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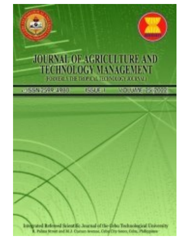

Original article

Chicken manure application and liming enhanced the soil chemical properties of andisols

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ABSTRACT

The availability of P (Phosphorus) is a major problem in Andisols due to its high P-fixing capacity. Improving the very low P availability is among the challenges in managing Andisols. This study was conducted to determine the timing of lime application in acidic Andisols and to assess the influence of chicken manure application on the availability of P. The experiment was laid out in a split-plot randomized complete block design (RCBD) with eight (8) treatments: main plot (L0 – with lime and L1 – without lime); subplot (T0 – control; T1 - 200-150-100 kg ha^{-1} N, P_2O_5, K_2O, T2 – 5 t ha^{-1} chicken manure, T3 – 7.5 t ha^{-1} chicken manure, T4 – 12 t ha-1 chicken manure, T5 – 100-75-50 kg ha^{-1} N, P_2O_5, K_2O + 5 t ha^{-1} chicken manure, T6 – 100-75-50 kg ha^{-1} N, P_2O_5, K_2O + 7.5 t ha^{-1} chicken manure, and T7 – 100-75-50 kg ha^{-1} N, P_2O_5, K_2O + 12 t ha^{-1} chicken manure).

Results showed that the sole application of chicken manure or combined with inorganic fertilizers significantly improved the total N, and available P, and lowered the amount of exchangeable Aluminum (Al) and acidity of the soil compared to control. The highest increase in soil available P was observed in T4 (12 t ha-1 chicken manure). Moreover, liming and chicken manure application significantly improved soil pH and decreased exchangeable Al and acidity of Andisols, which facilitates the availability of nutrients.

KEYWORDS: *Andisols, chicken manure, lime, P-fixing capacity, sweet pepper*

1 INTRODUCTION

The Andisols are the least extensive soil order, which account for less than 1% of the ice-free land area on Earth. They are loose, friable, and often rich in nutrients and support a wide variety of production systems (Perret and Dorel, 1999). However, if crops are planted in newly reclaimed Andisols, this may show inferior growth, which is due to the very high P-fixing capacity of the soil (Nanzyo, 2002). The high reactivity of phosphate to secondary minerals such as imogolite and allophane causes the unavailability of P (Wada, 1989). This will affect crop yield. Hence, it is essential to implement plant nutrient management practices to increase agricultural productivity and ensure food security for the population (FAO et al., 2013; Sanchez, 2010). The findings of Ch'ng et al. (2014) suggest that the use of organic amendments altered the soil chemical properties where it enhanced the P availability and effectively fixed the Al and Iron (Fe) instead of P. However, improper application of these amendments without knowing the nutrient status of the soil can also cause a major problem to crop production especially in Andisols which is a very porous soil. Furthermore, due to the acidic pH of Andisols, the application of chicken manure alone does not suffice the neutralization of its pH. Thus, amending it with lime is necessary. However, the timing of lime application is very critical due to the secondary minerals present in Andisols (Wada, 1989). Thus, this study was conducted to determine the effective incubation time of lime application in acidic Andisols and to assess the influence of chicken manure and lime application on the changes of some chemical properties and availability of P in Andisols.

2 MATERIALS AND METHODS

Soil Sample Collection and Preparation

Bulk soil surface samples (0-20 cm) were taken from Barangay Cabintan, Ormoc City, Leyte (11o 04.777' N 124o 43.492 E). The area is usually planted with fruit-bearing and leafy vegetables (Brassica oleracea var. capitate, Brassica rapa subsp. Cheninsis, Allium ampeloprasum var. porrum, Lycopersicon esculentum L. and Capsicum annum) which are Andisols. The samples were brought to the screen house for air-drying. Samples were spread and freed from stones and plant roots. After air-drying (2-3 days), the soil was pulverized and sieved using a four (4) mm wire screen to remove further big soil

