Evaluation of the use of wood ash for the reduction of soil acidity in Nano Jeno area, Lalo Kile woreda,Oromia regional state, Ethiopia

By: DIRIBA KEBEDE

A Thesis Submitted to School of Applied Natural Sciences Department of Chemistry in Partial Fulfillment of the Requirements for the Degree of Master in Chemistry

Office of Graduate Studies

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

September, 2018 Adama,

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Adviser:-TEGENE DESALEGN (PhD)

Co- adviser:-Hadgu H/Kiros (PhD)

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DECLARATION

I hereby declare that this M.Sc Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: Diriba Kebede Workneh

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This M.Sc Thesis has been submitted for examination with my approval as thesis advisor.

Advisor Name: Dr. Tegene Desalegn

Signature: _____

Date of submission: 17/09/2018

APPROVAL OF BOARD OF EXAMINERS

We, the undersigned, members of the Board of Examiners of the final open defense by **Diriba Kebede** have been read and evaluated his/her thesis entitled "**Evaluation of the use of wood ash for the reduction of soil acidiy in Nano Jeno area, Lalo Kile Woreda, Oromia regional state, Ethiopia**" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement of the Degree of Masters of Science in Chemistry

Supervisor /Advisor	Signature	Date
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Chairperson	Signature	Date
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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
AASH	After ash
ANOVA	Analyisis of Variance
AP	Available Phosphorous
AR	Ash Requirements
BASH	Before Ash
BD	Bulk Density
CCE	Calcium Carbonate Equivalent
CEC	Cation Exchangeable Capacity
Cmol/k	Centi mole per kilogram
CV	Coefficient of Variance
DAP	Diammonium Phosphate
DTPA	Diethylene tetra amine acetic acid
EIAR	Ethiopia Institution of Agriculral Research
FAO	Food and Agricultural Organisation
HARC	Holletta Agricultural Research Center
ISFMCP	Integrative Soil Fertility Mangement and Crop product
LSD	List Significant Difference
MC	Moisture Contents
NPK	Nitrogen Phosphorous and potassium
OC	Organic Carbon

OM	Organic Matter
PBS	Percentage of Base Saturation
Ppm	Parts per million
SAS	Statically Analysis System
SE	Standard Error
SNNPR	South Nation Nationality and Peoples Region
TN	Total Nitrogen
WA	Wood Ash

ABSTRACT

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 effects of soil acidity on plan t nutrients availability and to determine reduction in acidity on using wood ash in soil concentrat ion of an area.More specifically the study pointed out statistically,the difference between nutrient availability before and after treating with wood ash soil acidity was tested using paired t test and comparison of nutrient variation within the sites by using statistics ANOVA and also comparison of analytical methods such as soil pH (Water),phosphorous (Olsen method) and Calcium (AAS) using t test.The results indicated that the soil of study area were strongly acidic (pH<5.3) and exchangeable acidity (2.910±.020 upto 3.21±0.01 cmol/Kg). After 72 days greenhouse incubation of acid soils with wood ash, the results shows acidity was effectively reduced, which indicated it was properl limed and the effects of soil acidity on nutrient availability was clearly observed.The concentration of all anions, cations and micronutrients were found to be significantly different except TN and OC, between the soil samples for before and after adding ash.However, all anions and micronutrients were found to be significantly different (P<0.05) except OC, N and K among the different sites and lime factor.For comparison of analytical methods pH (Water), phosphorou s (Olsen method) showed significant difference but, Ca byAAS showed no significantdifference usi ng t-test.

Key words: *Soil acidity, adding wood ash, Exchangeable acidity, Greenhouse incubation, Nitos*

1. INTRODUCTION

1.1 Back ground of the study

In Ethiopia large surface areas of highlands located at almost all regional states of the country are affected by soil acidity. According to (Tolessa Debele et. al., 2009), about 40.9 % of the Ethiopian total land is affected by soil acidity. About 27.7% of these soils are dominated by moderate to weak acid soils with pH 4.5-5.5 in KCl, and around 13.2 % by strongly acidic soils with pH < 4.5 in KCl. The strongly acid soils are found in ecologies which receive high amount of rainfall and have warm temperatures through much of the year that often found in soil taxonomic orders of Oxisols and Ultisols(USDA. 1999) and Ferralsols (FAO. 2001).Soil acidity is now becoming a serious challenge to crop production in the highlands of Ethiopia (Taye Bekele.2007).

Thus, the most strongly acidic soils (having pH of 4.5 up to 5.5) which expanding both in scope and magnitude; severely limiting crop production (Wassie Haile et al. 2009/2011 ; Tamene Lulseged et al.2017).Recently, (Eyasu Elias, 2016) also reported that 80% of the Nitisols and Luvisol subgroup soils found in the north central and south western high lands of Ethiopia.The main soil forming factors giving rise to an increase in soil acidity in Ethiopi a involve climatic factors such as rain fall, temperature, topographic factors, morphological factors and severe soil erosion. Some of the well-known areas severely affected by soil acidity in Ethiopia is Nedjo of the western Oromia regional state (Hirpa L.et al., 2013).

The effect of soil acidity in these regions have caused mineral stress and infertility in the soil which can be attributed to excess aluminum, iron and manganese and to deficiencies of nitrogen,phosphous,potasium,Calcium,magnesium and host of micronutrients on the other (Chris Gazey et al .2009). Because of these circumstances a number of adverse effects are observed such as loss of crop diversity, decline in the yield of existing crops, lack of response to ammonium phosphate and urea fertilizers and complete failure of cropping land. Moreover soil acidity may lead to reduced yields, poor plant Vigor, uneven pasture and crop growth, poor nodulation of legumes, stunted root growth, persistence of acid-tolerant weeds, increased incidence of diseases and abnormal leaf colors are major symptoms which indicate soil acidity problem.

Increased acidity is also likely to lead to poor plant growth and efficient water use as a result of nutrient deficiencies and imbalance, and/or induced aluminum and manganese toxicity. Aluminum and Manganese in the root zone are known to cause a serious problem in plants, aluminum affected roots tend to be shortened and swollen, having as tubby appearance. Also high concentration of Al affects uptake and translocation of nutrients (especially immobilization of phosphorus in the roots), cell division, respiration, nitrogen mobilization and glucose phosphorylation of plants (Hue, N.V. 1998).

A number of studies have been carried out on the utilization of wood ash either for correcting nutrient deficiencies or imbalances due to acid deposition and leaching in forestry soils, or as a liming agent in agricultural soils. Application to soil is a convenient way of recycling some nutrients, such as Ca, K, Mg, Na and P and N are absent or generally present in wood ash at low concentrations, due to their volatilization during combustion (Vance E.D., Mitchell C.C. 2000).

In order to determine the extent of the above mentioned soil acidity problems in Nano Jeno a rea, Lalo Kile woreda, it was important to analyse the situation at depth and evaluate the inte rvention through treating with wood ash.

1.1. Statement of the Problem

Soil acidity is one of the major limiting factors to acid sensitive crop production in the weste rn highland of Oromia Region state.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 .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.

Lalo Kile woreda, Oromia region, is the most highland area (2556m above sea level) Wester n Oromia regional state.The woreda is located at a distance of around 543 km, west of the ca pital Addis Ababa with abundant rain fall 1100 mm is susceptible to acidification. Since soil acidity is known to exert an important influence on the growth of plants, crops productivity

and land use planners should be informed regarding the acidity of the land upon which they work. Soil acidity results unavailability of plant nutrients and toxicity of some elements which have detrimental effect on yield reduction.

However, Nano Jeno area of Lalo Kile woreda has a severe yield reduction problem; one rea son for reduction may be due to soil acidity problem. Although studying soil acidity problem s and quantitative analysis using soil laboratory tests to acquire solutions for this problem was very little. Because of the above fact the area is not food secured. The Productivity of the area is declining year to year and the farmers expand their farm land to peripheries and mountainous areas that are not favorable for cultivation. In order to secure sustainable crop production and reasonable yield, acidic soils of an area have to be corrected by addition of wood ash to a pH range which is suitable for better yield of crop production.

1.2. Objective

1.2.1. General Objective

The general objective of this study of an area is to investigate effects of wood ash on plant nutrient availability and to determine wood ash requirement to reduce the soil acidity for im proved nutrient availability under bean cultivation in different sites an area.

1.2.2. Specific Objectives

- To determine the extent of soil acidity in soil sample of the study area.
- To identify the effects of soil acidity on macro (P, Na, K, Ca, Mg) and micronutri ents (Fe, Cu, Mn and Zn) availability.
- Characterization of soil physical and chemical properties before and after application of wood ash.

1.3. Significance of the Study

The importance of this research is to provide an updated data about the status of soil acidity and its effects on plant nutrients availability in the area, hence used as base line information about wood ash application programs and to enhance, the status of soil fertility in the region. This will generate base line data in soil physicochemical property for woreda agricultural of ficials and agricultural development agents.

1.4. Limitations of the study

Due to time and budget constraints, this research work focuses on two kebeles of Lalo Kile woreda, and may not represent the whole woreda. The research is limited on the determinati on of major macro and micro nutrients, all soil quality parameters are not analyzed. Furthermore, maximum rates of wood ash requirements are not evaluated in the laboratories as well as on the field.

2. LITERATURE REVIEW

2.1. Soil pH and Its Effect on Plant Nutrients Availability

Soil pH is a measure of hydrogen ion (H^+ or H_3O^+) activity in the soil solution. Activity is similar to concentration in non salt affected soils.Soil pH influences many facets of crop pro duction and soil chemistry,including availabilities of nutrients and toxic substances, activitie s and nature of microbial populations, and activities of certain pesticides. Soil pH is defined as the negative logarithm of the hydrogen ions (H^+) activity (moles per litter) in the soil solution. As the activity of H^+ in the soil solution increases, the soil pH value decreases. Because of the logarithm scale, soil with a PH of 4 is 10 times more acidic than a soil with a PH of 5 and 100 times more acidic than a soil with a PH of 6.This means that a small decrease in soil PH results in a large in acidity (figure 2.1 and 2.2) (Chris Gazey and Stephen Davies.2009)

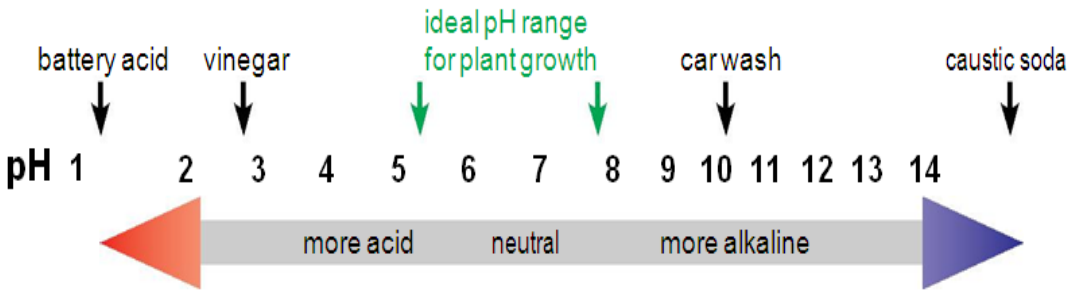

Figure 2.1 Examples of where common substances fit on the pH scale (Chris Gazey and Stephen Davies.2009)

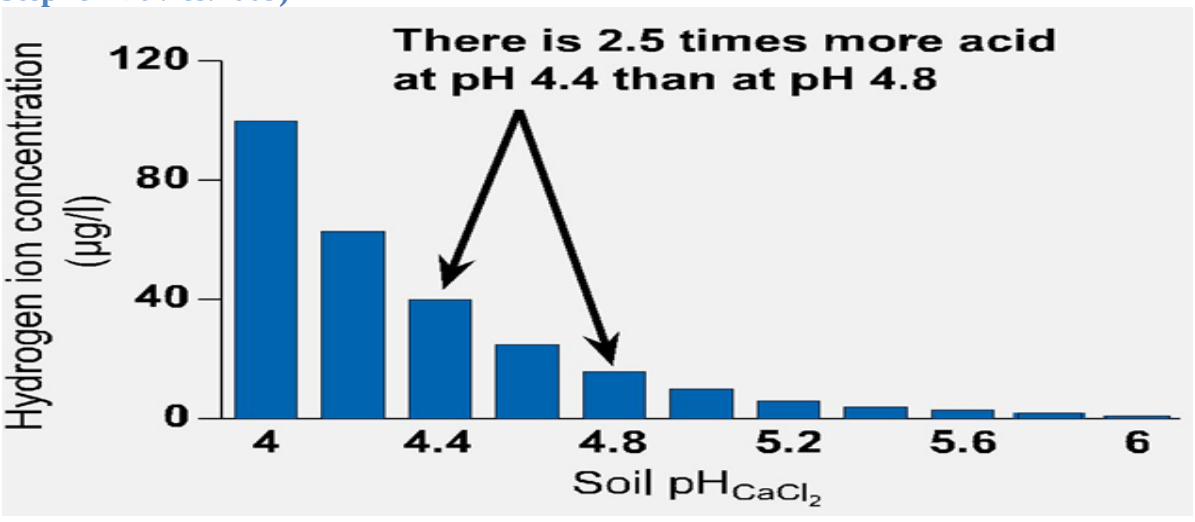

Figure2.2: comparison of degree of acidity Chris Gazey and Stephen Davies.2009).

Table 2.1 Descriptive ranges for pH (H_2O) with corresponding status or strength of acidity in soils

Denomination	PH(H_2O) Range	Denomination	PH(H_2O) Range
Ultra acid	**Less than** 3.5	Neutral	6.6-7.3
Extremely acid	3.5-4.4	Slightly alkaline	7.4-7.8
Very strong acid	4.5-5.0	Moderate alkaline	7.9-8.4
Strong acid	5.1-5.5	Strong alkaline	8.5-9.0
Moderate acid	5.6-6.0	Very strong alkaline	> 9.0
Slightly acid	6.1-6.5	-	-

Source: Bruce and Rayment (1982)

As the pH decreases below 5.5, the availability of manganese (Mn) increase and may reach a point to stop plant growth.Excess aluminum ion aluminum (Al^{3+}) in the soil solution interferes with root growth and function, as well as restricting plant uptake of certain nutrients, namely, calcium (Ca^{2+}) and magnesium ions(Mg^{2+}) (Ketterings, Q. M. 2005).

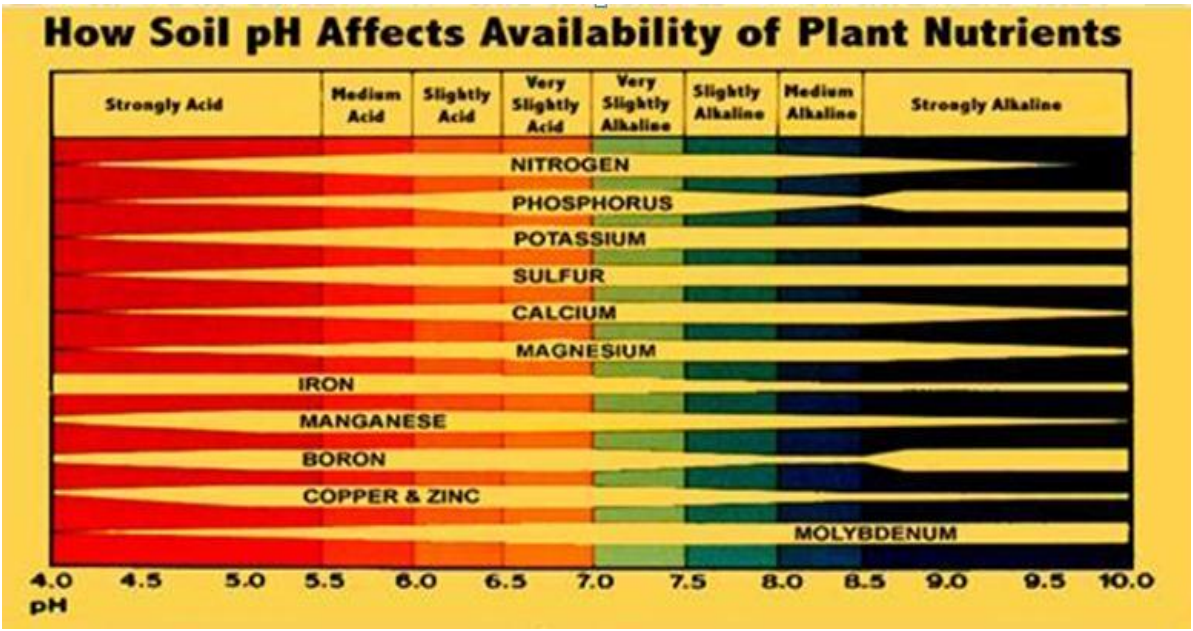

Figure2.3: The effect of soil pH on the availability of essential plant nutrients (Ketterings, Q. M. 2005).

