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Effects of Liming on Physicochemical Properties and Nutrient Availability of Acidic Soils in Welmera Woreda, Central Highlands of Ethiopia

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Soil acidity is one of chemical soil degradation problems which affect productivity of the soil in Ethiopian highlands. The purpose of this research was to identify the status of soil acidity and determine the amount of lime requirement for neutralization to increase plant nutrient availability in Welmera woreda, Oromia region. More specifically the study pointed out statistically, the nutrient availability before and after liming acidic soil using paired t-test. The results indicated that the soil of study area was strongly acidic (pH < 5.3) and exchangeable acidity was from 2.86±0.01 - 3.55±0.07 cmol/Kg. The soil showed low concentration of plant nutrients (AP, TN, K,Ca,Mg) and high in micronutrients (Cu, Fe, Mn, Zn) contents. After 90 days liming in greenhouse incubation of the soils, the results showed effective neutralization of the soil, which indicated it was properly limed and the effects of soil acidity on nutrient availability was clearly observed. The concentration of all anions(AP,TN, and OC), cations (Na^+, K^+, Ca^{+2} and Mg^{+2}) and micronutrients were found to be significantly different except TN and OC, between the soil samples for before and after liming. After limed acidic soils, anion and cations are improved their availability for plant while micronutrients are decreased from toxicity to normal condition.

Key Words: Incubation, Liming, Lime Materials, Nutrient availability, Soil acidity, Soil pH

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INTRODUCTION

Soil acidity is one of the major limiting factors to acid sensitive crop production in the western highland of Oromia Region, Ethiopia. It is often developed in regions where excessive rainfall coupled with that removes appreciable amounts of exchangeable basic ions like calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K) from the surface of soil. Its severity is extremely variable due to the effects of parent materials, land form, vegetation and climate pattern (Rowell, D.L et al., 1994). Its effects on crop growth are those related to the deficiency of major nutrients and the toxicity of aluminum (Al), manganese (Mn) and hydrogen (H) ions in the soil to plant physiological processes (Mesfin, A.,2009). In order to secure sustainable crop production and reasonable yield, acidic soils have to be corrected by addition of agricultural lime to a pH range which is suitable for better yield of crop production (Mesfin, 2009). Measuring lime requirement and estimating the level of acid saturation together with exchangeable acidity are the most common methods to alleviate soil acidity constraints to crop production (Achalu C., (2012). Agricultural liming material is the most common soil management practices whose addition to agricultural soil in moderate amounts may be beneficial as plant nutrients, minimize soil acidification. The beneficial effects of liming soil are neutralization of exchangeable Al, increase Ca and Mg, P, Mo availability, stimulate microbiological activity in soil; improve physical structure of soil by clumping together or flocculation, clay in to more stable aggregates

Liming raises the soil pH by adding calcium & magnesium to soil and causes the aluminium and manganese to go from the soil solution back in to solid (non-toxic) chemical forms. The lime requirement will vary depending upon the types of soil, the desired change in pH, buffering capacity of the specific soil, type of liming material, and the fineness or texture of the lime material (Birhanu A., 2010).

Once this amount is determined, a liming material must be selected that will economically satisfy the soil test recommendation and result in maximum, efficient production.

Frequency of liming is influenced by soil texture, rate of crop removal of Ca and Mg, amount of lime applied, quality of lime applied, soil buffer capacity, tillage and desired pH range(Birhanu A., 2010). Since all lime stones are not the same, the quality of lime varies significantly and should be an important consideration in lime management. Four factors are most important in assessing lime quality; chemical purity, speed of reaction, calcium and magnesium content, and moisture (Tekalign, B., 1992).