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clods and become ready for potting. About one (1) kg soil sample was set aside and sieved through a two (2) mm wire mesh for the determination of the initial soil chemical and physical properties. For organic matter determination, soil samples were passed through a 0.425-mm wire mesh. Initial soil samples were analyzed for the following soil parameters: Soil pH was determined potentiometrically using distilled water at a soil-solution ratio of 1:25 (ISRIC, 1995); organic matter (OM) using modified Walkley-Black (Nelson and Sommer, 1982); total N using the Micro-Kjeldahl method (ISRIC, 1995); available P was extracted using the Bray No. 2 method of Jackson (1958) and Murphy and Riley (1962) for color development and quantified by measuring the percent absorbance at 880 nm using spectronic 20; cation exchange capacity (CEC) using 1 N NH4OAc at pH 7 (ISRIC, 1995) and quantified using atomic absorption spectrophotometry (AAS); exchangeable Al and Acidity were extracted using KCl and quantified by titrating the resulting extract with 0.1 N NaOH (Thomas, 1982); extractable Cu and Zn were measured using 0.1 N dilute HCl method by Nelson et al. (1959); exchangeable potassium (K) was extracted using 1 N NH4OAc at pH 7 (ISRIC, 1995); exchangeable K, extractable Cu and Zn were quantified using atomic absorption spectrophotometer and soil texture determination was done using Pipette method (ISRIC, 1995). Soil analyses were carried out at Central Analytical Soil Laboratory and at the Department of Soil Science, VSU, Baybay City, Leyte. The rest of the bulk samples were prepared for the pot experiment using two (2) levels of lime (without and with lime) and eight (8) treatments with varying levels of chicken manure and inorganic fertilizers. Chemical analysis of chicken manure was also done to determine total N, P, K, Cu, and Zn. Pots were grown with sweet pepper (Capsicum annuum L.). At the final harvest, the soil sample in each pot was analyzed for pH, OM, Total N, available P, and exchangeable Al and Acidity.

Experimental Design and Layout

The experimental set-up was laid out in a split-plot Randomized Complete Block Design (RCBD) with three (3) replications. There were two pots in each treatment/replication. The main plot was the liming, and the subplot was the fertilizer treatments. The treatments were as follows:

Main Plot
L0 – with lime
L1 – without lime
Subplot
T0 – control
T1 – 200-150-100 kg ha^{-1} N, P_2O_5, K_2O
T2 – 5 t ha^{-1} chicken manure
T3 – 7.5 t ha^{-1} chicken manure
T4 – 12 t ha^{-1} chicken manure
T5 – 100-75-50 kg ha^{-1}N, P_2O_5, K_2O + 5 t ha^{-1} chicken manure
T6 – 100-75-50 kg ha-1N, P2O5, K2O + 7.5 t ha-1 chicken manure
T7 – 100-75-50 kg ha-1N, P2O5, K2O + 12 t ha-1 chicken manure

Statistical Analysis

Results were analyzed using the Statistical Tool for Agricultural Research (STAR v. 2.0.1) computer program. Each parameter was tested for differences using analysis of variance (ANOVA), and a comparison of means was tested using Tukey's Honest Significant Difference (HSD) Test at 5% level of significance.

3 RESULTS AND DISCUSSION

Soil Chemical Properties

Initial soil analysis (Table 1) showed that the soil used was strongly acidic and had a low amount of organic matter (OM), a very low amount of available P, exchangeable K, and also the micronutrients, especially Cu and Zn (Landon, 1991; Pantastico, 1973). Andisols has a very low amount of available P due to its high capacity to retain this nutrient (Quantin, 1986; Nanzyo, 2002). Results exhibited a P-fixing of 97.44 % in Andisols soil used. Furthermore, with the very low amount of exchangeable K and extractable Cu and Zn, crops grown in this type of soil will show inferior growth and can be corrected through the application of fertilizers or other nutrients to sustain the growth of crops.