As shown in figure 2.3, the greater nutrient availability is indicated by yellow thickened lines, where as narrow lines indicate a decrease in availability. Macronutrients such as nitrogen, phosphorus and potassium (NPK) (primary macronutrients) and Calcium, Magnesium and Sulphur (secondary macronutrients) are more available at pH between 6.5-7.5 (neutral and slightly acid and base), while micro nutrients such as iron, manganese, copper and zinc are available at pH < 6.5 (acidic condition), as shown in Figure 2.3 (Ketterings, Q. M. 2005).

2.2. Cause of Soil Acidity

"Soil acidity" is the term used to express the quantity of hydrogen (H^{+}) and aluminum (Al^{3+}) cations (positively charged ions) in soils. When levels of hydrogen or aluminum ions become too high and the soil becomes too acidic, the soils CEC becomes "clogged" with the positively charged hydrogen and aluminum ions, and the nutrients needed for plant growth are pushed out. This is why root growth and plant development suffer when soils become too acidic. Over time, soils also become acidic because calcium and magnesium leach out, hydrogen is added to soils by decomposition of plant residues and organic matter, nitrification of ammonium occurs when fertilizer (ammonium nitrate, ammonium sulphate, anhydrous ammonia), manure,or plants produce acidic cations such as hydrogen and alumin um ions (Eswaran, H. P.1997) .The following sections address the main source of soil acidity.

2.2.1. Parent materials

Due to differences in chemical composition of parent materials, soils become acidic after dif ferent lengths of time. Soils which are formed from acid nature of rocks (granites and sandstone) are very acidic while limestone valley soils are basic as they are formed from basic rocks (limestone), but acidic on the surface because of weathering (Paulos, D. 2001).

2.2.2. Rainfall (Leaching)

Excessive rainfall is an affective agent for removing basic cations over a long period of time (thousand years). Water passing through the soil leaches basic cation such as calcium (Ca^{2+}), magnesium (Mg^{2+}) and potassium (K^{+}) in to drainage water. These basic cations are replaced by acidic cations such as aluminum (Al^{+3}) and hydrogen (H^{+}). For these reason, a

soil formed under high rainfall condition are more acidic than those formed under normal conditions that based on the types of rainfall and types of soils (Paulos, D. 2001)

2.2.3. Organic matter decay and fertilizer

Decaying organic matter in both chemical and organic fertilizers may eventually make the soil more acidic, by producing H^+ which is responsible for acidity. Hydrogen is added in the form of ammonium-based fertilizers (NH_4^+), urea-based fertilizer [$(CO(NH_2)_2$], and as proteins (amino acids) in organic fertilizers. Transformations of this source of nitrogen in to nitrate (NO_3^-) releases H^+ to create soil acidity, as it is shown in Equation a and b. Therefore, fertilization with fertilizer containing ammonium or even adding large quantities of organic matter to a soil will ultimately increase soil acidity and lower the pH (Xu, R. K.et al. 2002)

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O \quad \text{..... (a)}$$

$$(CH_2O)\,n + O_2 \rightarrow H_2CO_3 + H^+ + HCO3- \quad \text{..... (b)}$$

Soil acidification occurs naturally very slowly as soil is weathered but it accelerated by productive agriculture. The two main causes of soil acidification are: - in efficient use of nitrogen and export of food and fiber from the farm.

2.2.3.1 Nitrate Leaching

Nitrogen is agricultural systems may be fixed from the atmosphere by legumes decomposed from soil organic matter (the dead remains of plants and animals) by soil organisms or added in various types of fertilisers.Different nitrogen fertilizers follows slightly different chemical path ways as they break down in the soil and contribute different amounts of hydrogen ions (acid) to the soil. Ammonium based fertilizers are the major contributors to soil acidification and this is increased by leaching. Ammonium nitrogen from fertilizers or soil organic matter is readily converted to nitrate and hydrogen ions by bacteria in the soil (as shown on figure 2.4).

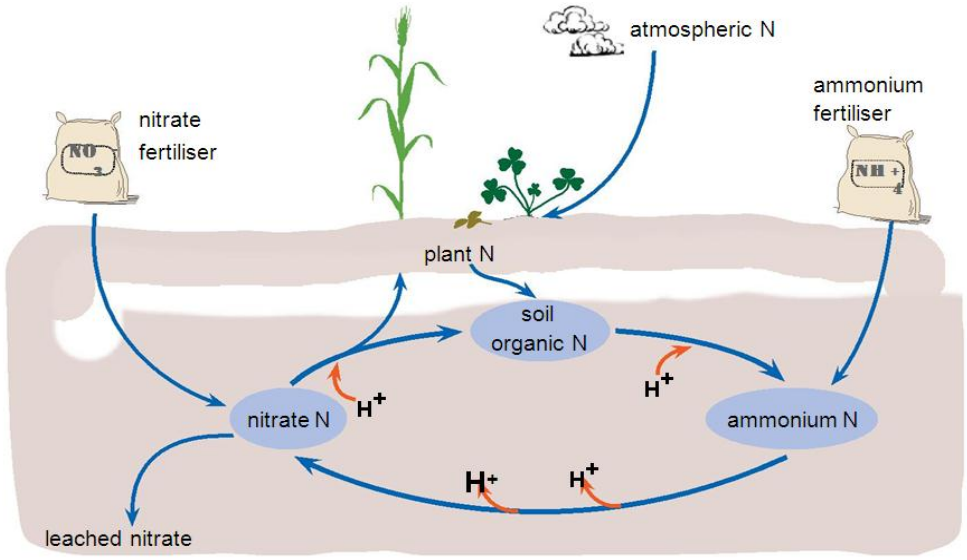

Figure 2.4. the main pathways showing the involvement of nitrogen (N) fertilizers in soil acidification (Chris Gazey and Stephen Davies.2009).

2.2.4. Plant uptake of basic cations

Removal of "base" cations, such as calcium, magnesium, potassium and sodium, are reported as a cause for soil acidity. These basic cations are removed by plants from the soil and replaced with H^{+}& Al^{+3} in order to maintain charge neutrality (Paulos, D. (2001).

2.2.5. Harvest of high yielding crops

Harvesting of crops has its effect on soil acidity development because crops absorb the lime like elements as cations, for their nutrition. When these crops are harvested and the yield is removed from the field, then some of the basic materials responsible for counteracting the acidity developed by other processes are lost, and the net effect is increase in soil acidity. Increasing crop yields will cause greater amounts of basic materials to be removed. Grain contains less basic materials than leaves or stems. For this reason, soil acidity will develop faster under continuous wheat pasture than when grain only is harvested. High yielding forages, such as Bermuda grass or alfalfa, can cause soil acidity to develop faster than other crops (Dawit, S. F. 2002).

2.3. Classification of Toxic Acidity in Soil

There are three general pools or sources of acidity: active, exchangeable and residual. Active acidity is the quantity of hydrogen ion (H^{+}) that are present in the soil water solution.

The active pool of hydrogen ions is in equilibrium with the exchangeable hydrogen ions that are held on the soil's action exchangeable complex. This pool most readily affects plant growth and active acidity may be directly determined using a pH meter, such as an electron probe. The second pool, exchangeable acidity, refers to the amount of acid cations, aluminum and hydrogen, occupied on the cation exchangeable capacity (CEC). When the CEC of a soil is high but at a low base saturation, the soil becomes more resistant to pH changes. As a result, it will require larger additions of lime to neutralize the acidity (Jiu-Y.et al., 2017). Residual acidity comprises of all bound aluminum and hydrogen in soil minerals. Out of all pools, residual acidity is least available (Chris Gazey and Stephen Davies.2009).

2.4. Some Acid Cations Toxicity and Their Effects on Soil Fertility and Plant Growth

2.4.1. The effect of aluminum toxicity

Soluble aluminum in the soil solution causes most of the problems associated with acidic soils. The principal effect of aluminum toxicity is to reduce the mass and function of roots. Generally this is seen in the field as stunted, shaped roots. This reduces their ability to extract moisture from deep in the soil. Aluminum toxicity can occur in soils that have large amounts of aluminum containing minerals. In such soils, aluminum can dissolve into t he soil solution as the soil pH drops below 5.4. In contrast, aluminum solubility decreases dramatically as the soil pH increases above 5.4.As a result, proper management of soil pH ca n prevent problems associated with aluminum toxi city. Much of the poor root development (and drought susceptibility) seen in soils with acid subsoil layers (pH less than5 .0) is generally due to primarily aluminum toxicity, which limits both rooting depth and the degree of branching as shown in Figure 2.5 Chris Gazey and Stephen Davies.2009) and Table 2.2 (Hossner, L. R. .1989).

Figure 2.5 Wheat seedlings grown in soil with a range of aluminum concentrations. Photo: S Carr (Chris Gazey and Stephen Davies.2009)

Excessive amounts of aluminum can inhibit root development and limit crop growth. Aluminum saturation is an expression which describes the relative abundance of aluminum in the soil. Like base saturation, aluminum saturation is the percentage of the cation exchang eable capacity (CEC) occupied by aluminum. Like all cations, aluminum held by the cation exchange complex is in equilibrium with aluminum in the soil solution. Although the toleran ce to aluminum varies among plant species, most plants do not tolerate greater than 15% aluminum saturation.

Aluminum toxicity reduces root growth			
S. No	**Al (ppm)**	**Cotton root length**	**Remark**
1	0	16cm	
2	0.25	11 cm	
3	0.5	8 cm	

Table 2.2: The decrease in cotton root length as concentration of aluminum increases (Jiu-Y.et al .2017)

There are two main effects of aluminum and hydrogen on growth: (I) injury to roots, and, (ii) decreased uptake of cations (Ca^{2+}, Mg^{2+},and K^{+}) as shown in Figure 2.5 (Chris Gazey and Stephen Davies.2009).The toxic effects of $Al^{3+}$and H^{+} are manifested quite differently in soils. In organic soils, aluminum is complexes very strongly by the organic fraction, therefore, there is very little Al^{3+} present. Consequently, poor plant growth resulting from low pH can be due primarily to H^{+} toxicity. In most instances this does not occur until the pH drops to pH 4.0 or less. In acid mineral soils (pH 5.0 or less) poor plant growth is due primarily to excessive levels of Al^{3+} (Hossner, L. R.1989). Root injury is observed at pH 5.0 and lower. At these low levels, lateral root development is suppressed and in some cases root tips are killed. The roots become discolored brown or a dull gray (similar to nematode damage) as shown in Figure 2.5.At low pH and low Calcium concent-rations, damage to root membranes is accentuated (Solomon D. 2008).

Conditions that cause aluminum toxicity

Aluminum toxicity occurs readily under acidic conditions, especially when pH values are equal to or less than 5.4.Equation c shows how Al^{+3} is formed from the insoluble $Al(OH)_3$ in acid environments. In the acidic soils of the tropics, aluminum toxicity may become a serious problem and limit crop yield.Management of soil pH is the key factor in avoiding a luminum toxicities. Aluminum toxicity may be ameliorated by treating with wood ash farme rs "fields (Sosulski, T. 2004).

$$Al(OH)_3 + 3H^{+} \rightarrow Al^{3+} + 3H_2O \quad \ldots\ldots\ldots\ldots\ldots \text{(c)}$$

2.4.2. Manganese toxicity

Manganese toxicity can become a problem in soils with manganese-containing minerals. When these minerals dissolve, manganese ions are released into the soil solution. Although manganese is an essential plant nutrient, excessive quantities of manganese may be detrimental to plant growth. Manganese toxicity symptoms include yellowing of leaves (chlorosis) of older leaves, which darken into small, brown spots. Although crop tolerance of manganese toxicity varies, most crops are sensitive to high levels of manganese. For example, manganese toxicity will result in the "sudden crash" syndrome of watermelon, in which plants suddenly wilt and die. Manganese toxicity is one of the factors that may limit plant growth on certain acid soils. Highly weathered soils that have large sesquioxide clay

content often contain high amounts of manganese (Shoemaker, H. E. 1989).The exchangeab le Mn in acid soils increases markedly at soil pH values less than 5.0.Plants growing on soils with a high content of exchangeable Mn accumulate large amounts of Mn in their tissues and growth is reduced. Treating with wood ash these soils to pH 5.5 and above decrease the solubility of Mn and uptake of Mn sufficiently to eliminate the toxicity and increase growth (Sosulski, T. 2004).

Conditions that cause manganese toxicity

Moist, organic soils under acidic conditions are especially susceptible. Like aluminum toxicity, management of pH is very important. When the soil pH drops below 5.2, manganese minerals become highly soluble and perhaps toxic. Farmers may reduce manganese toxicity by treating with wood ash and aerating fields. Aeration may be accomplished by irrigating less or draining water from fields (Sosulski, T. 2004). Figure 2.6 shows the effects of manganese toxicity on Teal wheat at different concentrations. From left to right plants were grown in solutions ranging from 0, 90 to 180 ppm manganese.

Figure 2.6 Well nodulated (left) compared to poorly nodulated sub clover plants (Chris Gazey and Stephen Davies.2009).

2.5 Nutrient Availability

A soil ability to hold and supply nutrients is related to its cation and anion exchangeable capacities, the number of parking spaces for nutrients on soil particles. Cation and anions

exchangeable capacities are influenced by soil PH.Soil with high amounts of clay and/or organic matter typically have higher cation exchangeable capacities (CEC) that is able to bind more cations such as calcium or potassium than more silty or sandy soils. They also have greater buffering capacity. Soil PH affects nutrients availability because the H+ ions take up space on de the negative charges along the soil surface (figure 2.7), displacing nutrients. The effects on nutrients availabilit depend on the size and change of the nutrients molecules and whether or not they can be lost to leaching. The metal nutrients Cu, Mn and Zn are small molecules when dissolve in water with 2-3 positive charges. Thus a high change to size ratio. They bind strongly to the surface of soil particles. At high PH (low $[H^+]$), these metal ions stick so tightly, thus are less available for plant uptake .At low PH (i.e acidity, high $[H^+]$), fewer can stick to the soil surface, making them more available for plant uptake. Surfur (S) and base forming cations (Ca^{++}, Mg^{++}, K^+ and Na^+) are relatively large molecules. In general potassium (K), surfur(S), calcium (Ca) and magnesium (Mg) are more available at higher PH; the micro nutrients are more available at lower PH **(**Ann McCauley .2017).

