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Effects of Compost and Mineral Sulfur Fertilizers on Phosphorus Desorption at Wujiraba Watershed, Northwestern Highlands of Ethiopia

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Abstract- Phosphorus fixation, which is responsible for low availability of P, is one of the major problems of crop growth in acidic soils such as Nitisols. It is one of the most chronic problems for crop yield decline in Wujiraba watershed. Therefore, an incubation study was conducted for two months to investigate the effects of compost and S fertilizers on P desorption in strongly acid soils (pH/KCl 4.53) and low P content (Bray II P 4.8 mg kg^{-1}). After air drying, grinding and passing through 2 mm sieve, 200 g of soil was placed to each pot. The experimental treatments included three rates of compost (0, 5 and 10 t compost ha^{-1}) and S (0, 15 and 30 kg S ha^{-1}) fertilizers were laid down in CRD with three replications. At the end of the incubation period, the analyzed data result revealed highly significant ($P \leq 0.001$) difference in available P by interaction effects of compost and S fertilizers whereby the highest (22.8 mg kg^{-1}) was recorded in pots treated with high dose of compost (10 kg compost ha^{-1}) and nil S fertilizer rates which increased by 301% relative to the control.

Keywords: *acidic soil, compost, incubation, nitisols, p availability, p fixation, s fertilizer.*

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EFFECTSOFCOMPOSTANDMINERALSULFURFERTILIZERSONPHOSPHORUSDESORPTIONATWUJIRABAWATERSHEDNORTHWESTERNHIGHLANDSOFETHIOPIA

Strictly as per the compliance and regulations of:

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Abstract- Phosphorus fixation is one of the major problems of crop growth in acidic soils such as Nitisols. It is also one of the most chronic problems for crop yield decline in Wujiraba watershed. Therefore, an incubation study was conducted for two months in pots to investigate the effects of compost and S fertilizers on P desorption in strongly acid soils with low P contents. The experimental treatments included three rates of compost (0, 5 and 10 t compost ha) and S (0, 15 and 30 kg S ha) fertilizers which were laid down in CRD with three replications. At the end of the incubation period, the analyzed data result revealed highly significant ($P \leq 0.001$) difference in available P by interaction effects of compost and S fertilizers whereby the highest (22.8 mg kg) was recorded in pots treated with high dose of compost (10 kg compost ha) and nil S fertilizer rates that increased by 301% relative to the control. Unlike compost fertilizer, S amendment decreased available P and increased exchangeable Ac and Al contents of soil. Therefore, this work indicated a decline in P fixation and exchangeable Al with application of compost fertilizer which is a cost effective measure on strongly acid soils with P deficiency.

Keywords: acidic soil, incubation, nitisols, p deficiency, p fixation, yield decline.

I. Introduction

Soil acidity is the most important factor affecting plant growth and limiting crop production (Fageria, 2009; Achieng *et al.,* 2010) due to high concentration of Al and Mn, and deficiency of P, N, S and other nutrients (Zdenko, 2003; Wang *et al.*, 2006; Abreha, 2013). It is common in regions where rainfall is high enough to leach appreciable amounts of exchangeable bases from soil surface (Achalu, *et al.,* 2012). Although acidification is a natural process, agricultural practices, environmental pollution, nutrient mining and other human activities have accelerated the process (Curtin and Syers, 2001).

It is estimated that 28.8% of African continent has acid surface soils (Eswaran et al., 1997; Hirpa *et al.*, 2013). Soil acidification affected large areas of Ethiopian highlands (EATA, 2013) estimating 40% of the total arable l and of the country (Mesfin, 2007; Hirpa *et al.,* 2013). Soil acidity also becomes a serious threat to areas of the western, southern and central highlands of Ethiopia (Wassie and Boke, 2009; Abreha, 2013) where the study area is part of.

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Although P is the most abundant elements and essential for plant growth (Fadly, 2005; Withers and Jarvie, 2008; Zhuo *et al.*, 2009a), it is one of the least available plant nutrients in soil (Raghothama and Karthikeyan, 2005). Available P in soil is very low (< 10%) relative to its total amount (Wang *et al.*, 2006; Adem *et al.,* 2009). Most of tropical soils are known to have low P status as it reacts with Al, Mn and Fe ions Chandrasekaran *et al.* (2010) that hinders crop production. High P adsorption in acid soils makes crops to utilize only 10 - 25% of P fertilizer applied (Bahl and Singh, 1986; Asmare, 2014).

Phosphorus deficiency remains a major constraint in rain fed upland farming systems (Fairhurst *et al.*, 1999; Akande *et al.,* 2011) despite main crop production lands. The insolubility of P is due to its affinity to cations such as Ca^{2+}, Mg^{2+}, Fe^{3+} and Al^{3+} which are not amenable to plant uptake (Jose *et al.,* 2003). Aluminum toxicity is the most important plant-growth limiting factors in many acid soils, particularly those with pH < 5.5 (Kabambe *et al.,* 2012) as Al phytotoxicity results in rapid inhibition of root growth (Zdenko, 2003).

Ethiopian soils, particularly Nitisol, are reported to have low available P contents (Yihenew, 2002) due to impacts of P fixation by acidic cations, mining of P by crop harvest and little P sourced fertilizers application (Asmare, 2014). The high P adsorbing soils require massive application of P sourced mineral fertilizers, OM and sustainable land management practices although not practiced by most small scale farmers of Ethiopia due to its high cost, low attention for local amendments and more emphasis for current food insecurity than nutrient depletions, respectively.