In the area even though excess natural and man made fertilizer were used, soil fertility and crop productivity were decreased from year to year. Before 15 years ago the area was known by high productivity of cereal crops and high land pulse crops, but now day the cereal crop productivity was very low while high land pulse and oil crops were almost diminution their productivity. Some unpublished studied reports on that area were also indicated the areas were under the risk in soil fertility and crop productivity. Information on the extent of soil acidity problem on plant nutrients availability and the amount of lime requirement to neutralize this soil in the area is generally little.

Although studying soil acidity problems and quantitative analysis using soil laboratory tests and green house experiment to acquire solutions for this problem was very little. This study was important to understanding the chemistry of plant nutrients when acid soils are limed for successful soil fertility management. Therefore, the present study explored the effects of lime to soil physicochemical properties and acid saturation under greenhouse conditions in western shoa highland.

MATERIALS AND METHODOLOGY

Description of Study Area

The study was conducted in Welmera Woreda, central high land of Ethiopia. The woreda is located at a distance of around 34 km, west of the capital Addis Ababa. Geographically, the study area was located 9^{0}05'55'' N, 38^{0}36'21'' E and altitudes 2556m above sea level. The mean annual temperature of the woreda was 21.3 ^{o}C and annually about 1100 mm rain fall received, and the rain pattern in distribution (short and long rainy season).The dominant soils of the area are reported to be nitisols which are sesquioxidic and moderately to strongly acidic (Temesgen D., *et al*., 2015). These soils have high clay content (35-56%), homogenous, highly developed medium angular blocky structures, and are silt clay to clay in texture.

The economic activities of the local society of the study area are primarily mixed farming systems that involve animal husbandry and crop production. The major crops areteff (*Eragrostistef*), barley (*Hordeumvulgare*), wheat *(Triticumaestivum)*, fababean (*Phaseoluslunatus*), maize (*Zea mays*) and potato (*Solanumtubersoum*) (MoFED, 2002).

Soil Sampling

A total of five representative fields were selected from two kebeles, Minjaro(Kata), Gefersa Minjaro and Gutu from wetabacha minjaro kebele and Kore and Gudu from Ade Simbirit Kotukebele which are named as sample site Minjaro**,**GM, Gutu, Kore and Gudu respectively. From each site, eight to fifteen sub-samples were composited by a radial sampling scheme using an auger(Wilding, L., 1985).

A total of five composite samples (about 9.5 kg) for liming and physicochemical analysis and fifteen cores for bulk density in three depths and cane sampling for moisture analysis were collected randomly from around 127 hecter of welmera woreda, bedi area at the depth of 0-30cm. The samples were air dried gently crushed (ground) in to fine texture and homogenized and sieved by using 0.25 mm mesh size sieve. From the sieved samples about 0.5 Kg were preserved in labelled plastic bags for laboratory analysis and 3 Kg per pot were limed in greenhouse incubation (Achalu, 2012).

Soil physical properties analysis

Soil moisture and bulky density were determined by using oven dry method while soil texture was analyzed by hydrometer after soil soaked by calgon solution and dispersed by mechanical stirrer (Bouyoucos, G.,1962).

Soil chemical properties analysis

The soil pH was measured potentiometrically with a digital pH meter in the supernatant suspension of 1:2.5 soils to water ratio (Huluka, G., 2005).

Soil organic carbon content was determined by the dichromate oxidation was estimated from the organic carbon content by multiplying the latter by 1.724. Total N was determined using the micro-Kjeldahl digestion, distillation and titration procedure as described by Bremner and Mulvaney (1982). Soils available P was extracted by the Bray-II method were quantified using spectrophotometer (wave length of 880 m) calorimetrically using the mixture of ammonium molybedate, sulphuric acid and potassium antimony tartrate as an indicator (Bray, R.,1945).