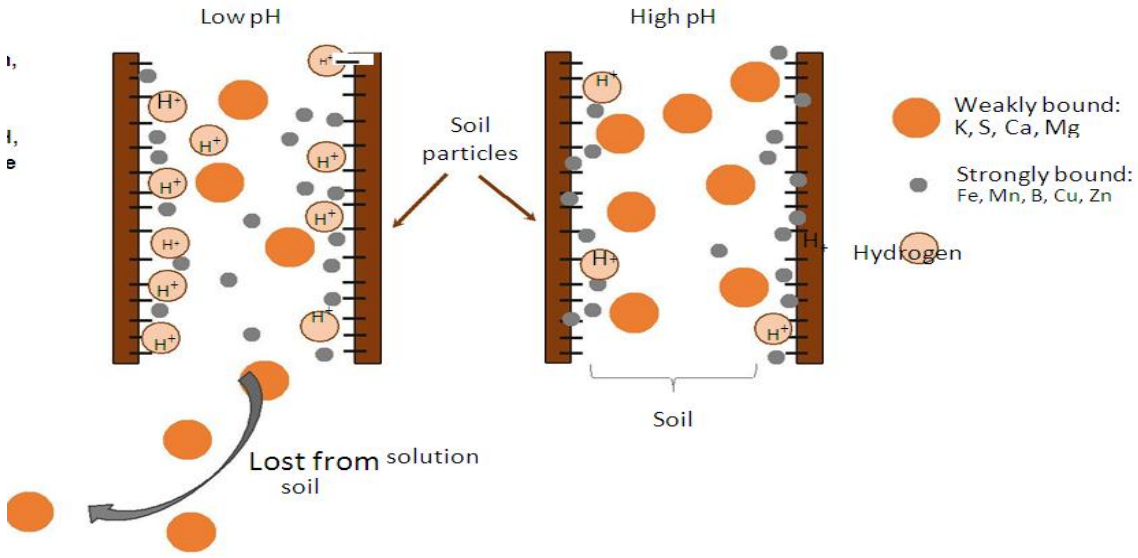

Figure 2.7. Potassium, sulfur, calcium and magnesium are more available at higher pH; the micronutrients are more available at lower pH (Ann McCauley .2017).

2.6. Effects of Soil Acidity on Macro Nutrients Availability

Acidification of the soil is a slow natural process and part of normal weathering. Besides the natural process, farming activities also cause an increase in the rate of acidification of

the soil. Changes in soil pH under agricultural use are measured in tens or hundreds of years rather than thousands of years as in the natural environment. Poor plant growth on acid soil is associated with a low pH value. The effects of soil acidity on growth of plants are complex and it's difficult to separate the direct effects from the indirect effects associated with changes in the solubility and availability of various elements affecting plant growth (Mesfin, A. 2007).

2.6.1. Nitrogen (N)

Roles of Nitrogen in soil fertility and plant growth

Nitrogen (N) is the fourth plant nutrient taken up by plants in greatest quantity next to carbon, oxygen and hydrogen, but it is one of the most deficient elements in the tropics for crop production (Sanchez, P.A., 1976; Mesfin Abebe, 1998; Mengel, K. et al .1987).
The total N content of a 10 soil is directly associated with its OC content and its amount on cultivated soils is between 0.03% and 0.04 % by weight (Mengel, K. et al .1987; Tisdale, S.L., et al. 1995**)**.

Nitrogen is a part of all living cells and is a necessary part of all proteins, enzymes and metabolic processes involved in the synthesis and transfer of energy. Nitrogen is a part of chlorophyll, the green pigment of the plant that is responsible for photosynthesis. Nitrogen helps plants with rapid growth, increasing seed and fruit production and improving the quality of leaf and forage crops. Nitrogen often comes from fertilizer application and from the air (legumes get their N from the atmosphere); water or rainfall contributes very little nitrogen (Havlin, LJ, et al .1999)

Nitrogen deficiency

Nitrification (conversion of NH_4^+ to NO_3); is reduced at lower pH value. Microorganisms as sociated with nitrification require a certain soil pH range to function efficiently. Since these organisms require large amounts of Ca^{+2} to perform the conversion, a pH of 5.5 to 6.5 is necessary for calcium to be available.

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O \ldots\ldots\ldots\ldots \text{(d)}$$

Rhizobium activity is increased as the pH value increases and the activity of bacteria (Rhizobia species) which are responsible for nitrogen fixation in legume crops decreases when the pH drops below 6.0. In addition to less N being produced by organisms for crop utilization, microbes responsible for the breakdown of crop residues and soil organic matter are also affected by acid soils. Other microorganisms vary in their tolerance to soil pH (Chris Gazey and Stephen Davies .2009).

2.6.2. Phosphorus (P)

Roles of phosphorus in soil fertility and plant growth

Phosphorus (P) is known as the master key to agriculture because lack of available P in the soils limits the growth of both cultivated and uncultivated plants.

Following N, P has more wide spread influence on both natural and agricultural ecosystems than any other essential elements. Like nitrogen, phosphorus (P) is an essential part of the process of photosynthesis and involved in the formation of all oils, sugars, starches, etc. It also helps with the transformation of solar energy into chemical energy, proper plant maturation, with standing stress and effects rapid growth and encourages blooming and root growth. It often comes from fertilizer, bone meal, and super phosphate (Foth, H.D.et al., 1997)

Phosphorus Deficiency

The main sources of plant available phosphorous are, the weathering of soil minerals, the decomposition and mineralization of soil OM and commercial fertilizers. Most of the soils in Ethiopia particularly Nitisols and other acid soils are known to have low P contents, not only due to the inherently low available P content, but also due to the high P fixation capacity of the soils (Mekonnen, G.,2015**).** Oxisols, Ultisols, Vertisols and Alfisols are generally low in total P while Andosols are generally high in P content (Mesfin Abebe, 1996).Aluminum toxicity is often manifested as a phosphorus deficiency. Phosphorous deficiency results in leaves purplish coloring on dark green, spindly, slow growth leaves. Mechanisms for the phosphorus deficiency include:

$$2Al^{+3} + Ca_3(PO_4)_2 \rightarrow 2AlPO_4 + 3Ca^{+2} \quad \text{..... (e)}$$

$2Fe^{+3} + Ca_3(PO_4)_2 \rightarrow 2FePO_4 + 3Ca^{+2}$……. (f)

1.At low pH of soil aluminum is highly soluble and react with phosphorous to form insoluble $AlPO_4$ which is precipitate and could not be absorbed by plant roots as shown in equation 'e'.

2. Phosphorus uptake is highly dependent on a finely branched, extensive root system with as many root hairs as possible. Reduced root growth result in reduction of phosphorus uptake.

3. Precipitation-adsorption reaction in soil and along the mucilaginous layer at the surface of the root and in the inter-cellular regions of the apical 3 to 4 mm of root tip.

4. Interference with P metabolism in the plant (Haynes, J. R. 2001).As it is shown in Figure 'f 'decrease in soil pH has also effect on increasing the level of Fe^{+3} in turn results in the formation of insoluble ferric sulphate ($FeSO_4$). Phosphate ions are adsorbed more strongly onto sesquioxide surfaces at lower soil pH due to the increasing positive charge on these colloids as soil pH decreases.

2.6.3. Soil organic matter

Roles of organic matter in soil fertility and plant growth

Soil OM arises from the debris of green plants, animal residues and excreta that are deposited on the surface and mixed to a variable extent with the mineral component (White, R. 1997). Soil OM is defined as any living or dead plant and animal materials in the soil and it comprises a wide range of organic species such as humic substances, carbohydrates, proteins, and plant residues (Dudal, R. A. 1993; Havlin LJ, et al .1999). Humus is the substance left after soil organisms have modified original organic materials to a rather stable group of decay products as is the colloidal remains of OM (Tisdale, S.L.et al.1995) reported that some of the functions of OM/humus are:-

(a) Aids in water management as residues or plants protect the soil surface from rain drop impacts, resist wind action, and thus, greatly aid in erosion control. Furthermore, decomposing OM causes soil aggregation, which aids infiltration and increases pore space in clay soils. Thus, water and oxygen holding capacity is increased, even beyond 11 the absorptive capacity of OM, (b) increases exchange and buffering capacity since well

decomposed OM or humus has a very high CEC that adds to the buffering capacity of the soil, (c) minimizes leaching loss because organic substances have the ability of holding substances other than cations against leaching, (d) sources of nutrients (N, P, S and most micronutrients) and growth promoting substances, that is, hormones or growth -promoting and regulating substances valuable to plants may be produced by organisms that decompose soil OM, (e) stabilizes soil structure, and (f) provides energy for microbial activity.

Organic Matter Deficiency

In most tropical environments, the conversion of forest vegetation to agricultural land results in a decline of the soil OM content to a newer, lower equilibrium (Woldeamlak Bewket .et al.2003**).** Most cultivated soils of Ethiopia are poor in OM contents due to low amount of organic materials applied to the soil and complete removal of the biomass from the field (Yi henew, G. 2002**)** and due to severe deforestation, steep relief condition, intensive cultivation and excessive erosion hazards (Mekonnen, G., 2015).

2.6.4. Potassium (K^+)

Roles of potassium in soil fertility and plant growth

Potassium is the third most important essential element next to nitrogen and phosphorus that limit plant productivity. Its behavior in the soil is influenced primarily by soil cation exchange properties and mineral weathering rather than by microbiological processes. Unlike nitrogen and phosphorus, potassium causes no off-site environmental problems when it leaves the soil system. It is not toxic and does not cause eutrophication in aquatic systems (Brady NC, Weil RR .2002**)** reported that the variation in the distribution of potasium depen ds on the mineral present, particles size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the parent material 17 from which the soil is formed.The greater the proportion of clay mine ral high in K, the greater will be the potential K availability in soils (Tisdale, S.L.et al .1995).

Potassium Deficiency

The fixation of potassium and entrapment at specific sites between clay layers tends to be lower under acid conditions. This situation is thought to be due to the presence of soluble aluminum that occupies the binding sites. Available potassium in soil is mainly K^+ in soil solution in equilibrium with exchangeable K^+ held on soil CEC. K^+ retention in acid soils is reduced because CEC is reduced. (Mekonnen, G. 2015**)** Described low presence of exchangeable K under acidic soils whiles (Kebede, D.et al., 2017) observed low K under intensive cultivation. Normally, losses of K by leaching appear to be more serious on soils with low activity clays than soils with high- activity clays, and potassium from fertilizer application move deeply (Havlin LJ,et al .1999). Lime application will increase CEC and K^+ retention, but K^+ concentration in solution will be reduced and could cause potassium deficiency (Brady NC, Weil RR .2002).

2.6.5. Calcium (Ca^{+2})

Roles of Calcium in soil fertility and plant growth

Calcium, an essential part of plant cell wall structure, provides normal transportation and retention of other elements as well as strength in the plant. It is also thought to counteract the effect of alkali salts and organic acids within a plant. Sources of calcium are dolomitic lime, gypsum, and superphosphate.

Calcium Deficiency

Many acid soils have very low amounts of exchangeable calcium and a low calcium saturation of the CEC. At these low levels of available Ca, the uptake may also be inhibited by Al. Although it is often difficult to separate the direct effects of hydrogen and aluminum from those of Calcium on plant growth, a number of points can be made about calcium in highly weathered soils. A calcium saturation of approximately 25 to 30 % appears to be adequate for supplying the calcium requirements of most plants. Growth may not be maximum at this calcium saturation because some other factor may limit yield (Hue, N.V.1998**)**

2.6.6. Magnesium (Mg^{+2})

Roles of magnesium in soil fertility and plant growth

Magnesium is part of the chlorophyll in all green plants and essential for photosynthesis. It also helps activate many plant enzymes needed for growth. Soil minerals, organic material, fertilizers, and dolomite limestone are sources of magnesium for plants.

Magnesium deficiency

Sandy soils at pH 5.0 are often very low in magnesium. At that pH value and below, plants begin to show magnesium deficiency symptoms. Plant uptake of magnesium from nutrient solutions is influenced by the hydrogen ion concentration. Uptake of magnesium by plants increases with increasing pH and reaches an optimum at approximately pH 5.5. The effect of the soil pH value on magnesium availability is probably due to an antagonism of both aluminum and hydrogen on magnesium uptake, particularly when the percent aluminum saturation is high. Reduction of aluminum and hydrogen is necessary for optimum magnesium availability. When soils are acid and low in available magnesium, the use of dolomite lime is the best approach to correct magnesium deficiencies (Hue, N.V.1998.)

As shown in Figure 2.3, in acidic soil (pH < 5.5) aluminum and hydrogen ions are highly available (25%-100%), while exchangeable cations (Na, K, Ca and Mg) are low in concentration (0 - 25%. At pH 6-7, aluminum was removed and exchangeable cations are occupied the site and Ca ion is highly available (21% - 95%).

2.6.7. Cation exchange capacity

The Cation exchange capacity (CEC) of soils is defined as the capacity of soils to adsorb and exchange cations (Brady NC, Weil RR .2002**)** Cation exchange capacity is an important parameter of soil because it gives an indication of the type of clay minerals present in the soil, its capacity to retain nutrients against leaching and assessing their fertility and environmental behavior.

Generally, the chemical activity of the soil depends on its CEC.

The CEC of a soil is strongly affected by the amount and type of clay, soil pH, exchangeable acidity and amount of OM present in the soil (Curtis, P. A. 1981**)** Both clay and colloidal OM are negatively charged and therefore can act as anions (Kimmins, J. 1997**)**

As a result, these two materials, either individually or combined as a clay-humus complex, have the ability to absorb and hold positively charged ions (cations). Soils with large amounts of clay and OM have higher CEC than sandy soils low in OM. In surface horizons of mineral soils, higher OM and clay contents significantly contribute to the CEC, while in the subsoil particularly where horizon exist, more CEC is contributed by the clay fractions than by OM due to the decline of OM with profile depth (Foth, H.D. et al .1997; Brady NC, Weil RR .2002).

Soil solutions contain dissolved chemicals, and many of these chemicals carry positive charges (cations) or negative charges (anions) (Fisher, R.F. et al., 2000**)** Cation exchange is considered to be of greater importance to soil fertility than anion exchange, because the majority of essential minerals are absorbed by plants as cations (Poritchett, W. a. 1987). The nutrients required for plant growth are present in the soil in a variety of forms (Kimmins, J. 1997).

They may be dissolved in the soil solution, from where they can be utilized directly. They may be absorbed onto exchange sites, from where they inter soil solution or be directly exploited by tree roots or microorganisms that come in contact with the exchange site. An exchangeable cation is one that is held on a negatively charged surface and displaced by another cation. The exchangeable cation is a desirable form of a nutrient being quickly brought into solution and made accessible to roots by the exchange with proton. Although the cation nutrients heldon the exchange sites form a readily available pool, they do not repr esent the cation supplying ability of the soil (Binkley, D.A. 1990; Binkley, D, Bell, R et al., 1992a). Cations removed from the exchange sites often are replenished rapidly from other sources, such as OM decomposition, mineral weathering, or release of ions fixed within the layers of clay minerals.

2.7. Effects of Soil Acidity on Some Micro Nutrients Availability

The term micronutrients refer to a number of elements that are required by plants in very small quantities. This term usually applies to elements that are contained in plant tissues in amounts less than 100 mg/kg (Foth, H.D. et al., 1997). According to the same authors, the four essential micronutrients that exist as cations in soils unlike to boron and molybdenum are zinc (Zn), copper (Cu), and iron (Fe) and manganese (Mn).

The availability of manganese, copper, zinc, and iron to plants generally decreases as the soil pH increases. Micro nutrients such as iron, manganese, copper and zinc are available when the soil is slightly in acidic condition, at pH 5.0 - 6.5, while iron availability increases as soil acidity increase from slightly acidic to strongly acidic as shown in Figure 2.3. On the other hands these micronutrient are reacted with water in soil solution and caused soil acidity by releasing hydrogen ions in soil as shown in equation 'g', 'h' and 'I'(Ketterings, Q. M. 2005).

$$Zn^{+2} + 2H_2O \rightarrow Zn(OH)_2 + 2H^{+} \quad \text{..... (g)}$$

$$Mn^{+2} + 2H_2O \rightarrow MnO + 2H^{+} \quad \text{..... ... (h)}$$

$$Fe^{+3} + 3H_2O \rightarrow Fe(OH)_3 + 3H^{+} \quad \text{..... (I)}$$

2.8. Availability of Micronutrient Cations in Relation to adding wood ash

Adding wood ash soils that are inherently low in manganese, copper, zinc and iron may enhance micronutrient deficiencies for a short or long period of time.