Although OM improves P availability via organic; humic and fulvic acids (Minggang, *et al.,* 1997; Gourango, 2007), its application is very low at Wujiraba watershed. These organic acids are released during OM decomposition which are responsible in increasing negative charges (raising pH) on Al and Fe oxide surfaces and decreasing such metallic ions by competing for binding sites as well as solublizing P mainly by producing CO_2 and forming H^2CO^3 (Kumari *et al.,* 2008; Nadar *et al.,* 2008; Paulo *et al.*, 2008).

Sulfate (SO^{42-}) retention is usually accompanied by a rise in pH of soil solution and improving P availability by releasing OH^- groups from the surface (Couto *et al.*, 1979; Mott, 1981) and increasing the ability of soils to retain basic cations (Bowden *et al.*, 1980). Although some researchers have found that gypsum increases the leaching of Al, Fe, Mn, it does not usually change soil acidity; while others reported that it did not improve the fertility of acid soils (Chalker-Scott's web page at http://www.theinformedgardener.com accessed on 18 February 2013) which is open for research work.

Soils of Wujiraba watershed are strongly acidic and P is the most deficient nutrients for crop growth with low application of P fertilizers and OM. Little research was done on P fixation problems in the study area. The effects of compost and S (gypsum) fertilizers on P desorption in acidic soils of northwestern highlands have not also yet been studied. Consequently, studying P desorption had paramount importance, and therefore, the objective of this study was to investigate the effects of compost and S fertilizers on soil P availability in acidic soils of Wujiraba watershed.

II. Materials and Methods

a) Description Of The Study Area

The study was conducted at Wujiraba watershed, located in Chilga District of North Gondar Zone in the Amhara National Regional State (Figure 1). The watershed is situated at about 60 km west of Gondar city and 760 km northwest of Addis Ababa (capital of Ethiopia). Geographically, the watershed lies at 12^0 32' 16''- 12^0 35' 20'' N latitudes and 37^0 03' 58''- 37^0 06' 23'' E longitudes with an area of 62.68 km^2 and elevations ranging from 1910 and 2267 masl.

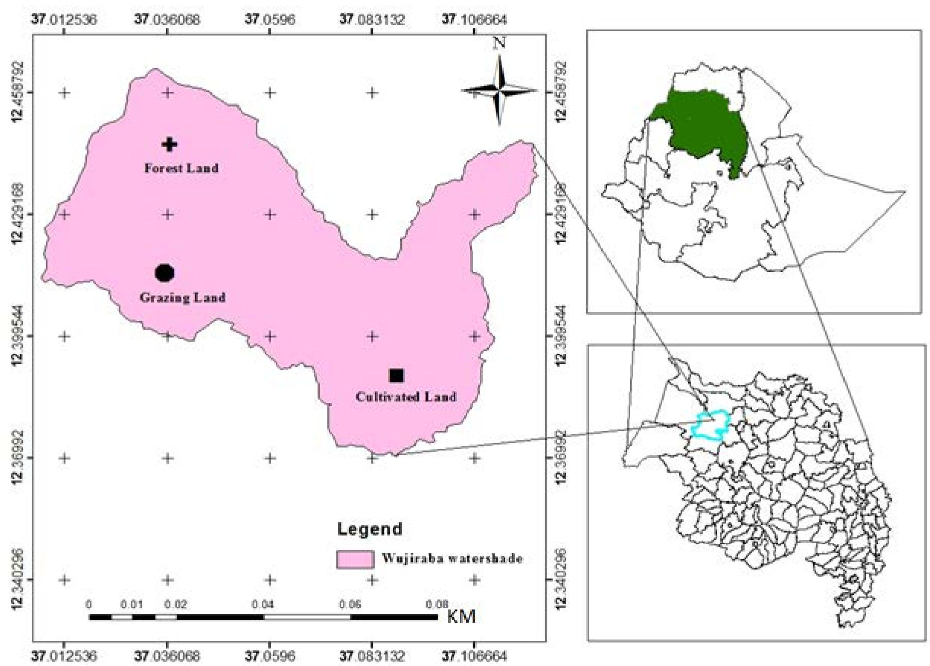

Figure 1 : Location map of the study area

Geologically, the study area is covered with thick trap series of volcanic rocks built-up in mid-Tertiary flood basalt pile and middle-Tertiary volcanic mountains of the Miocene and Pliocene–Quaternary basaltic volcanism. The soils of the study area were developed from the parent materials of volcanic origin, predominantly Tertiary basalt (Chorowicz *et al.,* 1998).

Wujiraba watershed is characterized by unimodal rainfall pattern with average annual rainfall of 1237 mm (Figure 2). The annual mean minimum and maximum temperatures were 13.6 and 23.7 ^{0}C, respectively. Natural vegetation of Wujiraba watershed is very low except some trees and grasses on reserved areas. The trees occurring on slopes, mainly churches, are remnants of once dense evergreen forest.