Table I. Initial chemical properties of the Andisols soil in Cabintan, Ormoc City

Property	Value	Critical Value (Landon, 1991; Pantastico, 1973)
pH (1:2.5 soil to H_2O)	5.08	<6.50 - >7.40)
Exchangeable Al (cmol/kg soil)	1.10	
Exchangeable Acidity (cmol/kg soil)	1.17	
OM (%)	5.68	>10.00
Total N (%)	0.35	<0.10 - >0.50
Available P (mg kg^{-1} soil)	2.20	<5.00 - >50.00
Exchangeable K (meq100 g^{-1} soil)	0.038	<0.15 - >0.50
Cation Exchange Capacity (CEC) (cmol/kg)	33.82	<10.00 - >20.00
Extractable micronutrients (mg/kg)		
Copper (Cu)	0.36	<1.00 - >14.00
Zinc (Zn)	0.10	<0.50 - >4.81

On the other hand, the low exchangeable K content in the soil was manifested in the bronzing condition of sweet pepper leaves, which was followed by necrosis and leaf drop (Ozaki and Hamilton, 1954; Miller, 1961). Furthermore, the application of different levels of chicken manure did not enhance the K content of the soil, which was still deficient. Based on the results, the chicken

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manure used in the experiment does not have enough K to supply the needs of the crops (Table 2).

Table 2. Chemical Properties of Chicken Manure

Property	Value
Total N (%)	3.12
Total P (%)	6.6
Total K (%)	0.00118
Total micronutrients (%)	
Copper (Cu)	28.25
Zinc (Zn)	1574.08

Potassium does not form any vital organic compounds in the plant. However, its presence is vital for plant growth because it is known to be an enzyme activator that promotes metabolism. In addition, the quality of fruits and vegetables will also improve (Lester et al., 2010; Ganeshamurthy et al., 2011). Therefore, without this nutrient element, it will result in stunted growth and reduce the size of fruits and the quantity of their production. The initial application of K in Andisols grown with sweet pepper provided the crop requirement of the plant

Lime Requirement and Its Application

Soil pH, on the other hand, after the application of lime and incubation for seven days, was significantly higher compared to soil without lime application (Figure 1). Results of the incubation experiments showed that with a higher level of lime T3 (18 t ha^{-1} of CaCO3), its neutralizing effect is much faster compared to T1 and T2 (5 t ha^{-1} and 12 ha^{-1} CaCO3), respectively. However, after seven days of incubation, T2 already reached 6.50 pH, which was the objective of the experiment. The additional cost incurred of lime application is mostly taken for granted by the farmers in Cabintan, Ormoc City. Most farmers apply lime during planting. Hence, its full benefits were not observed, especially that P-containing fertilizers were applied at planting. In this study, after seven days of application of dolomite at the rate of 12 t ha^{-1}, the soil pH of 6.50 was attained).

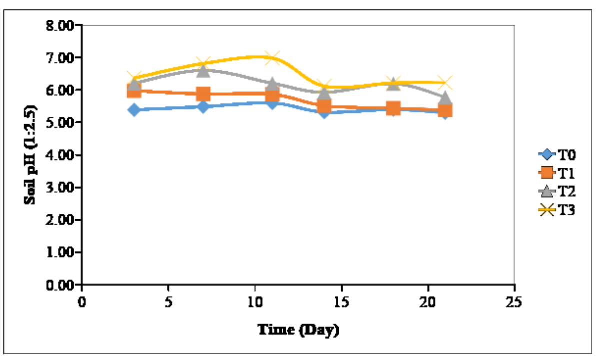

Figure 1. Changes in soil pH with time following addition of different CaCO3 rates

Legend:

T0 – control　　T2 – 12 t ha^{-1} CaCO3

T1 – 5 t ha-^{1} CaCO3　　T3 – 18 t ha^{-1} CaCO3

Results of the experiment showed that the application of pure chicken manure at all levels resulted in significantly higher soil pH compared to the treatments applied with combined chicken manure and inorganic fertilizers across lime and without lime (Figure 2). However, inorganic fertilizer alone (T1) and combined chicken manure (5 t ha^{-1}) and inorganic fertilizer (T5) treatments significantly showed lower pH compared to the control. This can be associated with the conversion of ammonium to nitrates from the NH_4^+ fertilizer source which causes acidification of the soil. Through soil microbiological action, nitrogen is oxidized, and hydrogen ions are generated (González et al., 2016). On the other hand, within the limed treatments, significant increases were observed in all treatments compared to without lime treatments. Lime contains basic elements such Ca or Mg which can increase soil pH. Liming raises the pH of the soil when net negative charges on soil surfaces are increased, thus resulting in an increase in the ratio of negative to positive charges (Sime, 2001; Espinosa, 2003). It reduces Al^{3+} and H^+ in the acid soil to form Al $(OH)_3$ and H_2O. The precipitation of Al^{3+} and H+ by the lime causes the pH to increase which facilitates nutrient availability (Onwonga et al., 2008). Moreover, it also declines the Al^{3+} activity as Al precipitates as hydroxyl-al polymers, and as a result, repulsive forces between particles dominate and lead to dispersion (Haynes and Naidu, 1998).

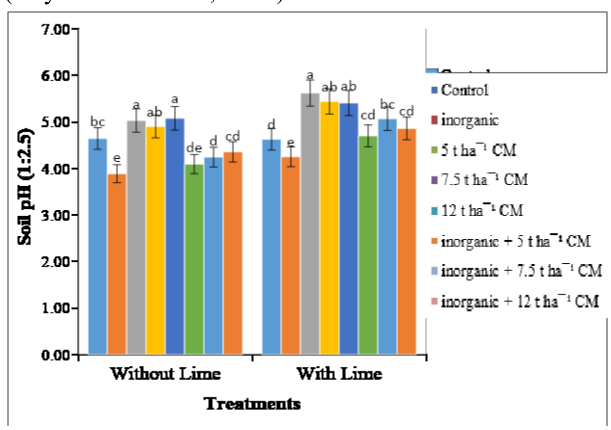

Figure 2. Soil pH as influenced by chicken manure (CM) and lime application on sweet pepper grown in Andisols

The soil organic matter (SOM) of Andisols was low (5.68 %) according to Landon, (1991), which could indicate that nutrients present in this soil are also low. Those treatments applied with lime and chicken manure have significantly higher SOM than those treatments without lime application (Figure 3). Application of lime significantly increases SOM than those without lime. Liming and application of organic fertilizer improved the biomass of sweet pepper, especially the root of sweet pepper that has accumulated in the soil. Lime contains carbonates that will be hydrolyzed and released hydroxyl ions, which increase soil pH and significantly increase

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available P (Antoniadis et al., 2015). However, with different treatments without lime group, there was no significant difference observed in SOM, which means that sole or combined application of chicken manure and inorganic fertilizer application did not significantly affect the SOM content but only in those treatments within the limed soil. Although numerous studies have shown that large increases in soil organic matter content can be achieved by adding organic manures and wastes to soils (Khaleel et al., 1981; Lal and Kang, 1982; Sanchez et al., 1989), in Andisols with initially high OM content. However, further increase on this parameter was not observed across treatments.

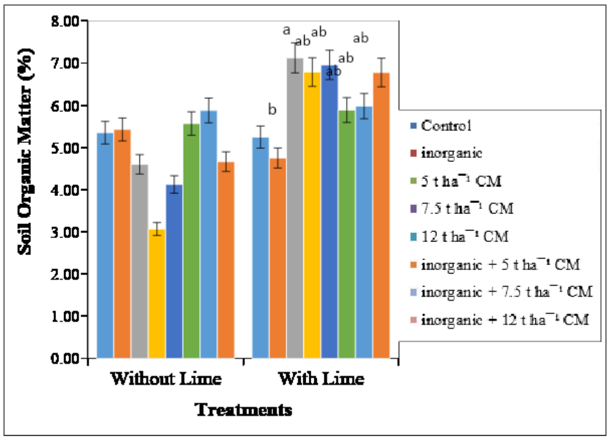

Figure 3. Soil Organic Matter as influenced by chicken manure (CM) and lime application on sweet pepper grown in Andisols