2.8.1. Manganese

According to [13], the sandy soils liming to a pH value near neutrality often produces manganese deficiency in certain crops as shown in Figure 2.8.a and b

Figure 2.8.The effects of manganese deficiency on wheat leaves (a) Soybean and leaves (b) (Ketterings, Q. M. 2005)

2.8.2. Molybdenum

The availability of Mo is very low in acid soils. Deficiency symptoms are most often observed with legumes. It is seen as N deficiency since Mo is required by the nitrogen fixing rhizoid. Soil pH is one of the most important factors affecting the availability of molybdenum and its uptake by plants. In contrast to the other plant micro nutrients, liming acid soils increases the availability of soil Mo. This might be due to hydroxide ion (OH-) replacing adsorbed Molybdate ions (MoO_2^{-4}). As shown on figure below the amount of Mo absorbed by soils and hydrous oxides is increased as pH is decreased. Molybdate ions replace the surface OH ions of hydrous oxides of Fe and Al. Accordingly figure 2.9 shown that as the pH decreases, surface OH ions are held less tightly and can be replaced by Molybdate ions (MoO_4^{2-}) (Hue, N.V.1998**).**

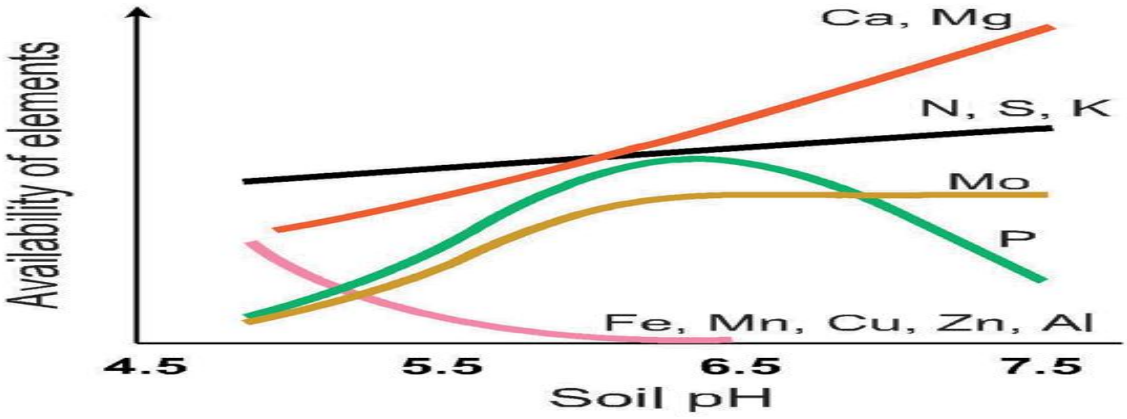

Figure 2.9.Relationship between soil pH and nutrient availability (Chris Gazey and Stephen Davies.2009)

2.9. Treating Soil Acidity with wood ash

A wood ash is an agricultural liming material capable of reducing soil acidity, i.e., increasing soil pH(as shown on figure 2.10) treating with wood ash 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 non-toxic chemical forms. Like other soil properties, the wood ash requirement will vary depending upon the types of soil.

There are four guidelines that help us to determine the wood ash requirement: the desired change in pH, (Huluka, G. 2005).

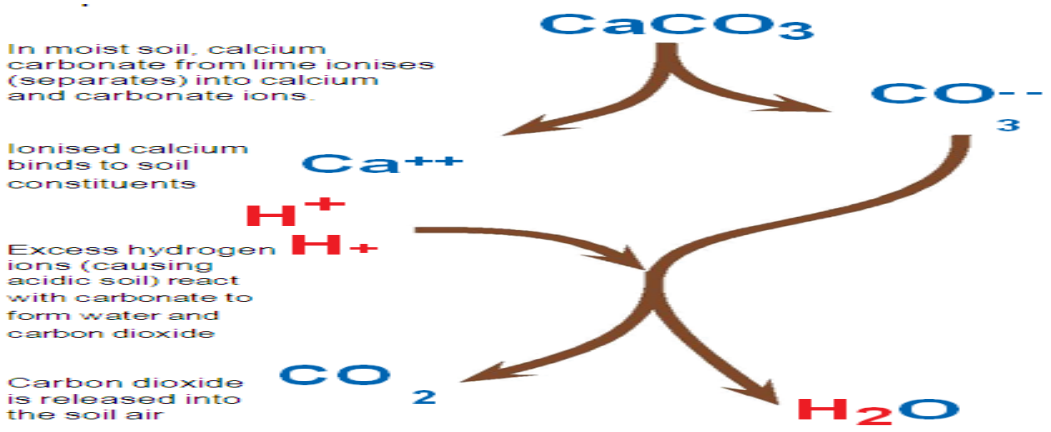

Figure 2.10.Simplified representation of how lime reacts in soil to treated acidity (Chris Gazey and Stephen Davies.2009)

2.9.1. The desired change in pH

The optimal pH range for most plant growth and plant nutrient availabilities are between 6.0-6.5. To avoid aluminum and manganese toxicity problems, a soil should be limed if the pH is less than 5.4 (Chris Gazey and Stephen Davies.2009).

3. MATERIALS AND METHODS

3.1. Description of Study Area

Nano Jeno kebele and Jiru Mariyam the study area was found in Lalo Kile woreda , Oromia regional state,Ethiopia. Lalo Kile woreda is located at $90^0$5'55" N, $38^0$36'21" E longitudes and 2556m above sea level. According to the local and the Ethiopian agro-climatic zonation (MoFED, 2002) the study area belongs to the temperate zone of Dega and Weyenadega or humid and sub-humid climatic zones. The mean annual rain fall of this woreda is around 1100 mm and the major soil type are Vertisol and Nitisol. The topography of the study site is mountainous and has a gentle sloping landscape. 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 are teff (Eragrostis tef), barley (Hordeum vulgare), wheat (Triticum aestivum), bean (Phaseolus lunatus), maize (Zea mays) and potato (Solanum tubersoum) (www.eiar.gov, et).

3.2. Chemicals and Materials

3.2.1. Apparatus

The apparatus used in this study includes:-

1. Digital analytical balance (Model ESJ200-4, England) with ± 0.0001g precision for weighed soil sample and solid chemicals for solution preparation.
2. PH meter (JENWAY 3020 PH meter, England) for pH measurement.
3. Oven (JAPSON MODEL DTC-201 Ambala, India) for drying of bulk density and soil moisture content.
4. Digital burette (BOSCH-Wage system GmbH, Germany) was used for titrating nitrogen, organic carbon and exchangeable acidity analysis.
5. Kjeldahl digestion blocks (Gallenhamp, England) apparatus for digesting soil samples.
6. 2 ML, 5 ML, and 10 ML pipettes and micropipette (DRAGONMED, Shanghai, China) were used for measuring different amounts of sample filtrates.
7. 50 ML, 250 Ml, 100 ML and 1000 ML volumetric flasks were used to dilute sample solutions and prepare standard solutions. 250 ML round bottom flasks fitted with reflux condenser were used in Kjeldahl digestion block (Gallenhamp, England) apparatus to soil samples, spiked soil samples and blank solutions.

8. Spectrophotometer (PG INSTRUMENT, MODEL T70/70+ with SINGLE BEAM RATIO MONITORING SYSTEM**,** Leicestershire, England) used for determining the concentrations of phosphorous in soil

9. Water deionizer (Bhanu Scientific Instruments, Model BASIC pH 4, India) is used for pro ducing demineralized water.

10. Magnetic stirrer (Jenway LTD, Hotplate & Stirrer, and Model 1103, U.K.) used for stirring purpose.

11. Whatman hardened ashless filter paper with 125 mm diameter (What man quantitative filter paper, Grade 540, New Delhi, India) were used for filtration.

12. The concentrations of Na, K, Mg, Ca, Fe, Cu, Mn and Zn in soil samples were determine d by atomic absorption spectrophotometer (Shimadzu, Model AA-6200,Japan) using air acetylene flame and connected to SAMSUNG personal computer.

13. Stainless steel soil sampling auger (Oakfield Apparatus Company, Oakfield, Wisconsin, USA) was used for soil sampling.

3.2.2. Chemicals and Reagents

1.Sodium hexametaphosphate (BDG chemical Ltd poole England) and sodium carbonate (UNICEMIE®, Mumbai India) in 10:1 were used for preparation calgon solution.1N of NH_4AOC (ammonium acetate) (CDH, New Delhi, India), $SrCl_2$ (stannous chloride) (LOBA CHEMIE® , Mumbai, India), MgO (magnesium oxide) and nessler reagent were used in the determination of Na, K,Mg and Ca analysis.

2.Standard stock solutions of phosphorous (50 mg/L) was prepared from 0.174 g of potassium di hydrogen phosphate (KH_2PO_4) (Samir Tech-Chem, Makarpura, Vadodara, India) and after drying at 105^oC in an oven for 2 hours, cooled in a desiccator and diluted to 1000mL distilled water.

3.Sodium bicarbonate 0.5 M ($NaHCO_3$) (AnalaR, BDH Laboratory Supplies, Poole, England), (NH4)2MoO4 (ammonium molbdate) (AnalaR, BDH Laboratory Supplies, Poole, England) and ascorbic acid (AnalaR, BDH Laboratory Supplies, Poole, England) were used in the determination of phosphorus analysis.45% NaOH (sodium hydroxide) (AnalaR, BDH Laboratory Supplies, Poole, England), 2% H_3BO_3(boric acid) (AnalaR, BDH Laboratory Supplies, Poole, England), 98 % H_2SO_4 (sulphuric acid)and

mixed reagent (methyl red and bromocrosel green 1:1 ratio) were used in the determination total nitrogen. 37% of 0.02N HCl (hydrochloric acid) (Samir Tech-Chem, India) and 0.5 N NaF (sodium fluoride) and phenolphthalein indicator were used in the determination of exchangeable acidity.

4.1N $K_2Cr_2O_7$ (potassium dichromate), 98% H_2SO_4 and 0.5N Fe (NH_4) $SO_4.H_2O$ (ammonium ferrous sulphate hydrate) used for determination of organic carbon in soil. Standard stock solutions of Na (1000 mg/L) and K (1000 mg/L) were prepared from 0.2541 g NaCl (Riedel-de Haën AG, Seelze-Hannover, Germany) and 0.1907 g KCl (Merck, Darmstadt, Germany), respectively, after drying at 110^{o}C in an oven for 2 hours, cooled in a desiccator and diluted to 1000 ML distilled water.

5. Dietylene triamine pentaacetic (DTPA) and H_2O_2 (hydrogen peroxide) were used in determination of micronutrients.$MnSO_4.H_2O$, $CuSO_4.5H_2O$,$ZnO_4.7H_2O$ and $CuSO_4.2H_2O$ were used for preparation of stock and standard solution of Mn, Cu, Zn and Fe.Distilled water was used for dilution of sample and working standard solutions and rinsing glassware and sample bottles prior to analysis. All chemicals and reagents used were analytical grade.

3.3. Methods

3.3.1. Soil survey

Reconnaissance survey was conducted to select two kebeles of Lalo Kile woreda before the commen cement of the soil sampling. Based on soil acidity problems rates of agricultural bureau these two kebeles, Nano Jeno and Jiru Mariyam in the specified woreda were selected. After the selection of kebeles, the next step was to select the sample sites. To take purposive sampling; the sample sites were systematically selected on the basis of similarity in soil color by visual observation, with closest slope and altitude to reduce altitude and slope as well as soil type difference impacts on the soil acidity. The cultivated and backyard land pieces have been under intensive cultivation with oxen tillage for long period of time according to the farmers‟ response. The backyard gets special treatment from application of manure and compost. The cultivated land use system has received urea and DAP fertilizers in most of the years under barley, wheat, potato, beans and teff cropping.

3.4. Sample Collection and Pre-treatment

Following the general soil survey, five representative fields were selected from two kebeles, Nano Jeno 1, Nano Jeno 2 and Jiru Mariyam 1, Jiru Mariyam 2 and Jiru Mariyam 3 which were lebeled as sample site NJ, NJ, J, J, and J respectively. From each site, around eight to fifteen sub-samples were composited by a radial sampling scheme using an auger (Wilding, L. 1985). During collection of samples; dead plants, furrow, old manures, wet spots, areas near trees and compost pits were excluded.

A total of five composite samples (about 4 kg) for adding wood ash and physicochemical analysis and five cores for bulk density and for moisture sampling were collected randomly from around 110 hector of Lalo Kile woreda, at the depth of 0-15 cm. The samples were air-dried and any visible external particles were removed. The dried samples were gently crushed (ground) and homogenized using mortar and pestle. Sieving was done using 0.25 mm mesh.

From the sieved samples about 1Kg were preserved in labeled plastic bags for laboratory analysis and 3 Kg were treated with wood ash in greenhouse incubation pots.

3.5. Determination and Analysis of Soil Physical Properties

3.5.1. Determination of soil moisture content and Bulk density

Soil moisture contents and bulk density were determined by oven drying. The wet disturbed and undisturbed soil samples were weighed and dried in an oven at 105^{o}C for 24 hours. On the next day it was removed from oven and cooled and re-weighed (Mesfin, A. 2009).

3.6. Determination and Analysis of Soil Chemical Properties

3.6.1. Determination of Soil pH, Organic carbon, Total Nitrogen and Available

Phosphorus Soil 25 ML of deionized water (pH 7.0) was added to 10 g of soil samples (1:2.5 ratios) and mixed thoroughly. Then after the instrument were calibrated using buffers of PH (4, 7 and 9) and mixed thoroughly.

Organic carbon

Soil organic matter was oxidized under standard conditions with $K_2Cr_2O_7$ in Sulphuric acid solution. 10 ML of 1N $K_2Cr_2O_7$ and 20 ML of 98 % H_2SO_4 were added in 0.5 g of

sample to destroy the organic matter, and the excess were determined by titration with 0.5 N $Fe(NH_4)_2(SO_4).6H_2O$ [Mohr‟s salt], using 2-3 drop of diphenylamine indicator to detect the first appearance of un-oxidized ferrous ion (Walkley, A. F. 1934). The organic carbon was calculated using the following formula:-

$$\%OC = (Vt - Vb) \times N \times 0.39 \times mcf/WtS$$ Where, Vt – mL of $FeSO_4$

Used for sample **Vb** – ML of FeSO4 **mcf** – moisture correction factor used for blank **mcf** – moisture correction factor **N-** Normality of Ferrous sulphate solution $0.39 = 3 \times 10^{-3} \times 10^2 \times 1.3$ **N-** Normality of Ferrous sulphate solution $0.39 = 3 \times 10^{-3} \times 10^2 \times 1.3$

3 = equivalent weight of carbon 1.3 = 77/100 of C oxidized

In this method about 77 % of the C is oxidized by $K_2Cr_2O_7$, so a correction factor of 100/77 = 1.3 is used in the calculation. The value of 77% is only approximation since the ineffectiveness of combustion varies with the type of organic matter present. Soil organic matter was determined by using correction formula:

$$\% OM = \% OC \times 2.74$$

Total Nitrogen

1 g of soil sample was weighed and 7 ML of 98 % H_2SO_4 was added and digested at 380 ^oC in Kjeldahl digestion block for 3 hrs to converted organic nitrogenous compounds into $(NH_4)_2SO_4$ during the oxidation and NH_4^+ion in the soil were liberated by distilling with 60 ML 45 % NaOH. The liberated $NH_4^+$was absorbed by 2% of 20 ML H_3BO_3 and back titrated with standard 0.1N H_2SO_4 (Bremner JM. 1965). The total nitrogen was calculated using the following formula:

$$\%TN = \frac{(Vt - Vb) \times N \times 0.014 \times 100}{1000 \times WtS \times mcf}$$

Where,

Vt – ML of 0.1N H_2SO_4. used for sample **Vb** – ML of 0.1N H_2SO_4. used for blank

Ws - Weight of sample **N** – Normality of NaOH 0.014 – Meq weight of nitrogen in grams.