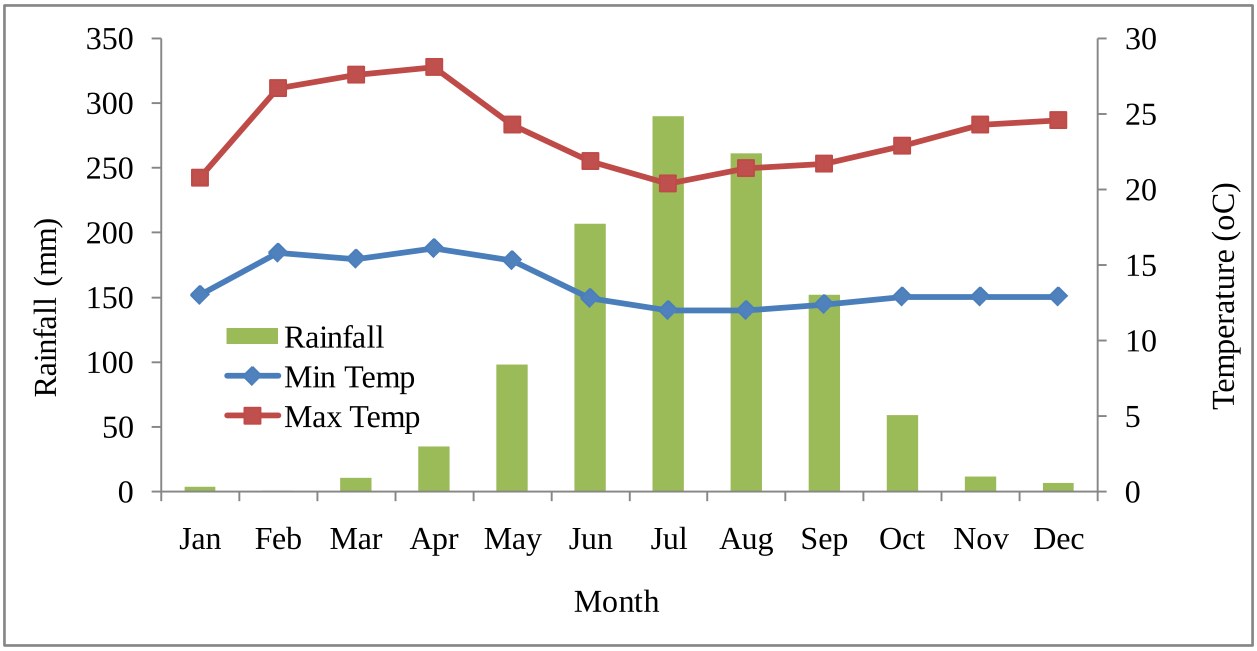

Figure 2 : Mean monthly rainfall and maximum and minimum temperatures of the study area

Economic activities of local community at Wujiraba watershed are primarily mixed farming system (crop production and animal husbandry). In the watershed, cultivated land accounts for 68.4% while grazing, settlement and forest together with area closure lands account 23.5, 5.3 and 2.8%, respectively (Chilga District Agriculture and Rural Development Office, 2012). The watershed is suitable for growing large variety of crops such as cereals, oil seeds, pulses, etc. Crops are grown in rotation by rain fed system.

b) Soil Sampling and Analysis

Six kilograms of composite surface (0 - 30 cm depth) acidic soils were collected from three blocks in cultivated land of soil group Nitisols (FAO, 2006) based on slope. Soil samples were collected by augur from thirteen sub-samples in each block and thoroughly mixed. Compost was prepared from local raw materials (clovers, grasses, leaves of trees, ashes, cow dung and urine, sheep and poultry manure and top soil) which are decomposable. It was prepared in pits with dimensions of 1.5 m length, 1.5 m width and 1 m depth and turned every month. Gypsum was also sieved in 2 mm sieve.

Before incubation study, collected soil and compost samples were prepared for physicochemical analyses. Soil and compost were air dried ground and passed through a 2 mm sieve except for total N and OC which were passed through 0.5 mm sieve. Analysis of samples was carried out at Bahir Dar Soil Testing and Fertility Improvement Laboratory and Amhara Design and Supervision Works Agency Soil Laboratory Centers based on their standard procedures.

Soils texture was analyzed by Bouyoucos hydrometer (Day, 1965). Bulk density was determined from undisturbed soil samples using core samplers (Rowell, 1997) while soil ρ_s was measured by psychnometer method (Barauah and Barthakulh, 1997). Total porosity was also calculated from values of ρ_b and ρ_s as: $f = \left(1 - \frac{\rho b}{\rho s}\right)100$.

Soil and compost pH was measured in 1:2.5 soils to KCl solution before incubation (Chopra and Kanwar, 1976) while after incubation, in suspension of 1:2.5 soils to water ratio. Total N was determined by micro-Kjedahl method (Jackson, 1958). Cation exchange capacity and exchangeable Ca, Mg, K and Na were extracted with 1 M NH_4OAc at pH 7 (Okalebo *et al.*, 1993). Organic carbon was determined by Walkley and Black method (Walkley and Black, 1934) while available P and S were determined by extraction with Bray II (Bray and Kurtz, 1945) and Turbidimetric methods (Kowalenko, 1985), respectively. Soil micronutrients of Fe, Mn, Cu and Zn were measured by atomic absorption spectrophotometer as described by Sahlemedhin and Bekele (2000). Exchangeable acidity was determined by saturating soil samples with 1M KCl solution and titrated with 0.02 M NaOH as described by Rowell (1994). From the same extract, exchangeable Al in soil samples was titrated with standard solution of 0.02 M HCl.

c) Experimental Design and Procedures for Incubation Study

Soil incubation study was conducted using compost and S fertilizers. For this study, composite soil samples, gypsum and compost were put in plastic pots. The treatments used were three rates of compost (0, 5 and 10 t compost ha^{-1}) and S fertilizer in the form of gypsum (0, 15 and 30 kg S ha^{-1}) that were laid down in CRD.

The experiment consists of nine treatment combinations with three replications. Twenty seven plastic pots were filled with 200 gm acidic soils each and thoroughly mixed with different compost and S fertilizer rates. Such soils with compost and gypsum were incubated for two months (April and May, 2013) at Gondar Agricultural Research Institute and subjected to uniform wetting at 60% FC adjusted every two days. Soil samples were taken at the end of incubation time (two months after), air dried ground and sieved through 2 mm sieve to determine pH, exchangeable Ac, Al and available P using the methods described above at Bahir Dar Soil Testing and Fertility Improvement Laboratory Center.

d) Statistical Analysis

Data were statistically analyzed as CRD by two ways analyses of variance using SAS software (SAS, 2002). Means were compared using LSD test by Fisher's test at 0.05. Correlation analyses were also carried out.