N is required in high amounts for most plants, including sweet pepper, and is also one of the most limiting nutrients in the soil. This element is abundant in the atmosphere as N_2 gas, but this form is not readily available for plant uptake. It needs to be converted into NH_4^+ or NO_3^- first through the process of biological or industrial N-fixation. Organic material such as chicken manure is a good source of N among the other organic materials. Thus, the application of chicken manure can enhance the availability of N in the soil and can be used by plants to complete their growth cycle. Results of the present study showed no significant difference between lime and without lime (Figure 4) in some of the treatments. However, a significant interaction was noted between lime and the different treatments. The application of fertilizers, either inorganic or chicken manure, significantly improved the total N in the soil compared to treatments without fertilizer (T0). Split application of urea fertilizer was done in which the first application was during the transplanting and then applied three times thereafter, every after the harvest. This resulted in a higher amount of N, especially in those treatments with inorganic fertilizer compared to control. Liming and application of organic fertilizer improved the biomass of sweet pepper, and thus, showed a significant effect on the SOM.

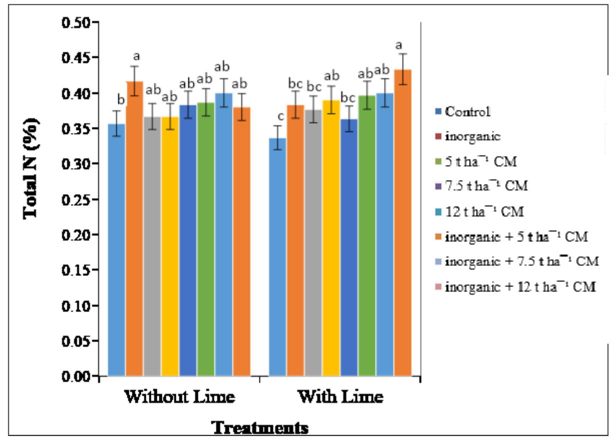

Figure 4. Total N (%) as influenced by chicken manure (CM) and lime application on sweet pepper grown in Andisols

On the other hand, exchangeable Al and acidity were significantly affected by lime and fertilizer application (Figure 5). The application of lime significantly reduced the exchangeable Al and acidity of Andisols. Moreover, sole application of chicken manure or in combination with inorganic fertilizers (T2 to T7) also significantly reduced the soil exchangeable Al compared to the control and inorganic fertilizer alone (T0 and T1). Considering the low pH of the soil, which is 5.08 (extremely acidic), a high concentration of Al is expected. However, with the application of chicken manure, Al concentration was significantly reduced. The reduction in exchangeable acidity and exchangeable Al could be related to the increase in soil pH. Furthermore, the increase in pH resulted in the precipitation of exchangeable and soluble Al as insoluble Al, thus reducing the concentrations of Al in the soil solution (Ritchie, 1994). In addition, Ch'ng et al. (2014) reported that Al was effectively fixed by the organic amendments instead of P and rendering P available by keeping the inorganic P in a bioavailable labile P pool for a longer period.

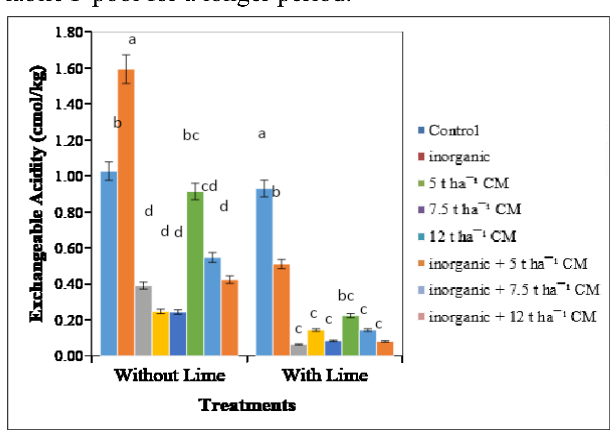

Figure 5. Exchangeable acidity (cmolc/kg) as influenced by chicken manure (CM) and lime application on sweet pepper grown in Andisols