Available Phosphorus

Olsen methods were used to determine available phosphorous content of the soil.2g of soil sample was extracted with 40 ML $NaHCO_3$ was used for extraction in Olsen method. The extracted soil samples were filtered and 5 ML aliquot was pipetted and 15 ML of distilled water was added. Phosphate in the extract were treated with Ammonium Molybdate-Sulphuric acid reagent and determined by spectrophotometer at 880 nm for Olsen methods after treating it with ascorbic acid as reducing agent (Bray, R.. 1945**).**

3.6.2. Determination of available exchangeable cation (Na^+, $K^+$and Ca^{+2}) by Atomic abs orption spectroscopy (AAS).

Exchangeable Na^+, K^+ , Mg^{+2} and Ca^{+2} were determined by using NH_4AOC method. 10 g of soil sample were weighed and transferred to 100 ML Erlenmeyer flask and soaked with 50 ML of 1N NH_4AOC and left overnight. The sample was leached by 30 ML of NH_4AOC seven times within 5 minute intervals; Na^+, K^+ ,$Mg^{+2}$and Ca^{2+}were determined by Atomic absorption spectroscopy (AAS) after calibrating the instrument with standard solutions of Na, K,Mg and Ca (Bray, R.. 1945).

3.6.3. Determination of micronutrients (Cu, Fe, Zn and Mn) by Atomic absorption spec trophotometer.

10 g of soil samples weighed and transferred to 100 ML Erlenmeyer flask and extracted with 40 mL of DTPA.The amounts of these nutrients in the extractants was determined by atomic absorption spectrophotometer at 248.3 nm, 279.5 nm, and 324.7 nm and 213.9 nm wavelengths for Fe, Mn, Cu and Zn, respectively (Bray, R.. 1945**)**

3.6.4. Exchangeable acidity (H^+ and Al^{+3}).

10 g of soil sample was leached with a neutral 10 ML of 1N KCl solution five times and made up to 100 ML. 50 ML of aliquot was transferred into 150 ML Erlenmeyer flask and 2-3 drop of phenolphthalein indicator was added and finally, titrated with a standard solution 0.02 N NaOH to pink colour and the amount of alkali used being equivalent to the sum of the H^+ and Al^{+3}ions.

The total exchangeable acidity was calculated using the following formula:

% **Exch. Acidity = (V – B) x N x VT x 100/Ws x Va**

Where,

V – ML of NaOH used for sample Va – Volume of aliquot in ML

B – ML of NaOH used for blank Va – Volume of aliquot in ML

Ws - Weight of sample in grams N – Normality of NaOH (0.02N)

The following procedure was used to determine exchangeable aluminum.

After determination of exchangeable acidity, few drops of 0.02 M HCl was added to make the titrated pink solution in the Erlenmeyer flask colorless and 20 ML of 1N NaF was added. If exchangeable Al^{+3} are present, the solution becomes pink again.

The solution was titrated with 0.02 M HCl until the pink color disappears to colorless (Kamprath, E. J. 1984**).**The total exchangeable acidity was calculated using the following formula:

% Exch. Al^{+3}= (V – B) x N x VT x 100/Ws x Va

Where, **V** – ML HCl used for sample **N** – Normality of HCl (0.02N)

B –ML of HCl used for blank **Va** – Volume of aliquot in ML

Ws - Weight of sample in g **VT**- Volume of extract in ML

3.6.5. Determination of wood ash requirements for neutralization of acid soil

The wood ash and soil samples were ground to fine texture (pass through 0.5 mm sieve).The five soil samples were replicated to fifteen and wood ash were added at different rates (6.5 g,7 g and 7.5g) and incubated in green house for 72 days. The incubated samples were mixed and water added with the interval of 2 to 3 days to increase the speed of reaction between acidic soil and wood ash, soil pH was tested within twelve days interval. Finally adding ash in the greenhouse incubation of soil samples were stopped when the pH of all samples reached target pH (6.8-7.12) by pH (H_2O) methods and the important parameters, which were determined before treating with wood ash were again analyzed to compare the differences (Chimdi, A.,2012**).**

Ash requirement (AR) was determined by the following formula:

$$\text{AR. (Kg/ha)} = \text{EA } \frac{\text{(cmol/Kg) *0.15 m *10}^4\text{ m}^2\text{ *BD (mg/m3) * 1000}}{\text{2000 cmol/Kg}}$$

Where, **EA** – Exchangeable Acidity and **BD** – Bulk Density **AR** – Ash Requirements

3.7. Instrumental Calibration Procedure

Uv-visible Spectrophotometer

The working standards for uv-visible spectrophotometric method (0, 0.5,1,2,3,4,5 mg/L) were prepared by measuring 1 ML to 10 ML of 100 mg/L KH_2PO_4 standard stock solution and transferred to 100 ML volumetric flask and all the reagents used in the sample were added to the solution and the resulting solutions were diluted with distilled water to the mark. As the instrument turned on, the mode of adjustment was placed at 0.00 absorbance, 100% transmittance and wavelength at 660 nm and 880 nm. Absorbance of each of the five standard solutions was measured and recorded starting with the most dilute standard. After each measurement, the polystyrene cuvette was rinsed first with distilled water and then with the next standard. Similarly, each sample solution was placed in a cuvette and the absorbance was measured and recorded for each triplicate sample. The concentration of phosphate was determined from the regression equation obtained using least square method, for the standard calibration curve as shown in Figure 4.1.

Atomic absorption spectroscopic (AAS)

The working standards for atomic absorption spectroscopic (AAS) method were prepared by measuring different volume of standard stock solution for different elements and transferred to 100 ML volumetric flask and all the reagents used in the sample were added to the solution and the resulting solutions were diluted with distilled water to the mark. As the instrument turned on, the mode of adjustment was placed at 0.00 (A) absorbance, 100% transmittance aspirate the standard series working solutions in to the atomic absorption and established the transmittance curve. In similar manner, aspirate the samples and record transmittance or absorbance. If dilution was necessary the distilled should be used as diluents.

3.9. Data analysis

The results of each analysis are reported as mean ± standard deviation of triplicate measurements. The data were treated with ANOVA and t-tests, as required at $p < 0.05$ significant level. Statistical analysis of the data was carried out by one-way analysis of variance (ANOVA) for comparing nutrient variation among the different sample sites before and after adding wood ash at 0.05 significant levels (Analytical Software, Tallahassee, FL). Since the variance of two sample means were unequal after checked by F-test (S1 # S2), t-test for two samples assuming unequal variance was preferred. Paired t-test was also used for comparison of analytical concentrations before and after adding ash soil samples using excel computer software.

4. RESULTS AND DISCUSSION

4.1. Soil pH and 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 it shows in Table 4.2, the concentrati on of exchangeable $Al^{+3}$is high (2.403±0.092 to 2.93±0.049 Cmol/Kg) indicating Al toxicity to be expected in the area. From the total exchangeable acidity as shown in Table 4.2, for all sample sites exchangeable Al^{+3} is higher than exchangeable H^+, which indicates exchangeable acidity is highly dominated the area than active acid from the three types of acidity described in section 2.2.This result in agreement with the result of, (Hue, N.V.1998**)** who reported exchangeable Al^{+3}as 2.76 ± 0.17 and total exchangeable acidity as 3.19±0.93C mol/Kg. So, high exchange between acid cations ($A^{+3}$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.

As it is shown in Table 4.1, 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. This is because the basic cations are insoluble at low pH, while acid cations are highly soluble and also basic cations have the properties to be leached out of the top soil layer in farm lands during summer in high rain fall area as described in section 2.3.2 (Paulos, D. 2001). So, in this study area, there is high exchangeable acidity and acid saturation percentage. This needs ameliorative measures like treating with wood ash. In this farm land use systems Al^{+3}toxicity may be a problem for crop production.

The results of total exchangeable acidity of this study are in agreement with the reports of many research findings for soil of the same pH range (Baligar, V.C. et al., 1997; Blamey, F.C.et al., 1997; Hazelton, P., Murphy, B. 2007). The reported results were found to be 2.93±0.73, 3.3±0.37 and 3.17±0.93 cmol/Kg of total exchangeable acidity, respectively.

Table 4.1: The average status of soil acidity and pH by water methods before adding wood ash.

Sample	Exch.Acidity(cmol/Kg)	Exch.Al^{3+}(cmol/Kg)	pH (H2O)	AP (ppm)	%TN
1	3.210±0.010	2.403±0.092	4.65	8.95±0.06	0.231±0.002
2	2.913±0.020	2.930±0.049	4.79	9.52±0.059	0.195±0.001
3	3.206±0.015	2.540±0.045	4.81	9.48±0.005	0.193±0.002
4	2.910±.020	2.743±0.045	4.62	8.99±0.010	0.223±0.002
5	3.013±0.015	2.846±0.045	4.91	8.76±0.003	0.190±0.005

Cmol/Kg –Centi mole per Kilogram of soil **RSD** – Relative Standard deviation

Exch.Al^{+3}-Exchangeable aluminum **TN**-Total Nitrogen

AP- Available Phosphorous Concentration of essential elements

In this study, the concentrations of available phosphorous, potassium, calcium and CEC are low. This is due to low pH and high exchangeable acidity. However, micronutrients such as iron and manganese are very high. These results clearly show that the highest concentration of Fe (297.38±0.545 to 389.78±0.374ppm) and Mn (89.75±.044 to 109.53±0.033ppm).On the other hand, the high concentration of Fe and Mn are, due to one of the cause of soil acidity by released H^+ to the soil as shown in Figure 2.4 and, equation 'h' and 'I'. According to (Landon 1991), the top soils having AP and CEC of > 25, 15-25 cmol/kg, 5-15 cmol/kg and < 5cmol/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 15 cmol/Kg) for AP and CEC, respectively as it is shown in Table 4.6. Also Ca < 5.2 cmol/Kg is classified as low and based on this all sample sites of the study area are low in Ca contents. 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 4.2.

Table4.2: The mean ± SD of exchangeable cations and micronutrient concentrations be fore adding ash of the different soil samples sites.

Sa	Exchangeable cations (ppm)				Micronutrients (ppm)			
	Na	K	Ca	CEC	Fe	Mn	Cu	Zn
1	8.448±0.001	5.40±0.22	20.35±0.044	32.13±0.01	379.38±0.547	108.74±0.093	5.68±0.007	1.98±0.005
2	8.117±0.001	5.57±0.188	15.32±0.009	34.21±0.01	389.78±0.374	109.53±0.033	4.57±0.026	1.090±0.003
3	8.328±0.004	5.79±0.070	18.24±0.006	33.32±0.01	297.38±0.545	97.68±.006	5.97±0.015	1.779±0.006
4	8.573±0.003	5.13±0.020	20.13±0.006	34.74±0.005	287.76±0.375	89.75±.044	4.94±0.050	1.94±0.048
5	8.243±0.002	5.8±0.010	17.43±0.006	32.14±0.01	326.04±0.044	98.63±0.011	5.86±0.025	1.78±0.068

CEC- Cation exchangeable capacity in mill equivalent/100 gram soil

4.2. A greenhouse incubation of treating acidic soil with wood ash

In this study the change in soil pH due to wood ash materials application results were recorded within twelve days intervals and the result indicates that the soil pH increases as treating with wood ash time increases. However, the change (increases) of soil pH in the first two months was lower than the remaining months. This might be due to strength of exchangeable acid in the first time and after long time interaction of wood ash 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 4.10.

This study shows that the farmers must stay at least more than two months after applying wood ash to sow their seeds. Except sun light variation and wood ash application rates, target pH and the decrease in the exchangeable acidity attains its minimum value at 72 days of incubation period. After 72 days of incubation the pH is 6.967 and exchangeable acidity is 0.412 Cmol/Kg in the soils. The application of wood ash materials in greenhouse incubation for 72 days reduced the acid soil by increasing soil pH and decreasing exchangeable

Al^{+3}.wood ash reacts with H^{+}in soil solution to produce H_2O and CO_2 and also convert $Al^{+3}$from toxic to none toxic forms (Saarsalmi, A. et al., 2007).

Table 4.3: A green house incubation of reaction of ash with soil acidity as a function of adding wood ash duration with pH.

WA time(days)	pH(H_2O)	Temp.(^{0}C)	Remark
0	4.0-4.2	22	
12	4.2-4.4	23	
24	4.5-4.70	23	
36	4.7-4.81	23	
48	5.2-5.3	23	
60	5.5-5.9	23	
72	6.3-6.9	22	

WA-Wood ashing

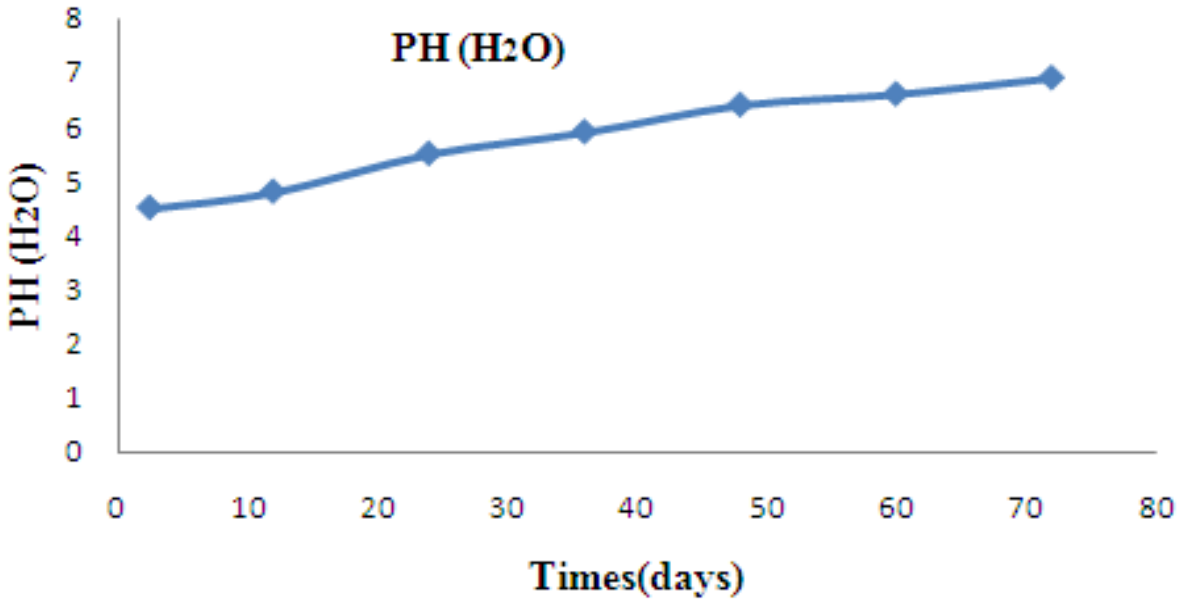

Figure 4.10: The effects of liming incubation time on soil acidity

4.3 Comparison of exchangeable acid and anions concentration before and after addin g ash

Anions such as OC, TN, AP availabilities and their interaction with plant root up take are limited by soil pH and acid toxicity. As it shown in Table 4.5, 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 adding ash, while there is no significant difference between the soil sample before and after adding ash, in their organic carbon content.The average pH was 4.759±0.114 and 6 .967±0.024 for before and after adding wood ash, respectively, which shows the area, was strongly acidic as it shows in Table 2.1 (USDA.1999**)** section 2.1.

A pH value of less than 5.5 is considered as a problematic for most microbial activities and t his directly influences availability of nutrients to plant growth and productivity (Solomon D. 2008**).** Like soil pH, Al^{+3}show high significant difference between before and after adding a sh. From total exchangeable acidity, exchangeable $Al^{+3}$is reduced from 2.690±0.096 C mol/ Kg was reduced, after green house incubation wood ash treated acid soil.

This indicates exchangeable acidity, which dominates the area, is removed from the soil.On the other hand, after adding wood ash, the availability of basic cations show increase as exch angeable acidities are decreased, to maintain positive and negative charge neutrality in soil s olutions (Bremner JM.1965)

Organic matter content is significantly affected by soil acidity and application of wood ash materials, as shown in Tables 4.4. Figure 4.10 also illustrate that except the effects of sample site variation, almost the mean concentration of OC in all soil samples show no significant difference before and after treating with wood ash. Similar conclusion was reache d by (Simard, R. C. 1994), who observed no effect of treating with wood ash on OC content of the acidic soil. The result of this study before treating with wood ash is in agreement with (Bray, R.. 1945**)** who reported OC concentration in the range 1.4–1.86 % in acidic soil. For all soil sample sites increasing the soil pH due to applied agricultural wood ash show a significant effect on total nitrogen content. This may be due to nitrogen losses from the soil and decreased nitrogen fixation due to less bacterial action in acid soil. However, phosphoro us availability is significantly affected by soil acidity. Table 4.4 illustrates, the phosphorous

concentration is found to be roughly doubled after treating with wood ash 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, J. R. 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.