III. Results and Discussion

a) Initial Soil Properties and the Composition of Compost

The results for soil and compost laboratory analyses which were done before incubation study were presented in Tables 1 and 2. Soil was clayey in texture, moderate in f, very low in pH, low in OC, total N, available P and S, high in CEC, medium in exchangeable Ca, Mg and K contents.

Table 1 : Physicochemical properties of the experimental soil before incubation

Parameters Unit		Values
Texture (%)	Sand	12.34
	Silt	27.98
	Clay	59.68
β_b (g cm^{-3})		1.2
β_s (g cm^{-3})		2.36
f (%)		47.8
pH/KCl		4.53
OC (%)		1.6
Total N (%)		0.15
Available P (mg kg-^{1})		4.8
Available S (mg kg-^{1})		2.9
CEC (cmole+ kg^{-1})		32.6
Exchangeable Ac (cmol+kg^{-1})		2.5
Exchangeable Al (cmol+kg^{-1})		1.8
Exchangeable bases (cmole+ kg^{-1})	Ca	9.9
	Mg	2.1
	K	0.59
	Na	0.23
PBS (%)		41.61
Available micronutrients (mg kg-^{1})	Fe	6.8
	Mn	17.5
	Cu	2.1
	Zn	0.69

In this experiment, laboratory analyses results for nutrient contents of compost before incubation revealed that of OC (18.5%), total N (0.83%), available P (650.7 ppm) and S (17.8 ppm), CEC (94.4 cmolc kg^{-1}, exchangeable Ca (47.1), Mg (26.7), K (2.5) and Na (0.4 cmolc kg^{-1}) as well as NH_4^+ (332.1) and NO_3^- (259.6 ppm) with C: N ratio of 22:1. These nutrients could be emanated by the activities of microorganisms during the decomposition of compost.

Table 2 : Laboratory analysis results for nutrient contents of compost before incubation

Compost	pH/ H_2O	CEC cmolc kg^{-1}	OC %	TN %	Av. P mg kg^{-1}	Av. S mg kg^{-1}	Ca cmolc kg^{-1}	Mg cmolc kg^{-1}	K cmolcg^{1}	Na cmolc kg^{-1}	NH_4^+ mg kg^{-1}	NO_3^- mg kg^{-1}
R1	7.2	96.4	19.11	0.81	646.32	17.5	47.62	26.08	2.54	0.37	312.0	269.6
R2	7.4	92.34	17.87	0.85	655.15	18.09	46.54	27.42	2.38	0.43	352.23	249.6

R1 and R2 = Replication 1 and 2

b) Effects of Compost and Sulfur Fertilizers on Soil pH

Soil pH is the most indicators of soil chemical properties and P availability. In this experiment, pH was significantly ($P \leq 0.05$) affected by the effects of compost and S fertilizer interactions (Table 3). The highest (5.57) pH was recorded in pots treated with 5 t compost ha^{-1} and nil S fertilizer rates while lowest (4.6) at nil compost and high dose of S fertilizers (30 kg S ha^{-1}). The experiment showed the increase of soil pH by compost and decrease by S fertilizer application. In this experiment, pH was positively correlated ($r = 0.34$) with available P but highly significantly ($P \leq 0.001$) and strongly negatively associated ($r = -0.67$ and -0.68) with exchangeable Ac and Al, respectively (Table 4).

c) Effects of Compost and Sulfur Fertilizers on Exchangeable Acidity and Aluminum

Exchangeable Ac and Al are the principal soil chemical properties that hinder crop growth in tropical soils. There was significant ($P \leq 0.01$) difference in exchangeable Ac by the combined effects of compost and S fertilizers (Table 3). The highest exchangeable Ac (2.88 cmol+kg^{-1}) was recorded in pots treated with fertilizer interactions of high dose of S (30 kg S ha^{-1}) and nil compost rates that showed an increase of 23.6% compared to the control. Significant ($P \leq 0.05$)) difference was also observed in exchangeable Al by the interaction effects of compost and S fertilizers (Table 3) whereby the highest (2.16 cmol+kg^{-1}) was observed again in pots treated with high doses of S Fertilizers (30 kg S ha^{-1}) and nil compost fertilizer rates that increased by 22% relative to the control. Nevertheless, the lowest exchangeable Al (1.37 cmol+kg^{-1}) was recorded in pots treated with high doses of compost fertilizers (10 tons compost ha^{-1}) and nil S fertilizer rates by showing a decrease of 22.6% relative to the control.

d) Effects of Compost and Sulfur Fertilizers on Phosphorus Availability

The extent of P desorption varied depending on the amounts and types of amendments used in incubation experiment. Available P content was highly significantly ($P \leq 0.001$) affected by compost and S fertilizer interactions (Table 3). The highest (22.8 ppm) available P was recorded in pots treated with high dose of compost (10 t compost ha^{-1}) and nil rates of S fertilizers that showed an increase of 301% relative to the control. The values of available P were increased with increasing compost but decreased with increasing S fertilizer rates. This experiment also revealed that the correlation of available P with exchangeable Ac and Al was highly significant ($P \leq 0.001$) and strongly negative ($r = -0.7$ and -0.69), respectively (Table 4).