Exchangeable basic (Ca, Mg, K and Na) ions were extracted using 1 M ammonium acetate (NH_4OAc) solution at pH 7. The extracts of Ca and Mg ions were determined using AAS while K and Na were determined by flame photometer. To determine the cation exchange capacity (CEC), the soil samples were first leached with M NH_4OAC, washed with ethanol and the adsorbed ammonium was replaced by sodium (Solomon D., 2008). The CEC was then measured titrimetrically by distillation of ammonia that was displaced by Na following the micro-Kjeldahl procedure. Total exchangeable acidity was determined by saturating the soil samples with 1M KCl solution and titrating with 0.02M HCl as described by Taye B. (2008). From the same extract, exchangeable Al in the soil was titrating with a standard solution of 0.02M HCl.

Determination of lime requirements for neutralization of acid soil

The lime material used for this experiment was pure $CaCO_3$ with 100% CCE which bought from the factory and 3 kg of soil sample per pot.

The lime recommendation on this study was based on the amount of exchangeable acidity (3.22 – 3.55 cmol/kg) measured by the lime requirement soil test and initial soil pH (4.9 – 5.3 H_2O).

The liming materials ($CaCO_3$ contain 100% CCE) and soil samples were ground to fine texture pass through 0.5 mm sieve.

The five soil samples were replicated to fifteen and lime materials were added at different rates (1.5g, 2g and 2.5 g) in each pot and incubated in green house for 90 days. The incubated samples were mixed and wetted by adding water with the interval of 2-3 days to increase the speed of reaction between acidic soil and lime at the field capacity moisture and soil pH was tested within two weeks interval. Finally, liming in the greenhouse incubation of soil samples were stopped when the pH of all samples reached target pH (6.8-7.2) by pH (H_2O) and (6.4- 6.8) by pH (KCl) methods and the important parameters, which were determined before liming were again analysed to identify the effects of lime on soil physicochemical properties(Achalu C.,2012).

Lime requirement (LR) was determined by the following formula (Kamprath, E.J., 1984):

$$\text{LR. } CaCO_3(\text{Kg/ha}) = \frac{\text{EA (cmol/Kg)} * 0.15\text{ m} * 10^4\text{ m}^2 * \text{BD (mg/m}^3) * 1000}{2000\text{ cmol/Kg}}$$

Where, EA – Exchangeable Acidity BD – Bulk Density
LR – Lime Requirements

Recovery tests for the Uv-visible spectrophotometer, Atomic absorption spectroscopy and Flame Photo meter methods were performed for soil samples using non-spiked and spiked samples in order to ascertain the reliability and efficiency of the analytical procedures for analyzing soil samples before liming and after liming.

Important instrument such as Uv-visible spectrophotometer for phosphorous analysis, flame photometer for sodium and potassium determination and atomic absorption spectrophotometer for Ca, Mg and micronutrient were calibrated by using standard solution (Yihenew, G., 2002).

Statistical analysis of the data was carried out by and one-way analysis of variance (ANOVA) using spss statistic SAS software for comparing nutrient variation among the different sample sites while t-test use to compare the mean concentration of nutrient before and after liming acidic soil(SAS Institute, 2004).

RESULT AND DISCUSSION

Instruments Calibration and Method validation

Calibration of instrument using working standard solution was done for Uv-Visible spectrophotometer, flame photometry and atomic absorption spectrophotometry which are used to determine the concentrations of available phosphorous, exchangeable cations and micronutrients in soil samples respectively. The linear correlation coefficients obtained, ranging between 0.9973 - 0.9996, are in acceptable ranges (Yihenew, G., 2002).

The recovery tests for soil samples were performed for evaluation of analytical methods and the result were within the range of 88.7 % to 111 % for both soil samples before and after liming and the recovery for all plant nutrients are within the acceptable range (80 - 120 %)(Yihenew, G., 2002).

Soil physical properties

In this study, soil moisture contents are found to be within the range of 37.3 % to 41.7 %, are higher than normal nitosol, which is moisture 28.72 – 32.64 % (HelufG. and Kibebow, K. (2012). This is due to the nature of soil type (class) which contains high silt and clay particles, low infiltration capacity and good water holding capacity.