However, treating with wood ash acid soil at pH > 6 make Ca highly soluble and react with phosphorous to form soluble $Ca_3(PO_4)_2$which is easily released as PO_4^{-3} for the plant roots and plant roots easily absorbed available phosphorous. On the other hand 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 (Haynes, J. R. 2001**)**. As shown in Table 2.1 and Figure 2.3 in section 2.2, the effects of Al^{+3} and H^+on plant growth cause injury to roots and decrease in uptake of nutrients (Hossner, L. R. 1989).

In this study, the mean P concentration in treated soil sample with wood ash is higher 12.896 ppm than before treating (9.144 ppm) which clearly shows highly significant effects of soil acidity on P availability. In this study, the mean P concentration before treating acid soil with wood ash is 9.144 ppm, which clearly shows highly significant effects of soil acidity on P availability and this is agreement with reported by (Adane B. 2014).

Table 4.4: The effects of addition of wood ash on some parameters and the paired t-test result before and after adding wood ash of soil samples.

Parameters	Mean ± SE		Paired t-Test		Difference
	B ASH	A ASH	Tcrit	Tcal	
pH (H_2O)	4.759±0.114	6.967±0.024	2.14	32.295	*
Exch. Acid	3.051±0.119	0.412±0.003	2.14	45.465	*
Exch. Al	2.690±0.096	0	2.14	23.090	*
%OC	1.439±0.376	2.703±0.017	2.14	7.637	*
%TN	0.207±0.018	0.237±0.006	2.14	2.972	*
AP(ppm)	9.144±0.317	12.896±0.451	2.14	3.930	*

OC-Organic carbon **B ASH**-Before adding ash **SE**-standard error

TN- Total Nitrogen **A ASH**-After adding ash

***** Significant different **ns**-No significant difference

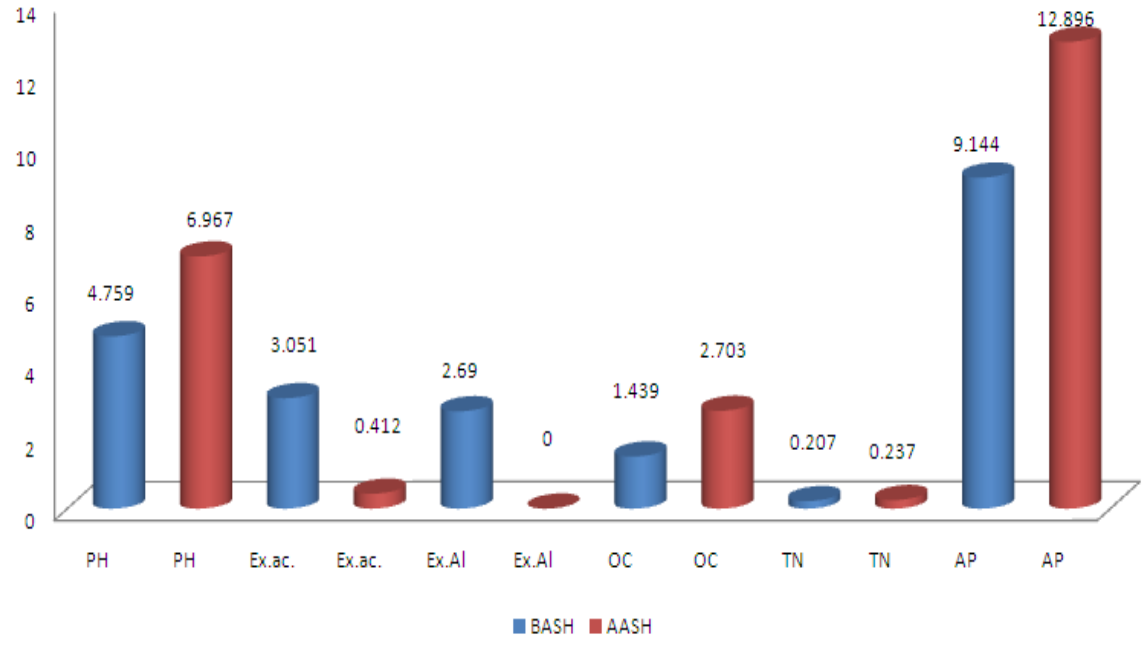

Figure 4.11: Comparison of the status of soil acidity and nutrient availability before and after adding wood ash

4.4 Comparison of exchangeable cations and micronutrients concentrations before and after adding ash.

4.4.1. Exchangeable cations

The results for the concentrations of macronutrients before and after treating soil sample with wood ash and associated paired t-test are summarized in Table 4.5 Sodium (Na^+) Sodium is an important element in order to determine the adequacy of plant nutrients. It has been reported that plants have an important ability to preserve sodium contents but prolonged deficiencies can affect strength of stem, decreased growth and reduced yield. Overall, the recommended range of Na element varies with soil and crop types. For nitosil, the recommended range is 0.6–17.8 ppm (Jones,B. J. Jr. 2001**)**. In this study concentration of sodium is found to be 8.342 and 10.210 ppm for before and after adding ash, 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 (5.387 and 15.100 ppm) for before and after treating soil sample with wood ash respectively, which shows significant difference between before and after adding ash as shown in Table 4.5 Deficiencies of potassium in nitosol of study area before adding ash 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 [46]. Calcium (Ca^{+2}) the exchangeable calcium in a soil has an important relation to soil pH and to the availability of several nutrient elements. The amounts of calcium and other basic cations present in a soil will decline as a soil becomes more acidic and increases as it becomes more alkaline. An excess of calcium causes calcium carbonate to precipitate and buffer the pH to a value near 8 (Tilahun D,.2004**).**

In this study,Ca concentration before treating with wood ash acid soil (18.29±1.923ppm) and after treating with wood ash (72.175±0.551ppm) clearly indicates the effects of soil acidity on calcium availability. The result is show that even though the total calcium present in soil is high, its availability to plant is limited by soil pH and others acid cations. The increasing exchangeable calcium availability during greenhouse incubation for

treating soil acidity with wood ash 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, N.V.1998**)** calcium phosphate easily release phosphate ion to plant roots while $AlPO_4$ and $FePO_4$ are precipitated and do not release $PO_4^{-3}$to plant roots. The highest concentration of Ca (17.4 mg/Kg), as shown in Table 4.6 is in agreement with the result reported by (Kamprath, E. J. 1984) who reported calcium concentration to be 157.9 ppm for same soil pH (KCl). On the other hand, the highest significant difference between mean concentrations of calcium (18.29 ppm and 72.175 ppm) before and after adding ash is due to the increase in the solubility of Calcium at higher pH (Tilahun D, .2004).

4.4.2. Cation exchangeable capacity

Cation exchangeable capacity is the total charge of the seats of cations (Na^+, K^+.Ca^{+2}, Mg^{+2}) in the soil and its availability is pH dependents (Lakew Desta et al.,2000). Many acid soils have very low amounts of exchangeable cations and a low calcium saturation of the CEC. At low pH, CEC are insoluble and their availability also decreases. Due to this, total positive charges in soil are not balanced with the total anions (negative charge) in the soil. As a result, acid cations are replaced to balance the seats of basic cations to maintain charge neutrality. Even though Ca availability is low, it's up taken by plant root is also inhibited by Al toxicity. In this study there is significant difference between CEC concentration before and after treating with wood ash, as shown in Table 4.5.

The highest significant difference of CEC before and after adding ash is due to low pH, exchangeable acid cations such as H^+ and Al^{+3} increase and occupies the site of basic cations. However, after 72 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 33.30±1.098 to 88.008±0.415 ppm before and after treat ing soil with wood ash, respectively, which indicates soil acidity highly affects CEC availabi lity as shown in Table 4.5.After agricultural wood ash applied to the soil, concentration of e xchangeable bases like Ca^{2+},increases in the solution and in turn increases CEC thereby decreasing the concentrations of the exchangeable acid ($Al^{+3}$and H^+) ions from the soil exchange complex were decreased (Kamprath, E. J. 1984**).**

Table 4.5: Comparison of the exchangeable cations and micronutrients concentration before and after adding wood ash in different sites of soil samples using paired t-test.

Parameters	Mean ± SE (ppm)		Paired t-Test		Difference
	B adding ash	A adding ash	t crit	t cal	
Na	8.342±0.164	10.210±0.159	2.14	5.757	*
K	5.387±0.310	15.100±0.137	2.14	45.241	*
Mg	4.613±0.950	38.75±2.70	2.14	13.588	*
Ca	18.29±1.923	72.175±0.551	2.14	33.008	*
CEC	33.30±1.098	88.008±0.415	2.14	54.588	*
Cu	5.406±0.572	2.65±0.108	2.14	7.226	*
Fe	336.07±0.023	32.286±0.379	2.14	14.345	*
Mn	100.87±7.687	23.58±0.296	2.14	32.502	*
Zn	1.722±0.337	1.232±0.06	2.14	3.505	*

CEC – Cation exchangeable capacity **tcal** - t-calculate

Significant different **tcrt** - t-critical

4.4.3. Micronutrients

The term micronutrients refer to a number of elements that are required by plants in very small quantities. This term usually applies to elements that are contained in plant tissues in amounts less than 100 ppm (Foth, H.D. et al., 1997)**.** According to (Foth, H.D.et al., 1997**)** the four essential micronutrients which are highly affected by exchangeable acidity that exist as cations in soils are zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn).Like exchange able cations, micronutrients such as Cu, Fe, Mn and Zn are significantly different before and after adding wood ash as shown in Table 4.6 Considering the mean results of Fe concentrati on,the highest (379.38ppm) and lowest (297.38 ppm) for soil samples of the study area, are in agreement with the study of (Adane B. 2014**)** for the same range of soil pH.

Similarly, the highest (109.53 ppm) and lowest (89.75 ppm) concentration is recorded for Mn before liming as shown in Table 4.6. The results of this study show that among the four micronutrients, Fe and Mn are significantly high in soil samples before adding ash as shown in Table 4.6. 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 as. (Rowell, D. L., 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 5.4 06, 336.07, 100.87 and 1.722 ppm for Cu, Fe, Mn and Zn, respectively. In this study, the res ult recorded for Mn and Fe before adding wood ash are high (100.87 ppm and 336.07 ppm) r espectively, 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 4.5 calculated > critical shows high significant difference between the results of before and after treating soil acidity with wood ash.

All micronutrients concentration in acid soil of pH (H2O) < 5.3 is higher than treated soil in the greenhouse incubation with pH (H2O) > 6.8. As it is described in section 2.1, the highest concentration of Fe and Mn (336.07 ppm) and (100.87 ppm) in soil acidity of before treating soil with wood ash 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. They also affect phosphorous and exchangeable cations (Na^{+}, K^{+}, Ca^{+2}, Mg^{+2}) availability (Ketterings, Q. M.2005**)** .Howe ver, after 72 days greenhouse incubation of treating acid soil with wood ash, the low mean concentration is recorded for Fe (32.286±0.379 ppm) and Mn **(**23.5823.58±0.296 ppm) as the pH increases to 6.967±0.024 at this pH, Fe and Mn insoluble and replaced by Ca^{+2} ion found in wood ash.

Similarly, the results of Cu and Zn concentration are decreases almost by half **(**5.406±0.572 to 2.65±0.108ppm and 1.722±0.337 to 1.232±0.06 ppm) after treating with wood ash respectively as shown in Table 4.5. The greatest difference of micronutrients before and after treating with wood ash indicates the status of soil acidity in the study area is significantly affecting the availability of micronutrients (Adane B. 2014**).** Figure 4.12 clearly illustrates that as soil pH increases due to treatment of acidic soil with wood ash, the availability of exchangeable cations also increases, while the availability of micronutrients decreases as soil pH increases.

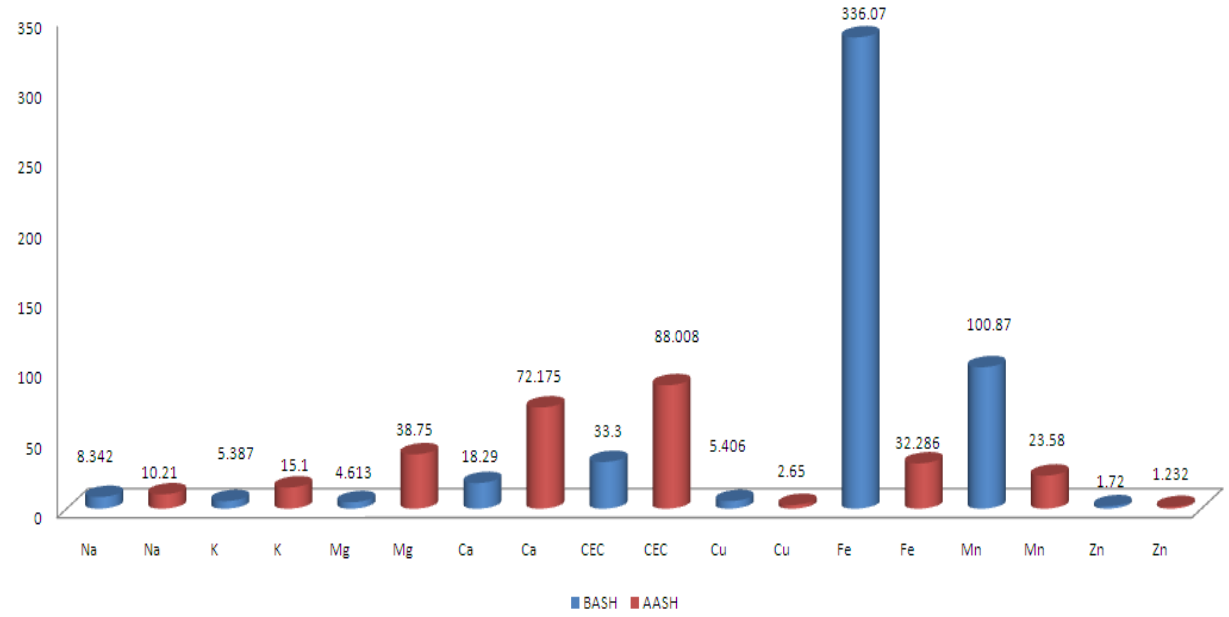

Figure 4.12: Effects of soil acidity on cations and micronutrients availability before adding ash (BASH) and after adding ash (AASH)

4.5. The variation of exchangeable acidity and anions concentration among different sample sites

ANOVA test shows that the existence of significant difference in soil organic matters among the five sample sites before treatment of acidic soil ($P < 0.05$).However, there is no significant difference among sample sites 1 and 4, 2 and 3 in their pH content, but as shown in Table 4.6, show significant difference between the rest of the sample sites in PH content. The exchangeable acidity between sample sites 1 and 3, 2 and 4 show no significant differen ce to each other, while the else samples site shows significant difference with each others. A vailable phosphorous in sample sites 1 and 4, 2 and 3 show no significant difference, while they show significant difference between the rest of the sample sites in its AP content from the other sites. The total nitrogen between sample sites 2 and 3, 3 and 5 show no significant difference, while they show significant difference between the rest of the sample sites in its TN content from the other sites. In general, sites 1 and 4 show similarities.