Table 3 : Interaction effects of compost and S fertilizer on soil pH , exchangeable Ac, Al and available P

Treatment	pH/H_2O	Exchangeable Acidity (cmol+kg^{-1})	Exchangeable Al (cmol+kg^{-1})	Available P (mg kg^{-1})
C0S0	5.20ab	2.33bcd	1.77bc	5.70 c
C0S1	4.90bc	2.43abc	1.85abc	5.75 c
C0S2	4.60 c	2.88a	2.16a	5.46 c
C1S0	5.57 a	2.15bcd	1.56bcd	12.94 b
C1S1	4.87bc	2.41bc	1.82abc	12.50 b
C1S2	5.37 a	2.51ab	1.91ab	12.32 b
C2S0	5.54 a	1.87d	1.37d	22.80 a
C2S1	4.90bc	1.98cd	1.47cd	21.58 a
C2S2	5.41ab	2.00cd	1.54bcd	22.02 a
R^2	0.71	0.69	0.66	0.99

CV (%)	5.23	11.6	12.9	6.14
F-Test	*	**	*	***
LSD (0.05)	0.32	0.26	0.38	1.01

Means with the same letter are not significantly different; C0, C1, C2 = 0, 5, 10 t compost ha^{-1} and S0, S1, S2 = 0, 15, 30 kg S ha^{-1}

Table 4 : Pearson's correlation matrix for various soil pH, available P, exchangeable Ac and Al

	pH	Av P	Ex Ac	Ex Al
pH	1.0			
Av P	0.34	1.0		
Ex Ac	-0.67***	-0.7***	1.0	
Ex Al	-0.68***	-0.69***	0.98***	1.0

****Significant at P = 0.001; ** significant at P = 0.01; * significant at P = 0.05 levels; Av. P = available P; Ex A c= exchangeable acidity; Ex Al = exchangeable aluminum*

IV. Discussion

Soils of cultivated lands in the study area are clayey in texture, moderate in f, very low in pH, low in OC, total N, available P and high in CEC, medium in exchangeable Ca, Mg and K contents and affected by soil acidity and Al toxicity problems. These all might be due to low OM content, high leaching of basic cations and mining of nutrients, soil erosion as well as acidifying effects of mineral fertilizers. The high clay content of the soil in this study could increase P fixation due to its high surface area. Havlin *et al.* (1999) reported that P fixation tends to be more pronounced and ease of P release tends to be lowest in soils with higher clay content.

After the incubation study, soil pH was increased with increasing compost rate which might be due to being as the source of soil microorganisms that enabled the liberation of basic cations which substitute the acid cations (H^+, Al^{3+}, etc). Johannes (2000), Tesfay *et al.* (2006) and Sarwar *et al.* (2010) reported that compost has librated alkaline substances and cations such as Ca^{2+}, Mg^{2+}, K^+ which increase CEC and pH level that counteract soil acidification. Similarly, Erich *et al.* (2002) elucidated that the deprotonation of carboxylate group (COOH), phenolic and alcoholic hydroxyls (OH) reduce soil acidity. However, Eduardo *et al.* (2013) reported oppositely that different functional groups, that are part of the soil OM pool can release H^+, thereby, creating a more acidic environment.

However, pH was decreased with the increase in S fertilizer rates which might be due to the production of sulfuric acid (H_2SO_4) by the activity of thiobacillus bacteria that release H^+ ions. Al-Oud (2011) reported that S plays an important role in reducing soil pH through its transformation to sulfuric acid by S oxidizing bacteria. Shainberg *et al.* (1989) and Skwierawska *et al.* (2008) also noted that high content of S in the soil causes soil acidification and gypsum treatment decreased soil pH from 4.8 to 4.5 due to Ca^{2+} ions dissolution from gypsum and replacement by H^+ and Al^{3+} ions. Furthermore, Shainberg *et al.* (1989) reported that gypsum treatment decreased surface and subsurface soils pH from 4.8 to 4.5 and 4.8 to 4.1, respectively.

Exchangeable Ac and Al were increased with the increase in S fertilizer rates which might be due to acidifying effect of S fertilizers by reducing pH value. However, exchangeable Ac and Al were decreased by increasing compost fertilizer rates which might be due to increase in organic anions, rise in pH and basic cations by its oxidation. Hue (1992) and Abreha (2013) stated that adsorption of organic anions on hydrous Fe and Al surfaces, and release of hydroxyl ions from OM increase pH and reduce exchangeable Ac in soil solution. Yang *et al.* (2013) also reported that exchangeable Al concentration evidently decreased by fulvic acid production of compost decomposition. Huck *et al.* (2014) further revealed that reduction in exchangeable Ac and Al partly relates to the increase in soil pH by OM that precipitate exchangeable and soluble Al as insoluble Al hydroxides, thus reducing concentrations of Al in soil solution.

In this experiment, available P was increased with increasing compost fertilizer rates. This increase might be due to P solublizing/mineralizing effect of organic acids and phosphatase enzymes, shielding of compost on P adsorption sites, chelation of Al and Fe with complexing agents and its subsequent removal from a soil as well as a rise in soil pH. Erich *et al.* (2002), Myungsu *et al.* (2004), Ano and Ubochi, 2007 and Jen *et al.* (2008) found that application of compost can enhance the availability of soil P and even fixed P can be made available to plants after solubilization by soil microorganisms bsides complexation of soluble Al and Fe by organic molecules. Phosphorus solubilizing bacteria and fungi can increase soil P availability by acid phosphatase enzyme that affects P acquisition and P use efficiency in plants (Song and kaeppler, 2001; Petra *et al.*, 2007; Adem *et al.,* 2009. Similarly, Al-Oud (2011) and Carine *et al.* (2006) reported that compost amendments enriched with microorganisms have the ability to increase OC, N and S nutrients. Sharif *et al.* (2010) also stated that humic acid is produced through decay/oxidation of OM by microbial action that can break Fe or Al bond P in acidic soil and release P in soil solution. Besides, Gaard (1996) and Geissen and Guzman (2006) revealed that especially in tropical countries where P is strongly adsorbed by Fe and Al oxides, increase in OM leads to P mobilization and reduction in its adsorption.