In this study, the results of soil bulk density are found to be in the 1.1 – 1.2 g/cm^{3}and its low for all sample sitesas shown in Table 1. This is due to high clay and silt contents of soil and compactness that occupy small volume (Desta, B., 2002).

In this study the soil samples have high clay contents about 43.5 %, moderate silt about 36.75 % and low sand contents, about 18.5 %, which show a soil class of clay or nitosol(Van Lierop, W. (1991).

Status of soil acidity

The results of this study indicate that the pH of the study area is below 5.5 and acid cations such as H^+ and Al^{+3} are responsible for such acidity. As shows in Table 2, the concentration of exchangeable Al^{+3} is high (2.33 to 2.85 cmol/Kg) indicating Al toxicity to be expected in the area. This result in agreement with the result of, Susolski T. (2004) who reported exchangeable Al^{+3} as 2.76 ± 0.17 and total exchangeable acidity as 3.19±0.93 cmol/Kg. So, high exchange between acid cations (Al^{+3} and H^+) and basic cations (Na^+, K^+, Ca^{+2}, Mg^{+2} and NH_4^+) is expected and Al^{+3} toxicity may affect the availability of basic cations specially during plant roots uptake of the nutrients.

Exchangeable acidity indicates the presence of excess Al^{+3} and H^+ ion on the soil colloid as compared to total cation exchange capacity (CEC) of the soil and the acid cations are occupy the site of basic cations. So, in this study area, there is high exchangeable acidity and acid saturation percentage (Haynes, J. R., 2001). This needs ameliorative measures like liming.

Exchangeable cations and micronutrient before liming

In this study, the concentrations of available phosphorous, potassium, calcium and CEC are low. This is due to low pH and high exchangeable acidity. According to Landon(1991), the top soils having AP and CEC of > 25, 15-25 cmol/kg, 5-15 cmol/kg and < 5 cmol/kg are classified as high, medium, low and very low, respectively. Based on the above ratings, the soils of all the site of the study area qualify for low status (less than 15 ppm and 15cmol/Kg) for AP and CEC, respectively as it is shown in Table 2 and 3. However, micronutrients such as iron and manganese concentration are very high (208.17±11.37-190.08±21.43 ppm) and (130.01±7.17-102.44±7.65 ppm) respectively. Similarly the concentration of Fe and Mn> 66.5 ppm was classified as high and based on this classification; the results of Fe and Mn, in all sample sites are high as shown in Table 3.

A greenhouse incubation of liming acid soil

Liming raises the soil pH by adding calcium & magnesium to soil and causes the aluminum and manganese to go from the soil solution back in to solid (non-toxic) chemical forms.

In this study the change in soil pH due to lime materials application results were recorded within two weeks intervals and the result indicates that the soil pH increases as liming time increases. However, the change (increases) of soil pH in the first two months was lower than the remaining month. This might be due to strength of exchangeable acid in the first time and after long time interaction of lime materials and acid cations and the acid became weak and change of soil pH is expected to increase rapidly as it is shown in Figure 1 & Table 4.

This study shows that the farmers must stay at least more than two months after applying lime to sow their seeds. Except sun light variation and lime application rates, target pH and the decrease in the exchangeable acidity attains its minimum value at 90 days of incubation period. After 90 days of incubation the pH(KCl)is 6.8 and exchangeable acidity is 0.93 Cmol/Kg in the soils. The application of lime materials in greenhouse incubation for 90 days neutralized the acid soil by increasing soil pH and decreasing exchangeable Al^{+3}. Lime ($CaCO_3$) reacts with H^+ in soil solution to produce H_2O and CO_2 and also convert Al^{+3} from toxic to none toxic forms (Taye, B., 2008).