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The decreased amount of exchangeable Al and acidity of the soil is also affected by the application of lime. It reduces Al^{3+} and H^+ in the acid soil to form $Al(OH)_3$ and H_2O. The application of lime and the different treatment combinations have highly significant interactions with each other. The soil did not only respond to the application of lime but also to the different treatments either in the sole or combined application of chicken manure and inorganic fertilizers (Tables III). In addition, Repsiene and Skuodiene (2010) found that lime and manure, when applied sole or combined, had a significant effect in reducing Al, increasing Ca, pH, and Mg. In comparison, T4 had decreased significantly in exchangeable Al and acidity either with or without lime application but not significantly different from the rest of the treatments except for T0 andT1. On the other hand, without the application of lime T1 had increased its exchangeable Al from 1.10 cmolc/kg (Table II) to 1.71 cmolc/kg (Table 4). For the treatments applied with lime, the significant decrease of exchangeable Al did not vary between T3 to T7 (exchangeable Al). Further, T2 to T7 for the exchangeable acidity significantly showed lower values compared to T1 and T0 (control).

Table 3. Interaction effect of chicken manure and lime application on the soil exchangeable Al and acidity of Andisols (cmol/kg)

Treatments	Exchangeable Al (cmol/kg)		Exchangeable Acidity (cmol/kg)	
	Main plot			
	w/o lime	w/ lime	w/o lime	w/ lime
Control	1.21ab	0.79a	1.03ab	0.93a
T_1	1.71a	0.51ab	1.59ab	0.51ab
T_2	0.56cd	0.11b	0.39bc	0.06b
T_3	0.34cd	0.16b	0.25c	0.14b
T_4	0.18d	0.19b	0.24c	0.08b
T_5	0.96bc	0.22b	0.91bc	0.22b
T_6	0.72bcd	0.22b	0.55bc	0.14b
T_7	0.41cd	0.21b	0.42bc	0.08b

Treatment means within a column having the same letter/s are not significantly different from each other at a 5 % level of significance

Legend:
T0 – control
T1 – 200-150-100 kg ha^{-1} N, P_2O_5, K_2O
T2 – 5 t ha^{-1} chicken manure
T3 – 7.5 t ha^{-1} 1 chicken manure
T4 – 12 t ha^{-1} chicken manure
T5 – 100-75-50 kg ha^{-1} N, P_2O_5, K_2O + 5 t ha^{-1} chicken manure
T6 – 100-75-50 kg ha^{-1} N, P_2O_5, K_2O+ 7.5 t ha^{-1} chicken manure
T7 – 100-75-50 kg ha^{-1} N, P_2O_5, K_2O + 12 t ha^{-1} chicken manure