Nevertheless, available P was decreased with increasing S fertilizer rates which might be due to liberation of sulfuric acid. Simon (2002) and Brauer, *et al.* (2005) in their incubation studies reported that gypsum in soils made P less available by tying it up as insoluble Ca phosphates, and heavy gypsum application can even tie up it more. However, opposite results were reported by Taalab *et al*. (2008) in Nubaria-Egypt on P availability who stated that extractable P was significantly increased when various P sources were combined with S fertilizer.

V. Conclusions

Application of compost fertilizer increased while S decreased pH and P availability in acidic soils. Although exchangeable Ac and Al were decreased with increasing compost rate, they were increased with increasing S fertilizers. Large application of compost fertilizer could alleviate the problem of P fixation but S rather exacerbated its adsorption. The increase in P desorption with increasing compost rate could be the result of its capacity in raising soil pH, chelating on Al and Fe as well as solublizing/mineralizing by organic acids which made it an alternative input for acid soil management. Thus, application of high OM such as compost could significantly increase while S fertilizers decrease P desorption in acidic soils. Hence, regular application of compost or other alternative sources of OM to small holder farms in the highlands of Ethiopia (affected by soil acidity) could result in improving P availability while S fertilizers aggravate P fixation.

VI. Acknowledgements

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References Références Referencias

1. Abreha, K., 2013. Soil Acidity Characterization and Effects of Liming and Chemical Fertilization on Dry Matter Yield and Nutrient Uptake of Wheat (*Triticum Aestivum* L.) on Soils of Tsegede District, Northern Ethiopia. PhD Dissertation, Haramaya University, Ethiopia.
2. Achalu, C., H. Gebrekidan, K. Kibret and A. Tadesse, 2012. Status of selected physicochemical properties of soils under different land use systems of Western Oromia, Ethiopia. *Journal of Biodiversity and Environmental Sciences.* 2: 57 - 71.
3. Achieng, J. O., Ouma, G., Odhiambo, G. and Muyekho, F, 2010. Effect of farmyard manure and inorganic fertilizers on maize production on Alfisols and Ultisols in Kakamega, western Kenya *Agriculture and Biology Journal of North America*.
4. Adem G.¸ N. Ataog, M. Turan, A. Esitken, and Q. M. Ketterings, 2009. Effects of phosphate-solubilizing microorganisms on strawberry yield and nutrient concentrations. *Journal of Plant Nutrition and Soil Science.* 172: 385 - 392.
5. Akande, M.O., E.A. Makinde, O.A. Aluko, F.I. Oluwatoyinbo and J.A. Adediran, 2011. Rock phosphate amendment effects on kenfa (*Hibscus cannabinus* L.) growth and yield, Institute of Agricultural Research and Training, Obafemi Awolowo University, PMB 5029 Moor Plantation, Ibadan, Nigeria. *Tropical and subtropical agroecosystems*. 14: 559 - 565.
6. Al-Oud, S.S., 2011. Improving phosphorus availability from phosphate rock in calcareous soils by amending with: organic acid, sulfur, and/ or organic manure. *Ozean Journal of Applied Sciences.* 4: 1943 - 2429.
7. Ano, A.O. and C.I. Ubochi, 2007. Neutralization of soil acidity by animal manure: mechanism of reaction. *African Journal of Biotechnology*. 6: 364 - 368.
8. Asmare M., 2014. Phosphorus Status, Adsorption Characteristics, Kinetics and Availability to Wheat Crop as Influenced by Applications of Various Amendments on Acid Soils of Farta District, Northwestern Highlands of Ethiopia, PhD Dissertation, Haramaya University, Ethiopia.
9. Bahl, G.S. and N.T. Singh, 1986. Phosphorus diffusion in soils in relation to some edaphic factors and its influence on P uptake by maize and wheat. *The Journal of Agricultural Science*. 107: 335 - 341.
10. Barauah, T.C. and H.P. Barthakulh, 1997. A Text Book of Soil Analysis. Vikas publishing house, New Delhi, India.
11. Bowden. J.W., A.M. Posner and J.P. Quirk, 1980. Adsorption and charging phenomena in variable chargesoils. In B.KG. Theng (ed.) Soils with variable charge. *New Zealand Society of Soil Science*. 147 - 165.
12. Brauer, G.E., D.H. Aiken, S.J. Pote, L.D. Livingston, T.R. Norton and J.H. Edwards, 2005. Amendment effects on soil test phosphorus. *Published in Journal of Environmental* Quality. 34: 1682 - 1686.

