New Jersey. 515 p.

- Kaiser M, RH Ellerbrock and HH Gerke. 2008. Cation exchange capacity and composition of soluble soil organic matter fractions. *Soil Sci Soc Am J* 72 (5): 1278-1285.
- Landon JR. 1984. Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Booker Agriculture International Limited. 450 p.
- Majumdar SP, RL Meena and GDS Baghel. 2000. Effect of levels of compaction and potassium on yield and quality of tomato and chilli crops grown on highly permeable soils. *J Indian Soc Soil Sci* 48(2): 215-220.
- Meek B, L Graham and T Donovan. 1982. Long-term effects of manure on soil nitrogen, phosphorus, potassium, sodium, organic matter, and water infiltration rate. *Soil Sci Soc Am J* 46: 1014-1019.
- Morlat R and R Chaussod. 2008. Long-term additions of organic amendments in a loire valley vineyard. I. effects on properties of a calcareous sandy soil. *Am J Enol Vitic* 59 (4): 353-363.
- Plucknett DL and HB Sprague. 1989. *Detecting Mineral Nutrient Deficiencies in Tropical and Temperate Crops*. Westview Press, Boulder, San Francisco, London. 553 p.
- Pratt PF and AE Laag. 1977. Potassium accumulation and movement in an irrigated soil treated with animal manures. *Soil Sci Soc Am J* 41: 1130-1133.
- Ruehlmann J and M Korchens. 2009. Calculating the effect of soil organic matter concentration on soil bulk density. *Soil Sci Soc Am J* 73: 876-885.
- Sparks DL. 1995. *Environmental Soil Chemistry*. Academic Press. San Diego California. 267 p.
- Stewart WM and LR Hossner. 2001. Factors affecting the ratio of cation exchange capacity to clay content in lignite overburden. *J. Enviro. Qual.* 30 (4) : 1143 - 1149
- Tim FP-UGM. 2001. Penyiapan Design Model Kerjasama dengan Fakultas Pertanian UGM dalam Rangka Kegiatan Model Pengembangan Lahan Pantai. Dinas Pertanian Tanaman Pangan Prop. DIY, Tim FP-UGM, Yogyakarta. 122 p (in Indonesian).
- Tim FP-UGM. 2002. Aplikasi Unit Percontohan Agribisnis Terpadu di Lahan Pantai. Propinsi DIY Kerjasama FP-UGM dengan Dinas Pertanian Tanaman Pangan Prop. DIY, Tim FP-UGM, Yogyakarta. 118 p (in Indonesian).
- Uebler RL. 1984. Effect of loading rate and soil amendments on inorganik nitrogen and phosphorus leached from a wastewater soil absorption system. *J Environ Qual* 13: 475-479.
- Van-Es HM, RR Schindelbeck and WF Jokela. 2004. Effect of manure application timing, crop, and soil type on phosphorus leaching. *J Environ Qual* 33 (3): 1070-1080.
- Zekele T and BC Si. 2005. Scaling relationships between saturated hydraulic conductivity and soil physical properties. *Soil Sci Soc Am J* 69: 1691-1702.
- Zotarelli L, JM Scholberg, MD Dukes and R Munoz-Carpena. 2007. Monitoring of nitrate leaching in sandy soils. *J Environ Qual* 36 (4): 953-962.