Table 4.6: Comparison of different parameters within different sample sites before adding ash

Sample	pH(H_2O)	Exch.Acid(Cmol /kg	AR(g/Kg)	%OC	%TN	AP(ppm)
1	4.65^{B}	3.2100^{A}	2.41	1.873^{A}	0.231^{A}	8.952^{AB}
2	4.79^{AB}	2.9133^{B}	2.18	1.076^{AB}	0.195^{B}	9.527^{A}
3	4.81^{A}	3.2033^{A}	2.40	1.126^{AB}	0.193^{B}	9.489^{A}
4	4.62^{B}	2.9100^{B}	2.18	1.886^{A}	0.223^{A}	8.990^{AB}
5	4.91^{A}	3.0133^{AB}	2.25	1.236^{AB}	0.190^{B}	8.768^{B}
CV	2.39	0.656	1.511	26.12	0.97	0.295
LSD<0. 05	0.116	0.148	0.14	0.389	ns	0.322

Cmol/Kg-Centi mole per kilogram of soil **ns** - Not Significant difference Means with the same letter are not significantly different **CV**–Coefficients of Variance Means with the same letter are not significantly different **ppm** - parts per million **AP** - Available Phosphorous in parts per million **AR** Ash Requirment **LSD<0.05** Least Significant differenc e at 95% confidence interval

ANOVA test shows that the existence of significant difference in soil total nitrogen and available phosphorous among the five sample sites after adding ash. As it is summarized in Table 4.8, there is no significant difference among sample sites 4 and 5 in their pH content, but they show significant difference between the rests of the sample sites in PH content. There is no significant difference among sample sites 1and 3, 2 and 5 in their exchangeable acidity content. But they show significant difference between sample site the rest samples. All sample sites show significant difference except that of sample sites 3 and 4 in the sample sites in OC content, whiles all sample sites show significant difference in PH except that of sample sites 4 and 5 content as shown in Table 4.7.

Table 4.7: Comparison of different parameters within different sample sites after adding ash

Sample Site	pH (H_2O)	Exch. Acid (Cmol/Kg)	%OC	%TN	AP (ppm)
1	6.99^{AB}	0.417^{AB}	2.800^{A}	0.270^{A}	10.250^{AB}
2	7.12^{A}	0.404^{B}	2.613^{BC}	0.211^{AB}	12.359^{AB}
3	6.96^{AB}	0.415^{AB}	2.680^{AB}	0.250^{AB}	11.820^{AB}
4	6.86^{BC}	0.427^{A}	2.683^{AB}	0.224^{AB}	15.116^{A}
5	6.88^{BC}	0.399^{B}	2.740^{AB}	0.236^{AB}	13.936^{AB}
CV	1.315	3.556	2.405	5.44	3.768
LSD<0.05	0.087	0.013	0.0614	0.025	1.746

Cmol/Kg-Cent mole per kilogram of soil **ns** - Not Significant difference

Means with the same letter are not significantly different **CV** – Coefficients of Variance

Means with the same letter are not significantly different **LSD<0.05** Least Significant differe nce at 95% confidence interval.

4.6 The variation of exchangeable cations and micronutrients concentration among diff erent sample sites

ANOVA test reveals that there is significant difference in Na, Mg, Ca, Fe, Mn and Cu content among the five soil sample sites. However, K and Zn do not show significant differe nce in some of the five sample sites as shown Table 4.8.Sample sites 1 and 2, 2 and 5, 3 and 4 show no significant difference in their K contents, while other the sample sites have signifi cant difference among themselves, where us sample sites 1and 4,3 and 5 show no significant difference in their Zn contents, while other the sample sites have significant difference amon g themselves. Sample site 1 and 5 shows no significant difference, while there is significant difference between among the else sample site in their CEC contents.

Table 4.8: Comparison of metal elements within the five different sites before adding ash

Sample	Na (ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	CEC (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)
1	8.45^{AB}	5.40^{B}	5.97^{A}	20.35A	32.13^{BC}	379.38^{AB}	48.73^{B}	5.68^{B}	1.98^{A}
2	$8.^{12AB}$	5.57^{B}	3.24^{C}	15.32^{C}	34.21^{AB}	389.78^{A}	49.52^{AB}	4.57^{C}	1.09^{B}
3	8.33^{AB}	5.79^{A}	5.14^{AB}	18.24^{B}	33.32^{B}	297.38^{BC}	47.74^{AB}	5.97^{A}	1.78^{AB}
4	8.57^{A}	5.13^{C}	4.56^{B}	20.13^{AB}	34.74^{A}	287.76^{C}	49.75^{A}	4.94^{BC}	1.94^{A}
5	$8.^{24AB}$	5.80^{A}	4.16^{BC}	17.43^{BC}	32.14^{BC}	326.04^{B}	48.62^{BC}	5.86^{AB}	1.78^{AB}
CV	1.966	5.755	20.594	10.508	3.296	12.842	7.621	10.581	19.570
LSD< 0.05	0.165	0.299	0.928	1.939	1.393	45.900	7.708	0.582	0.263

Double letter such as AB, BC shows a very least significant difference between A and AB than A and B (A>AB>B>BC>C…).

ANOVA test reveals that there is significant difference in Na, Mg, Mn and Cu content amon g the five soil sample sites. Sample sites 2 and 4 show no significant difference in their K co ntents. As shown in Table 4.9.Sample sites 1 and 5 shows no significant difference, while the else sample sites shows significant difference in their Ca contents. There is no significant difference in soil sample sites 1 and 4, and 5, 2 and 3, 4 and 5 in their CEC contents, but there is significant difference between the rests of the sample sites.

There is no significant difference among sample sites 1and 3, 2 and 5 in Fe content, but significant difference occurs between the rest sample sites. Sample sites 2, 3 and 4 as well as also sample sites 4 and 5 show no significant difference in their Zn content, but there is significant difference between the rest of sample sites as well as also from each other in Zn content.

Table4.9: Comparison of metal elements within the five different sites after treating with wood ash

Sample Site	Na(ppm)	K (ppm)	Mg (ppm)	Ca (ppm)	CEC (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
1	9.59^{BC}	15.23^{B}	46.15^{A}	70.39^{BC}	89.86^{A}	2.05^{C}	32.22^{AB}	23.98^{B}	1.609^{A}
2	10.44^{B}	14.57^{BC}	18.69^{C}	75.49^{A}	87.54^{AB}	2.79^{B}	30.98^{BC}	22.57^{BC}	1.247^{B}
3	9.44^{C}	15.12^{AB}	42.15^{BC}	71.72^{B}	85.74^{AB}	3.11^{A}	32.33^{AB}	25.15^{A}	1.237^{B}
4	10.57^{AB}	14.59^{BC}	43.88^{AB}	73.39^{AB}	89.64^{A}	2.98^{AB}	34.86^{A}	24.12^{AB}	1.110^{BC}
5	10.99^{A}	15.98^{A}	42.92^{B}	70.21^{BC}	88.92^{A}	2.31^{BC}	31.04^{BC}	22.09^{C}	0.958^{C}
CV	6.05	3.53	27.03	2.96	2.01	15.77	4.55	4.86	19.02
LSD< 0.05	0.635	0.511	7.299	2.155	1.374	0.433	1.291	1.150	0.197

*Means with the same letter are not significantly different ns – No significant difference Means with different letter are significantly different .Double letter such as AB, BC shows a very least significant difference between A and AB than A and B (A>AB>B>BC>C…)

5. CONCLUSIONS AND RECOMMENDATIONS ONE-SIMPLE STATISTICS.

This study assesses soil acidity status 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 plant nutrients. It is found that the average values of exchangeable acidity and exchangea ble Al show results within the ranges 3.051±0.119 cmol/Kg and 2.690±0.096 cmol/Kg respe ctively. From this study, it is observed that soil acidity and liming factor directly affect plant nutrients. As compared by paired t-test, except OC and Mn, all macro and micronutrients are significantly affected by soil acidity. Application of wood ash results in reduction of exchan geable acidity, Al saturation and thereby increasing soil pH.

In addition, treatment of acidic soil with wood ash result in an increase in the concentration of the basic nutrient elements in the soil solutions, the exchange complex to the levels required and increasing nutrient availabilities for plant uptakes. After 72 days greenhouse incubation of treated with wood ash acid soil, all treated soils attain the target pH 6.967±0.024 and decrease in exchangeable acidity to 0.412±0.003 cmol/Kg.

During application on of wood ash, 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 reacti on of wood ash and acidic soil period increases.The following (figures 5.1a,b and c)show th at the different between wood ash treated and not treated acidic soil.

Figure 5.1a. Bea plant in treated and not treated acidic soil after 45 days respectively.

Figure 5.1b. Bea plants in treated and not treated acidic soil after 75 days respectively.

Figure 5.1c. Bea plants in treated and not treated acidic soil after 75 days respectively.

So, the farmer must stay at least two months after applying the wood ash to sow his/her seeds. This is due to the reaction between wood ash materials and soil acidity is slow and time dependent. 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 wood ash to the soils under study. This study area is found to be medium to high in N content and it is also found that the Phospharus content to be medium to high after treating with ash. Therefore, in this area it is recommended to use treating with wood ash instead of applying more fertilizers.

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7. Appendix .1

Figure 4.1 – 4.9, The calibration graphs of macro and micronutrients analyzed which listed in Table 4.1 are shown within their corresponding slope, intercept and correlation coefficients.