13. Bray, H.R. and L.T. Kurtz, 1945. Determination of organic and available forms of phosphorus in soils. *Soil Science*. 9: 39 - 46.
14. Carine, S., V. Degrange, R. Oliver, P. Millard, C. Commeaux, D. Montange and X.L. Roux, 2006. Alteration and Resilience of the Soil Microbial Community Following Compost Amendment: Effects of Compost Level and Compost-borne Microbial Community.
15. Chandrasekaran, B., K. Annadurai and E. Somasundaram, 2010. A Text Book of Agronomy. New age of International Publishers.
16. Chopra, S.H. and J.S. Kanwar, 1976. Analytical Agricultural Chemistry. Kalyani Publisher.
17. Chorowicz, J., B. Collet, F.F. Bonavia, P. Mohr, J.F. Parriot and T. Kome, 1998. The Tana basin, Ethiopia: intra-plateau uplift, rifting and subsidence, *Elsevier.* 295:351-367.
18. Couto, W., D.J. Lathwell and D.R. Bouldin, 1979. Sulfate sorption by two Oxisols and an Alfisol of the tropics. *Soil Science*. 127: 108 - 116.
19. Curtin, D, Syres and J.K., 2001. Lime-induced changes in indices of soil phosphate availability. *Soil Science Society of American Journal*. 65: 147 - 152.
20. Day, P.R. 1965. Particle fraction and particle size analysis. pp. 545 - 567. In: Black CA et al. (Eds). Methods of Soil Analysis. Part 2. *American Society of Agronomy*, Madison.
21. EATA (Ethiopian Agricultural Transformation Agency), 2013. Status of Soil Resources in Ethiopia and Priorities for Sustainable Management, Overview of Ethiopia's Soil Program. GSP for Eastern and Southern Africa Mar. 25 - 27, 2013, Nairobi, Kenya.
22. Eduardo, M, J. Fuentes, V. Pino, P. Silva and E. Acevedo, 2013. Chemical and biological properties as affected by no-tillage and conventional tillage systems in an irrigated Haploxeroll of Central Chile. *Soil and Tillage Research.* 126: 238 - 245.
23. Erich, M.S., C.B. Fitzgerald and G.A. Porter, 2002. The effect of amendments on phosphorus chemistry in potato cropping system. *Agriculture, Ecosystems and Environment*. 88: 79 - 88.
24. Eswaran, H., P. Reich and F. Beinroth, 1997. Global distribution of soils with acidity. In: *Plant- Soil Interactions at Low pH.* Moniz, A.C (eds.). *Brazilian Soil Science Society*. Pp. 159 - 164.
25. Fadly, H.Y. 2005. Soil Organic Matter Decomposition: Effects of Organic Matter Addition on Phosphorus Dynamics in Lateritic Soils. University of Western Australia. Pp. 20 - 98.
26. Fageria, N.K. 2009. The Use of Nutrients in Crop Plants. CRC Press, Taylor and Francis Group, USA.
27. Fairhurst, T.R., R. Lefroy, E. Mutert and N. Batijes, 1999. The Iportance, Distribution and Causes of Phosphorus Deficiency as a Constraint to Crop Production in the Tropics. Agroforestry Forum. pp. 2 - 8.
28. FAO (Food and Agriculture Organization) of the United Nations, 2006. World Reference Base for Soil Resources. A framework for International Classification, Correlation and Communication. World soil resources reports 103. Rome, Italy.
29. Gaard, A. F., 1996. Effect of fresh and composted cattle manure on phosphate retention in soil. Acta. Agriculture Scandinavica, Section B*. Soil and Plant Science.* 46: 98 - 105.
30. Geissen, V. and G. M. Guzman, 2006. Fertility of tropical soils under different land use systems- a case study of soils in Tabasco, Mexico. *Applied Soil Ecology.* 31: 169 - 178.
31. Gourango, k., 2007. Phosphorus Speciation in Biosolids Amended Soils: Correlating Phosphorus Desorption, Sequential Chemical Extractions, and Phosphorus-xanes Spectroscopy, University of Saskatchewan Saskatoon, Saskatchewan, Canada.
32. Halvin, J.L., J.D. Bedton and S.L. Tisdale, 1999. Soil Fertility and Fertilizers. Macmillian, Pub. Co., Newyork. P. 247.
33. Hirpa L., N. Dechassa, S. Gebeyehu, G. Bultosa4 and F. Mekbib, 2013. Response to Soil Acidity of Common Bean Genotypes (*Phaseolus vulgaris* L.) Under Field Conditions at Nedjo, Western Ethiopia. Science, Technology and Arts Research Journal, 2(3): 3 - 15.
34. Huck, Y.C., O.H. Ahmed and N.M. Ab-Majid, 2014. Improving Phosphorus Availability in an Acid Soil Using Organic Amendments Produced from Agroindustrial Wastes. *The Scientific World Journal.*
35. Hue, N.V. 1992. Correcting soil acidity of a highly weathered Ultisol with chicken manure and sewage sludge. *Community of Soil Science and Plant Analysis*. 23: 241 - 264.
36. Jackson, M.L., 1958. Soil Chemical Analysis. Prenstice-Hall, Inc., Engle Wood Cliffs. New Jersey. pp.183 - 204.
37. Jen, H.C., J.T. Wu and W.T. Huang, 2008. Effects of compost on the availability of nitrogen and phosphorus in strongly acidic soils. *Taiwan Agricultural Research Institute,* Wufeng, Taiwan ROC.
38. Johannes, B., 2000. The Use of Composted Organic Waste in Viticulture- A Review of the International Literature and Experience, Environment Australia, Canberra Sustainable Industries Branch.
39. Jose L. P. Bucio, A. Cruz-Ramirez and L. Herrera-Estrella, 2003. The role of nutrient availability in regulating root building. *Current Opinion in Plant Biology.*6: 280 - 287.
40. Kabambe,, V. H., A. C. Chilimba, A. Ngwira, M. Mbawe, G. Kambauwa and P. Mapfumo, 2012. Using innovation platforms to scale out soil acidity-ameliorating technologies in Dedza district in central

Malawi. African Journal of Biotechnology. 11(3): 561 - 569.