Andisols applied with organic fertilizers led to significant changes in nutrient status. Available P in the soil seemed to increase after harvest, such that the application of lime and chicken manure significantly improved P contents (Table 1). Liming increases the pH of the soil, thereby changing the availability of many plant nutrients. In addition, liming restricts the availability of Al, which can be toxic to plants (Haynes and Mokolobate, 2001). However, results revealed that liming did not significantly affect the available P, but across the different treatments (within lime and without lime), a significant variation was noted (Figure 6). This could be attributed to the synergistic effect of OM from chicken manure that was added in T3 to T7 hence, resulting in a significantly higher available P. OM affects the retention of P because of its adsorption on clays, which occurs through ligand exchange with the surface hydroxyl groups, similar to phosphate and therefore, specifically adsorbed onto the surface generating a competitive effect on P adsorption (Mora and Canales, 1995a, 1995b; Haynes and Mokolobate, 2001; Jara et al., 2005). New adsorption sites could be generated by OM, which allows it to stimulate P adsorption through the formation of stabilization products between P, Al, Fe, and OM (De Brouwere et al., 2003). The application of organic manures not only produces the highest and sustainable crop yield but also improves soil fertility and productivity (Allah et al., 2013; Datt et al., 2013). In particular, in this study chicken manure application also improved the P availability of the soil. It contains more stable mineral-associated P than many manures and may act as a longer-term P source when used in crop production (Waldrip-Dail et al., 2009). Verde et al. (2013) reported that the sole application of manure or combined with lime increased mostly the available soil P, but the increase was not significant. Furthermore, Abera et al. (2005) also found that higher application of manure resulted in higher extractable P in the soil. There is a significant positive effect in treatments applied with sole and combined chicken manure and inorganic fertilizers compared to T1 and control (Figure 6). There was also no significant difference in treatments 6 and 7, respectively. The significant increase of available P could be due to the decrease of exchangeable Al and acidity, which could tie up P, thus, rendering it unavailable. Furthermore, this type of soil has a very high sorption capacity due to a large number of amorphous materials such as allophane (USDA, 1976). Based on the sorption-desorption study conducted, Andisols has the ability to fix 97.44 % of P. The present study conformed to the high P-fixing capacity experiment of Nierves and Salas (2015). Furthermore, Tonfack et al. (2009) suggest that the application of adequate dosage of chicken manure at the right time is capable of sustaining tomato fruit production. Hence, the application of chicken manure at 12 t ha-1 actually enhanced the available P of Andisols where the Al was effectively fixed by the chicken manure instead of P and

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thereby improving crop growth (Ch'ng et al., 2014). Too much P nutrient may cause toxicity to the crop and can also cause micronutrient deficiency and impair nitrogen use (Landon, 1991).

The principal chemical constraint of Andisols is its high capacity to fix the P, and this varies with the type of clay mineral (Córdova et al., 1996). In addition, the higher P fixing potential of the soil was due to its humus-Al complexes, which are apparently difficult to satisfy. Córdova et al. (1996) suggested that Andisols requires a high P application every cycle of cropping due to the low P residual effect. On the other hand, results showed that T4 has a significantly higher available P compared to other treatments. Thus, the sole application of chicken manure at 12 tons ha-1 improved significantly the available P in the soil (Figure 6).

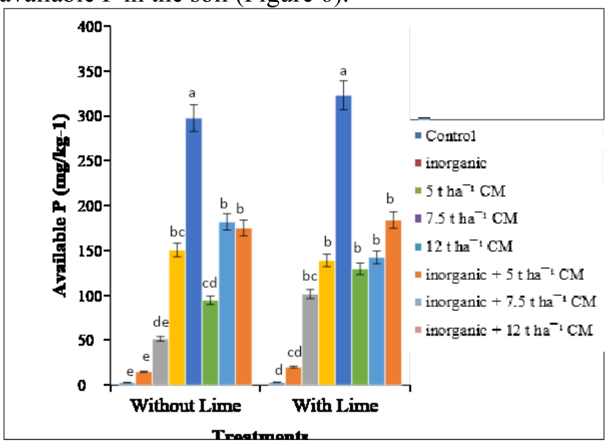

Figure 6. Soil available P (mg/kg) as influenced by chicken manure (CM) and lime application on sweet pepper grown in Andisols

4 CONCLUSIONS AND RECOMMENDATION

Based on the results obtained, the following conclusions can be drawn:

a. Lime application in acidic Andisols is effective when applied at least seven days before transplanting of sweet pepper;

b. Sole application of chicken manure at a rate of 12 t ha-1 significantly improved soil available P in Andisols compared to other treatments. Moreover, applications of chicken manure either singly or in combination with inorganic fertilizers significantly increased available P compared to inorganic application alone and the control; and

c. Liming and chicken manure application significantly improved soil pH and decreased exchangeable Al and acidity of Andisols.

Based on the present study, it is recommended to apply 5 t ha-1 lime and 12 t ha-1 chicken manure for improved soil chemical properties and availability of nutrients specifically P in Andisols.

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