Comparison of exchangeable acid and anions before and after liming

As it shown in Table 5 paired t-test results reveal that significant differences are observed in the pH, total exchangeable acidity, exchangeable Al^{+3}, available phosphorous, and total nitrogen concentrations between soil samples before and after liming, while there is no significant difference between the soil sample before and after liming, in their organic carbon content. The average pH (H_2O) was 5.05±0.06 and 7.36±0.07 for before and after liming, respectively, which shows the area, was strongly acidic.

Like soil pH, exchangeable H^+ and Al^{+3} show high significant difference between before and after liming. From total exchangeable acidity, exchangeable Al^{+3} is reduced from 1.98±0.04 to 0.027cmol/Kg and

Table 1: The mean± SD results of soil physical properties

sample	% Moisture	BD (g/cm^3)	Texture			
			% Clay	% Silt	% Sand	S. Class
Minjaro	38.2±1.1	1.13±0.013	42.75	38.75	18.5	Clay
GM	41.8±0.91	1.2±0.016	43.25	36.75	20	Silt-Clay
Gutu	38.1±1.58	1.14±0.014	43.5	37.25	19.25	Clay
Kore	39.9±1.14	1.19±0.004	44	38.50	17.5	Clay
Gudu	37.3±1.8	1.21±0.006	43.75	36.50	19.75	Clay

BD- Bulk Density and S.Class- Soil Class

Table 2: The average status of soil acidity and pH by both water and KClbefore liming

Sample Site	Exch.Acidity (cmol/Kg)	Exch. Al^{3+} (cmol/Kg)	Exch. H^+ (cmol/Kg)	pH(KCl)	pH (H_2O)	Avail.P (ppm)	%TN
Minjar	3.22±0.01	2.23±0.04	0.99±0.07	4.1	4.9	7.4±.1	0.22±0.002
GM	2.86±0.02	1.6±0.01	1.26±0.03	4.06	4.9	9.6±0.075	0.18±0.003
Gutu	3.49±0.02	2.1±0.01	1.48±0.04	4.04	5.1	10.47±0.048	0.16±0.005
Kore	3.21±0.07	2.3±0.06	0.91±0.06	4.07	5.3	9.72±0.093	0.21±0.004
Gudu	3.16±0.07	1.89±0.01	1.27±0.08	4.01	5.06	8.51±0.16	0.19±0.002

Cmol/Kg – Centi mole per Kilogram of soil TN – Total Nitrogen AP - Available Phosphorous Exch.Al^{+3} and H^+ - Exchangeable aluminium and hydrogen

Table 3: The mean ± SD of exchangeable cations and micronutrient before liming

Sample site	**Exchangeable cations (ppm)**					**Micronutrients (ppm)**			
	Na	K	Ca	Mg	CEC	Fe	Mn	Cu	Zn
Minjar	1.7±0.02	5.7±0.02	24±0.08	17.3±0.06	86.4±1.53	208.7±2.47	107.2±2.73	6.08±0.017	2.6±0.069
GM	1.1±0.01	6.2±0.03	20.6±0.08	9.17±0.07	77.0±1.64	190.1±2.43	130.01±2.17	4.56±0.016	2.4±0.048
Gutu	1±0.02	6.1±0.02	26.9±0.03	13.8±0.09	78.7±1.51	207.7±2.83	114.07±3.41	4.83±0.023	2.3±0.068
Kore	1.3±0.01	5.1±0.03	30.4±0.02	16.6±0.06	105.1±1.4	202.9±1.95	105.71±2.89	6.14±0.034	2.7±0.063
Gudu	1±0.01	5.8±0.09	25.7±0.02	12.7±0.09	97.0±2.03	192.7±3.29	102.44±2.65	4.73±0.017	2.01±0.059

CEC- Cation exchangeable capacity

Table 4: A greenhouse incubation of liming acidsoil as a function of duration with pH

Liming time(days)	**pH(KCl)**	**Temp.(^{0}C)**
BL	4.1-4.3	23
14	4.2-4.4	22
28	4.57-4.72	23
42	4.7-4.9	23
56	5.1-5.3	23
70	5.6-5.9	23
84	6.4-6.9	22