41. Kowalenko, C.G., 1985. A modified apparatus for quick and versatile sulphate sulfur analysis using hydriodic acid reduction, *Communication Soil Science and Plant Analysis*.
42. Kumari, A., K.K. Kapoor, B.S. Kundu, and R.K. Mehta, 2008. Identification of organic acids produced during rice straw decomposition and their role in rock phosphate solubilization, Department of Microbiology, CCS Haryana Agricultural University, Hisar, India. *Plant, Soil and Environment*. 54: 72 - 77.
43. Mesfin, A., 2007. Nature and Management of Acid Soils in Ethiopia. Addis Ababa, Ethiopia.
44. Minggang L., M. Osaki, I.M. Rao and T. Tadano, 1997. Secretion of phytase from the roots of several plant species under phosphorus-deficient conditions. *Plant and Soil*. 195: 161 - 169.
45. Mott, C.B., 1981. Anion and ligand exchange p. 179 - 219. In D.J. Greenland and M.H.B. Hayes (ed.) the chemistry of soil processes. John Wiley and Sons. New York.
46. Myungsu, P., S. Olayvanh, S. Wansik, K. Eunhee, C. Jongbae and S. Tongmin, 2004. Effects of long-term compost and fertilizer application on soil phosphorus status under paddy cropping system. *Communications in Soil Science and Plant Analysis.* 35: 1635 - 1644.
47. Nader, R.H., W. Amal, E.K. Abou and N.Z. Raafat, 2008. Effect of organic and bio-fertilizers on phosphorus and some micronutrients availability in a calcareous soil, Soil, Water and Environment Research Institute, Agriculture Research Center, Giza, *Egypt. Research Journal of Agriculture and Biological Sciences.* 4: 545 - 552.
48. Okalebo, J.R., K.W. Guathua, and P.L Woomer, 1993. Soil Laboratory Methods and Plant Analysis. Working Manual. Karhsobf. Nairobi. Kenya. 55p.
49. Paulo, S.P., A. Merlin and C.A. Rosolem, 2008. Organic Compounds from Plant Extracts and Their Effect on Soil Phosphorus Availability.
50. Petra M., Z. Solaimana and Z. Renge, 2007. Brassica genotypes differ in growth, phosphorus uptake and rhizosphere properties under P-limiting conditions. Soil Biology and Biochemistry, 39: 87 - 98.
51. Raghothama , K.G. and A.S. Karthikeyan, 2005. Phosphate acquisition. *Plant and Soi*.274:37-49.
52. Rowell, D.L., 1994. Soil Science: Methods and Applications. Addison Wesley Longman Limited. England. 350p.
53. Rowell, D.L., 1997. Soil Science: Method and Application. Addison Wesley Longman Group UK, Singapore.
54. Sahlemedhin S. and T. Bekele, 2000. Procedure for Soil and Plant Analysis. National Soil Research Centre, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia.
55. Sarwar, G., H. Schmeisky, M.A. Tahir, Y. Iftikhar and N.U. Sabah, 2010. Application of green compost for improving soil chemical properties and fertility status. *The Journal of Animal and Plant Sciences.* 20: 258 - 260.
56. SAS (Statistical Analysis System), 2002. SAS User's Guide: Statistics Released 6.12. SAS. Inst. Inc. cary NC, USA.
57. Shainberg, I., M.E. Sumner, W.P. Miller, M.W. Farina, M.A. Pavan and M.V. Fey, 1989. Use of gypsum on soils. *Advanced Soil Science.* 9: 1 - 111.
58. Sharif, M., M. Abida, J. Khan and I. Ul-Haq, 2010. Extractable phosphorus as affected by humic acid application in salt affected soils. *Sarhad Journal of Agricultur*. 26(3): 381 - 386.
59. Simon, W., 2002. Aquaculture Fundamentals, the Use of Lime, Gypsum, Alumnium and Potassium Permanganate in Water Quality Management.
60. Skwierawska, M., L. Zawartka and B. Zawadzki, 2008. The effect of different rates and forms of sulfur applied on changes of soil agrochemical properties. *Plant and Soil Environment*.54:171 - 177.
61. Song, J. Yun and S.M. Kaeppler, 2001. Induction of maize acid phosphatase activities under phosphorus starvation. *Plant and Soil.* 237: 109 - 115.
62. Taalab, A.S., F.A. Hellal and M.A. Abou-Seeda, 2008. Influence of phosphate fertilizers enriched with sulfur on phosphorus availability and corn yield in calcareous soil in arid region, Ozean. *Journal of Applied Sciences*. 1:105-107.
63. Tesfay, T., A. Nordgren and A. Malmer. 2006. Soil Respiration characteristics of tropical soils from agricultural and forestry land-uses at Wondo Genet (Ethiopia) in response to C, N and P amendments. *Soil Biology and Biochemistry.* 38: 125 - 133.
64. Walkley, A. and C.A. Black, 1934. An Examination of Different Methods for Determining Soil Organic Matter and the Proposed Modification by the Chromic Acid Titration Method.
65. Wang, J., H. Raman, G. Zhang, N. Mendham and M. Zou, 2006. Aluminum tolerance in barely Horidium vulgarie L.: Physiological mechanisms, genetics and screening methods. *Journal of Zhejiang University Science*. 7: 769 - 787.
66. Wassie H. and S. Boke. 2009. Mitigation of Soil Acidity and Fertility Decline Challenges for Sustainable Livelihood Improvement: Research Findings from Southern Region of Ethiopia and its Policy Implications. Awassa Agricultural Research Institute.
67. Withers, P.A. and H.P. Jarvie, 2008. Delivery and cycling of phosphorus in rivers, A review. *Science and Total Environment*. 400: 379 - 395.

68. Yang S., Z. Zhang, L. Cong, X. Wang, and S. Shi, 2013. Effect of fulvic acid on phosphorus availability in acid soil. *Journal of Soil Science and Plant Nutrition*, 13(3): 526 - 533.
69. Yihenew, G., 2002. Selected chemical and physical characteristics of soil Adet Research Center and its testing sites in northwestern Ethiopia. Ethiop. J. natural resources. ESSS. Addis Ababa, Ethiopia. *Ethiopian Journal of Natural Resources*. 4(2): 199 - 215.
70. Zdenko R., 2003. Handbook of soil Acidity, University of Western Australia Perth, Western Australia Australia, Marcel Dekker, Inc. 270 Madison Avenue, New York, NY 10016.
71. Zhuo, A., L He and H. Zhao, 2009a. Effect of organic acids on inorganic phosphorus transformation in soils and its readily available phosphate. *Acta Ecologica Sinica*. 29(8): 4061 - 4069.