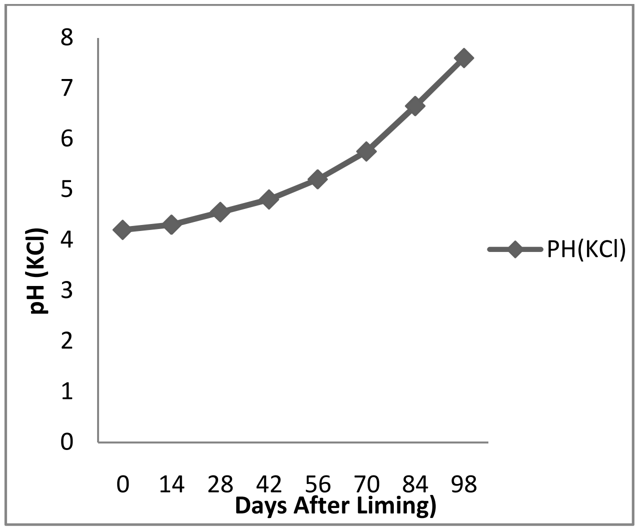

Figure 1: The effects of liming incubation time on soil acidity

exchangeable H^+ was reduced from 3.19±0.01 to 0.73±0.01cmol/Kg, after a greenhouse incubation liming of acid soil. This indicates exchangeable acidity, which dominates the area is removed from the soil. On the other hand, after liming, the availability of basic cations show increase as exchangeable acidities are decreased, to maintain positive and negative charge neutrality in soil solutions (Achalu, 2012).

Similar conclusion was reached by Simard *et al* (1994) who observed no effect of liming on OC content of the acidic soil. For all soil sample sites increasing the soil pH due to applied agricultural lime show a significant effect on total N content. This may be due to N losses from the soil and decreased N fixation due to less bacterial action in acid soil.

However, phosphorous availability is significantly affected by soil acidity. As illustrates in Table 5, the phosphorous concentration is found to be roughly doubled after liming for all soil sample sites. This is due to the nature of existence of phosphorous in soil. The existence of P is highly limited by soil pH. At pH < 5.5 P exists in the form of $AlPO_4$ and $FePO_4$, while at pH > 5.5 it exists in the form of $Ca_3(PO_4)_2$, $H_2PO_4^-$ and HPO_4^{-2}. On the other hand, there is a high competition between acid cations such as Al^{+3}, $Fe^{+3}$and basic cations such as Na^+, K^+, Ca^{+2} and Mg^{+2} to be bonded to PO_4^{-3}.

According to Haynes *et al* (2001) at low soil pH, Al and Fe are highly soluble and react with phosphorous to form insoluble $AlPO_4$ and $FePO_4$, which are precipitates and could not be absorbed by plant roots. Absorption of PO_4^{-3} by plant roots depends on root length and hairs (branches) on the root. This is due to the less mobile nature of phosphate ion and it could not move towards to plant roots rather than plant roots are moves towards to PO_4^{-3} to uptake it (Yihenew, G. (2002). In this study, the mean P concentration in limed soil sample is higher (20.85 ppm) than before liming (9.14 ppm) which clearly shows highly significant effects of soil acidity on P availability and this is agreement with reported by Adane B. (2014).

Comparison of exchangeable cations and micronutrients before and after liming

Sodium (Na^+): In this study concentration of sodium is found to be 0.12 and 10.6 ppm for before and after liming, respectively, which shows significant difference indicating that the soil acidity affecting the sodium availability.

Potassium (K^+): In this study, the results obtained for potassium are (5.67 and 14.58 ppm) for before and after liming respectively, which shows significant difference between before and after liming. Deficiencies of potassium in nitosol of study area before liming in acid soil is due to insolubility of K^+ at low pH, leaching easily by high rain fall and replacement by soluble H^+ and Al^{+3} in water solution (Huluka, (2005).

Calcium (Ca^{+2}): In this study, Ca concentration before liming acid soil (25.5±0.002 ppm) and after liming (171±2.7 ppm) clearly indicates the effects of soil acidity on calcium availability. The increasing exchangeable calcium availability during greenhouse incubation for liming soil acidity is due to soil pH increase and this is also for phosphorous availability and plant root uptake of PO_4^{-3} in the form of $Ca_3(PO_4)_2$. According to Hue (1998) calcium phosphate easily release phosphate ion to plant roots while $AlPO_4$ and $FePO_4$ are precipitated and do not

Table 5. The effects of liming on some selected soil chemical properties

Parameters	Mean ± SE		Paired t-Test		Difference
	BL	AL	t_{crit}	t_{cal}	Significant
pH (H_2O)	5.05±0.06	7.36±0.17	2.13	34.60	*
pH (KCl)	4.06±0.04	6.88±0.08	2.13	63.70	*
Exch. Acid	3.19±0.021	0.73±0.006	2.13	14.70	*
Exch. Al	1.98±0.04	0.027±0.003	2.13	30.09	*
%OC	1.24±0.001	1.23±0.007	2.13	1.51	ns
%TN	0.16±0.003	0.23±0.007	2.13	4.00	*
AP(ppm)	9.14±0.075	20.85±0.004	2.13	8.10	*

BL-Before Liming AL-After Liming * Significant different ns-No significant difference

Table 6: Comparison of the exchangeable cations and micronutrients before and after liming

Parameters	Mean ± SE (ppm)		Paired t-Test		
	BL	AL	tcrit	tcal	Significant
Na	1.2±0.002	10.46±0.07	2.13	57.87	*
K	5.78±0.003	14.58±0.042	2.13	23.20	*
Ca	25.52±.004	171±0.083	2.13	18.97	*
Mg	13.91±0.061	39.81±0.3	2.13	16.72	*
CEC	85.52±0.019	244.14±0.054	2.13	7.30	*
Cu	5.276±0.004	2.53±0.078	2.13	26.44	*
Fe	200.304±0.095	30.456±0.071	2.13	37.55	*
Mn	112.044±1.86	23.488±0.175	2.13	18.68	*
Zn	2.402±0.048	1.44±0.003	2.13	7.17	*

CEC – Cation exchangeable capacity tcal - t-calculate tcrt - t-crtical

release PO_4^{-3} to plant roots. On the other hand, the highest significant difference between mean concentrations of calcium (25.5 and 171 ppm) before and after liming is due to the increase in the solubility of Ca at higher pH(Tekalign, B.,1992).

Cation exchangeable capacity (CEC): In this study there is significant difference between CEC concentration before and after liming, as shown in Table 6. The highest significant difference of CEC before and after liming is due to low pH, exchangeable acid cations such as H^+ and Al^{+3} increase and occupies the site of basic cations (Tekalign, B.,1992). However, after 90 days greenhouse incubation acid cations leave the sites and replaced by basic cations in the soil solution. The result of this study shows that the mean concentration of CEC changes from 85.52 ± 0.019 to 244.14 ± 0.054 ppm before and after liming, respectively, which indicates soil acidity highly affects CEC availability.

Micronutrients: Like exchangeable cations, micronutrients such as Cu, Fe, Mn and Zn are significantly different before and after liming as shown in Table 6. Considering the mean results of Fe concentration, the highest (200.17 ppm) and lowest (190.08 ppm) for soil samples of the study area, are in agreement with the study of Birhanu (2010) for the same range of soil pH. Similarly, the highest (130.01 ppm) and lowest (102.44 ppm) concentration is recorded for Mn before liming. The results of this study show that among the four micronutrients, iron and copper are significantly high in soil samples before liming. The highest concentration of all micronutrient elements (Fe, Cu, Mn, and Zn) recorded in acid soil is due to the availability of these nutrients at low pH. McDowell(1994)reported the concentration of micronutrients are 3.10, 197.63, 117.31 and 1.58 ppm for Cu, Fe, Mn and Zn respectively, which is in agreement with this study which gives of 2.956, 200.3, 112.04 and 1.44 ppm for Cu, Fe, Mn and Zn, respectively. In this study, the result recorded for Mn and Fe before liming are high (112.04 ppm and 200.3 ppm) respectively, which shows at low pH both nutrients are highly soluble.

In this study, the effects of pH and soil acidity on micronutrients availability are clearly observed in Table 6t-calculated >t-critical shows high significant difference as shown in Table 6. All micronutrients concentration in acid soil of pH(H_2O) < 5.3 is higher than limed soil in the greenhouse incubation with pH(H_2O) > 6.8. The highest concentration of Fe and Mn (200.03 ppm) and (112.04 ppm) in soil acidity of before liming are indicators of the increasing in concentration of micronutrients as soil pH decreases. On the other hand Fe and Mn are the main causes of soil acidity next to Al^{+3} by producing H^{+} in soil solution (HelufG. and Kibebow, K. (2012).

However, after 90 days greenhouse incubation of liming acid soil, the low mean concentration is recorded for Fe (30.45 ppm) and Mn (23.87 ppm) as the pH increases to 7.3 at this pH, Fe and Mn insoluble and replaced by Ca^{+2} ion found in lime. Similarly, the results of Cu and Zn concentration are decreases almost by half (5.276 ± 0.004 to 2.53 ± 0.078 ppm and 2.402 ± 0.048 to1.44 ± 0.003 ppm) after liming respectively as shown in Table 6. The greatest difference of micronutrients before and after liming indicates the status of soil acidity in the study area is significantly affecting micronutrients availability (Solomon, 2008). Table 6, clearly illustrates that, as soil pH increases due to liming, the availability of exchangeable cations also increases, while the availability of micronutrients decreases as soil pH increases.

CONCLUSION

This study assesses lime requirement and its effect on plant nutrient availability. The results reveal that soils in all of the sample sites are acidic pH (H_2O) < 5.3 with low concentration of soil macro nutrients. It is found that the average values of exchangeable acidity and exchangeable Al show results within the ranges 3.49-2.86 cmol/Kg and 2.3-1.86cmol/Kg respectively.

From this study, it is observed that soil acidity and liming factor directly affect plant nutrients. As compared by paired t-test, except OC, macro and micronutrients are significantly affected by soil acidity. Application of lime results in reduction of exchangeable acidity, Al saturation and thereby increasing soil pH. In addition, treatment of acidic soil with lime result in an increase in the concentration of the exchangeable cations (Na^{+}, K^{+}, Ca^{+2} and Mg^{+2}) and decrease micronutrients(Cu, Fe, Mn and Zn) in the soil solutions, from exchange complex to the levels required and increasing nutrient availabilities for plant uptakes.

After 90 days greenhouse incubation of liming acid soil, all limed soils attain the target pH 6.9 and decrease in exchangeable acidity to 0.93 cmol/Kg and Al to 0.027cmol/kg. During application of lime, soil pH increases slightly in the first two months and fastly increases after two months due to a slight decrease in the strengths of acidity as liming period increases.

RECOMMENDATION

So, the farmer must stay at least two months after applying the lime to sow his/her seeds. This is due to the reaction between lime materials and soil acidity is slow and time dependent reaction. To validate the findings of the present greenhouse incubation study and for the profitability of acid sensitive crops production, farmers may need to apply optimum lime to the soils under study.

This study area is found to be medium to high in N and P content after liming acid soil. Therefore, in this area it is recommended to use liming instead of applying more fertilizers for increase crop productivity.

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