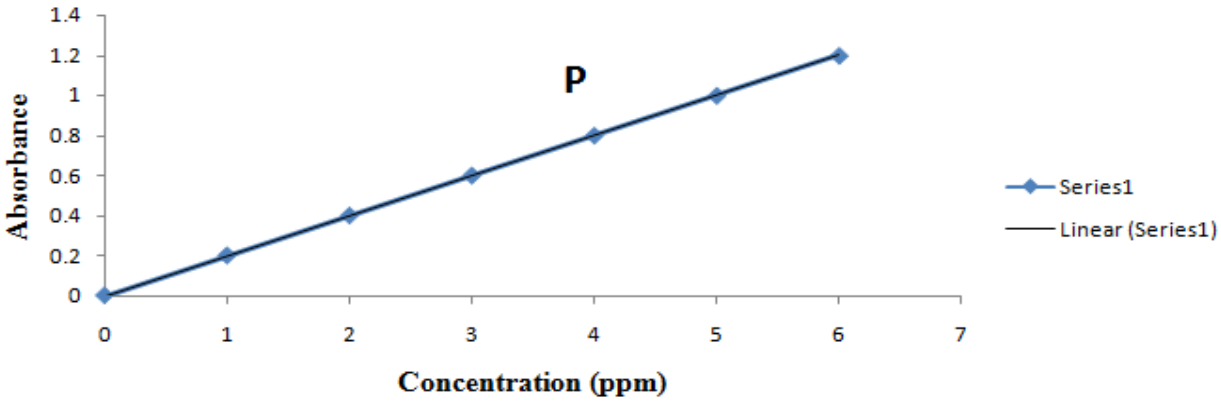

Figure 4.1: Calibration curve of phosphorous

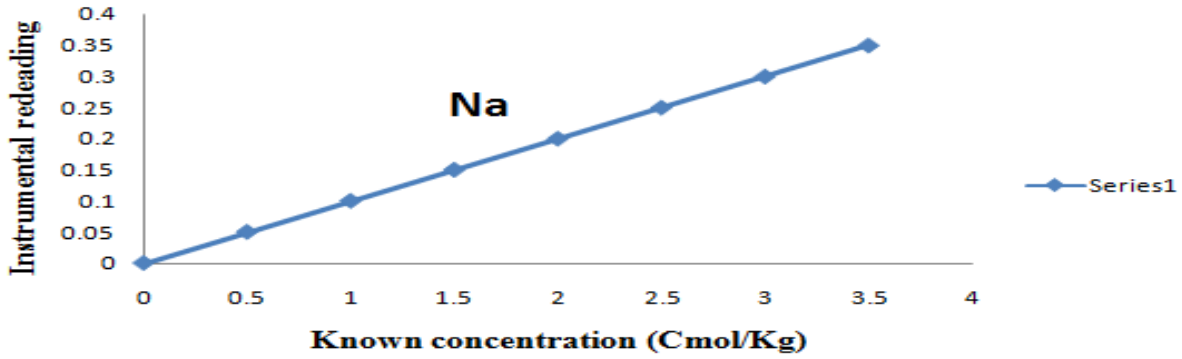

Figure 4.2: Calibration curve of Na

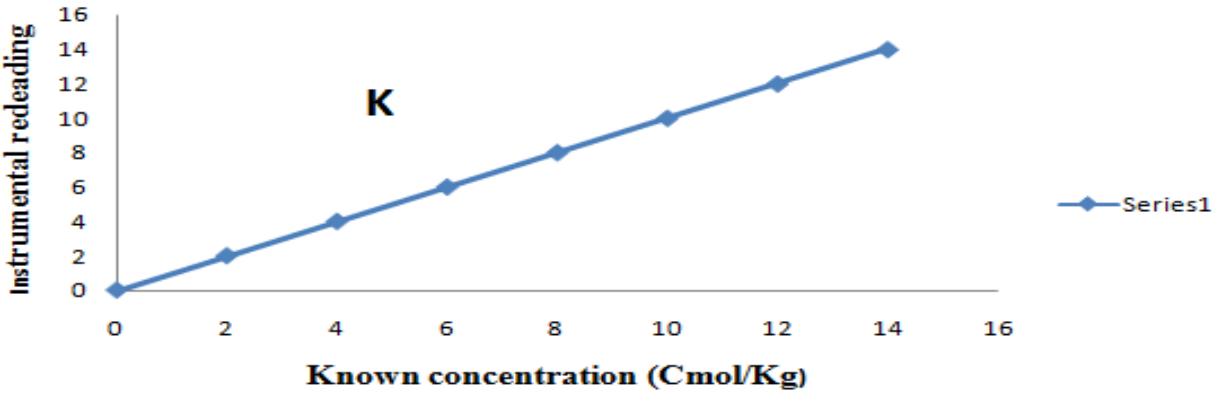

Figure 4.3: Calibration curve of K

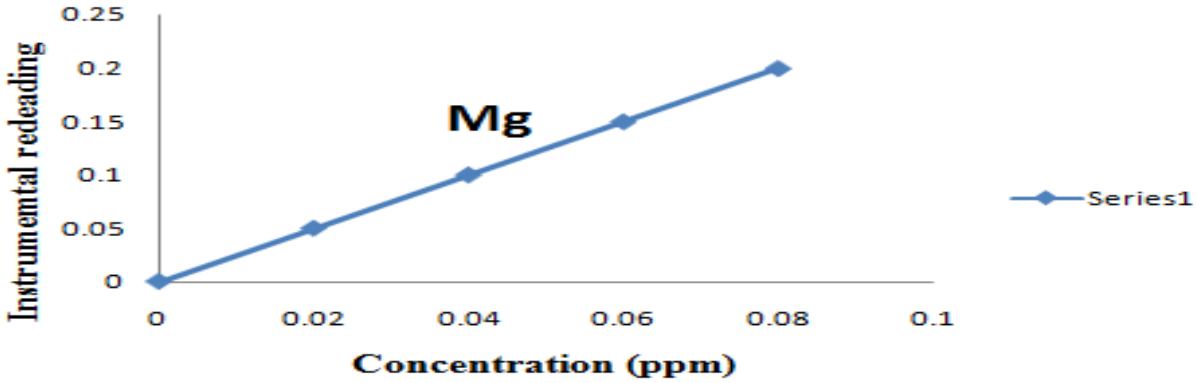

Figure 4.4: Calibration curve of Mg

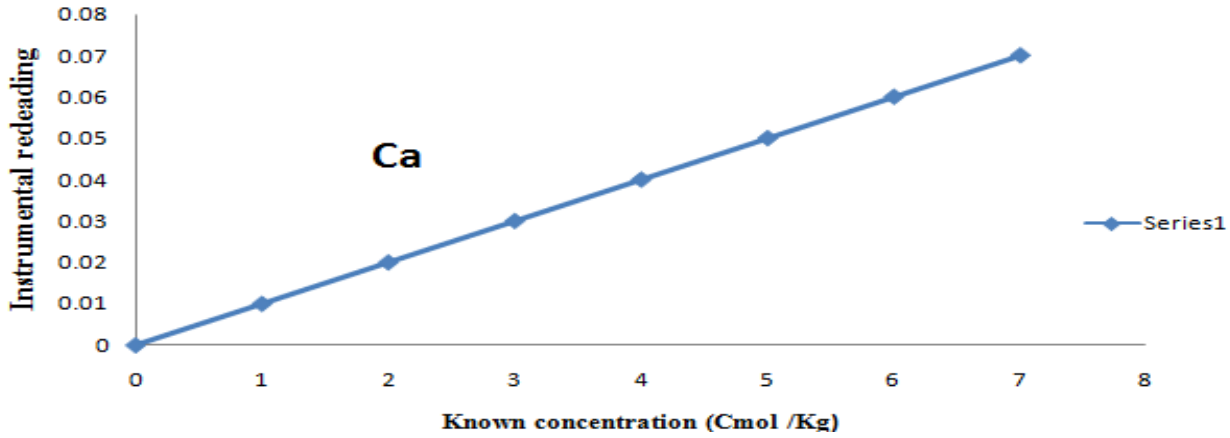

Figure 4.5: Calibration curve of Ca

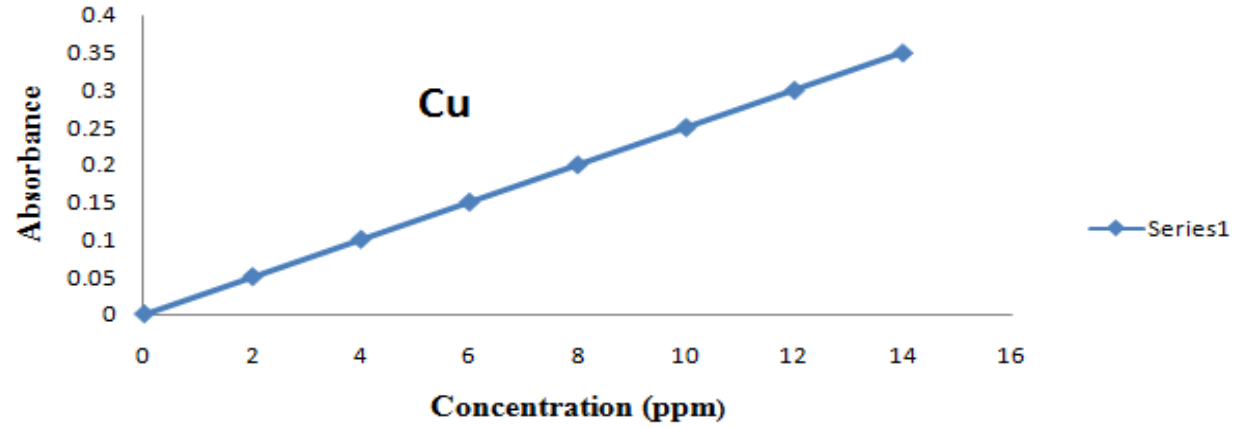

Figure 4.6: Calibration curve of Cu

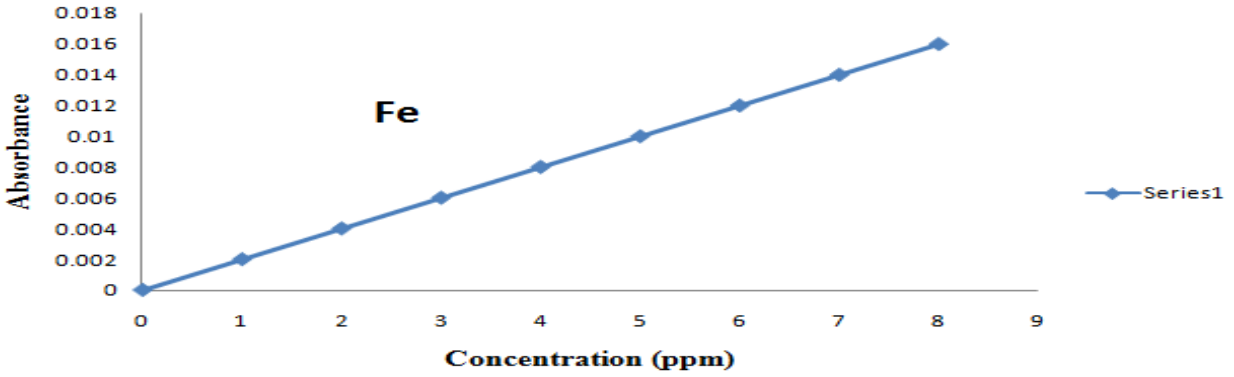

Figure 4.7: Calibration curve of Fe

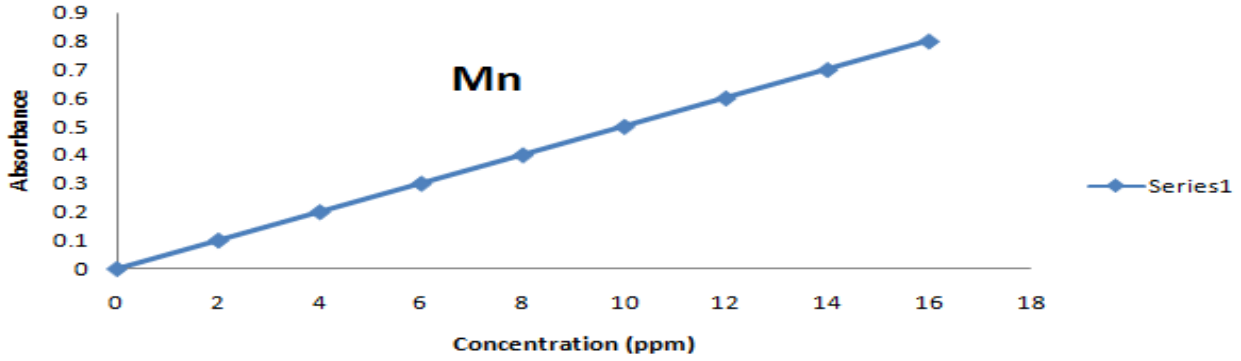

Figure 4.8: Calibration curve of Mn

Table 4.1: Concentration values of working standard solutions, regression equation and correlation coefficients of calibration curves.

Elements	Intermediate (ppm)	Working standard solution(ppm)	Regression equation	Correlation coefficient(R^2)	Analytical Method
P	50	1, 2, 3, 4, 5	y = 0.32x + 0.0144	0.9991	Spectrophotometer
Na	200	4,8,10,16	y = 1.0249x - 0.293	0.9993	AAS
K	100	2,4,6,8,10	y = 0.98x + 0.1	0.9992	AAS
Ca	250	2, 4, 6, 8, 10	y = 1.0518x - 0.467	0.9971	AAS
Cu	50	1, 2, 4	y= 0.0046x+ 0.0045	0.9993	AAS
Fe	100	1, 2, 4, 6	y= 0.0033x - 0.0002	0.9983	AAS
Mn	100	1, 2, 4	y = 0.0047x + 0.004	0.9973	AAS
Zn	50	1, 2, 4	Y =0.0194x + 0.0002	0.9996	AAS

8. APPENDIX -2

One way outcome of soil samples before treating with wood ash (A) and after treating with wood ash (B) respectively. "A"

Multiple Comparisons

Dependent Variable	(I) soil	(J) soil	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
sodium	a	b	.331000*	.002366	.000	.32573	.33627
		c	.119667*	.002366	.000	.11439	.12494
		d	-.125667*	.002366	.000	-.13094	-.12039
		e	.204333*	.002366	.000	.19906	.20961
	b	a	-.331000*	.002366	.000	-.33627	-.32573
		c	-.211333*	.002366	.000	-.21661	-.20606
		d	-.456667*	.002366	.000	-.46194	-.45139
		e	-.126667*	.002366	.000	-.13194	-.12139
	c	a	-.119667*	.002366	.000	-.12494	-.11439
		b	.211333*	.002366	.000	.20606	.21661
		d	-.245333*	.002366	.000	-.25061	-.24006
		e	.084667*	.002366	.000	.07939	.08994
	d	a	.125667*	.002366	.000	.12039	.13094
		b	.456667*	.002366	.000	.45139	.46194
		c	.245333*	.002366	.000	.24006	.25061
		e	.330000*	.002366	.000	.32473	.33527
	e	a	-.204333*	.002366	.000	-.20961	-.19906
		b	.126667*	.002366	.000	.12139	.13194
		c	-.084667*	.002366	.000	-.08994	-.07939
		d	-.330000*	.002366	.000	-.33527	-.32473
potassium	a	b	-.170000	.111421	.158	-.41826	.07826
		c	.363333*	.111421	.009	.11507	.61160
		d	.276667*	.111421	.032	.02840	.52493
		e	-.387000*	.111421	.006	-.63526	-.13874
	b	a	.170000	.111421	.158	-.07826	.41826
		c	.533333*	.111421	.001	.28507	.78160
		d	.446667*	.111421	.002	.19840	.69493
		e	-.217000	.111421	.080	-.46526	.03126
	c	a	-.363333*	.111421	.009	-.61160	-.11507
		b	-.533333*	.111421	.001	-.78160	-.28507

		d	-.086667	.111421	.455	-.33493	.16160
		e	-.750333*	.111421	.000	-.99860	-.50207
	d	a	-.276667*	.111421	.032	-.52493	-.02840
		b	-.446667*	.111421	.002	-.69493	-.19840
		c	.086667	.111421	.455	-.16160	.33493
		e	-.663667*	.111421	.000	-.91193	-.41540
	e	a	.387000*	.111421	.006	.13874	.63526
		b	.217000	.111421	.080	-.03126	.46526
		c	.750333*	.111421	.000	.50207	.99860
		d	.663667*	.111421	.000	.41540	.91193

magnisium	a	b	2.728000*	.036656	.000	2.64632	2.80968
		c	.825000*	.036656	.000	.74332	.90668
		d	1.406000*	.036656	.000	1.32432	1.48768
		e	1.807000*	.036656	.000	1.72532	1.88868
	b	a	-2.728000*	.036656	.000	-2.80968	-2.64632
		c	-1.903000*	.036656	.000	-1.98468	-1.82132
		d	-1.322000*	.036656	.000	-1.40368	-1.24032
		e	-.921000*	.036656	.000	-1.00268	-.83932
	c	a	-.825000*	.036656	.000	-.90668	-.74332
		b	1.903000*	.036656	.000	1.82132	1.98468
		d	.581000*	.036656	.000	.49932	.66268
		e	.982000*	.036656	.000	.90032	1.06368
	d	a	-1.406000*	.036656	.000	-1.48768	-1.32432
		b	1.322000*	.036656	.000	1.24032	1.40368
		c	-.581000*	.036656	.000	-.66268	-.49932
		e	.401000*	.036656	.000	.31932	.48268
	e	a	-1.807000*	.036656	.000	-1.88868	-1.72532
		b	.921000*	.036656	.000	.83932	1.00268
		c	-.982000*	.036656	.000	-1.06368	-.90032
		d	-.401000*	.036656	.000	-.48268	-.31932

calcium	a	b	5.039333*	.017194	.000	5.00102	5.07764
		c	2.113667*	.017194	.000	2.07536	2.15198
		d	.220000*	.017194	.000	.18169	.25831
		e	2.927667*	.017194	.000	2.88936	2.96598

	b	a	-5.039333*	.017194	.000	-5.07764	-5.00102
		c	-2.925667*	.017194	.000	-2.96398	-2.88736
		d	-4.819333*	.017194	.000	-4.85764	-4.78102
		e	-2.111667*	.017194	.000	-2.14998	-2.07336
	c	a	-2.113667*	.017194	.000	-2.15198	-2.07536
		b	2.925667*	.017194	.000	2.88736	2.96398
		d	-1.893667*	.017194	.000	-1.93198	-1.85536
		e	.814000*	.017194	.000	.77569	.85231
	d	a	-.220000*	.017194	.000	-.25831	-.18169
		b	4.819333*	.017194	.000	4.78102	4.85764
		c	1.893667*	.017194	.000	1.85536	1.93198
		e	2.707667*	.017194	.000	2.66936	2.74598
	e	a	-2.927667*	.017194	.000	-2.96598	-2.88936
		b	2.111667*	.017194	.000	2.07336	2.14998
		c	-.814000*	.017194	.000	-.85231	-.77569
		d	-2.707667*	.017194	.000	-2.74598	-2.66936
cation exchageable capacity	a	b	-2.080000*	.007601	.000	-2.09694	-2.06306
		c	-1.190000*	.007601	.000	-1.20694	-1.17306
		d	-2.613333*	.007601	.000	-2.63027	-2.59640
		e	-.010000	.007601	.218	-.02694	.00694
	b	a	2.080000*	.007601	.000	2.06306	2.09694
		c	.890000*	.007601	.000	.87306	.90694
		d	-.533333*	.007601	.000	-.55027	-.51640
		e	2.070000*	.007601	.000	2.05306	2.08694
	c	a	1.190000*	.007601	.000	1.17306	1.20694
		b	-.890000*	.007601	.000	-.90694	-.87306
		d	-1.423333*	.007601	.000	-1.44027	-1.40640
		e	1.180000*	.007601	.000	1.16306	1.19694
	d	a	2.613333*	.007601	.000	2.59640	2.63027
		b	.533333*	.007601	.000	.51640	.55027
		c	1.423333*	.007601	.000	1.40640	1.44027
		e	2.603333*	.007601	.000	2.58640	2.62027
	e	a	.010000	.007601	.218	-.00694	.02694
		b	-2.070000*	.007601	.000	-2.08694	-2.05306
		c	-1.180000*	.007601	.000	-1.19694	-1.16306
		d	-2.603333*	.007601	.000	-2.62027	-2.58640
Iron	a	b	-10.403333*	.342559	.000	-11.16660	-9.64006
		c	82.000000*	.342559	.000	81.23673	82.76327
		d	91.616667*	.342559	.000	90.85340	92.37994

		e	53.333333*	.342559	.000	52.57006	54.09660
	b	a	10.403333*	.342559	.000	9.64006	11.16660
		c	92.403333*	.342559	.000	91.64006	93.16660
		d	102.020000*	.342559	.000	101.25673	102.78327
		e	63.736667*	.342559	.000	62.97340	64.49994
	c	a	-82.000000*	.342559	.000	-82.76327	-81.23673
		b	-92.403333*	.342559	.000	-93.16660	-91.64006
		d	9.616667*	.342559	.000	8.85340	10.37994
		e	-28.666667*	.342559	.000	-29.42994	-27.90340
	d	a	-91.616667*	.342559	.000	-92.37994	-90.85340
		b	-102.020000*	.342559	.000	-102.78327	-101.25673
		c	-9.616667*	.342559	.000	-10.37994	-8.85340
		e	-38.283333*	.342559	.000	-39.04660	-37.52006
	e	a	-53.333333*	.342559	.000	-54.09660	-52.57006
		b	-63.736667*	.342559	.000	-64.49994	-62.97340
		c	28.666667*	.342559	.000	27.90340	29.42994
		d	38.283333*	.342559	.000	37.52006	39.04660
manganes	a	b	-.791000*	.039635	.000	-.87931	-.70269
		c	11.057000*	.039635	.000	10.96869	11.14531
		d	18.987333*	.039635	.000	18.89902	19.07565
		e	10.110333*	.039635	.000	10.02202	10.19865
	b	a	.791000*	.039635	.000	.70269	.87931
		c	11.848000*	.039635	.000	11.75969	11.93631
		d	19.778333*	.039635	.000	19.69002	19.86665
		e	10.901333*	.039635	.000	10.81302	10.98965
	c	a	-11.057000*	.039635	.000	-11.14531	-10.96869
		b	-11.848000*	.039635	.000	-11.93631	-11.75969

		d	7.930333*	.039635	.000	7.84202	8.01865
		e	-.946667*	.039635	.000	-1.03498	-.85835
	d	a	-18.987333*	.039635	.000	-19.07565	-18.89902
		b	-19.778333*	.039635	.000	-19.86665	-19.69002
		c	-7.930333*	.039635	.000	-8.01865	-7.84202
		e	-8.877000*	.039635	.000	-8.96531	-8.78869
	e	a	-10.110333*	.039635	.000	-10.19865	-10.02202
		b	-10.901333*	.039635	.000	-10.98965	-10.81302
		c	.946667*	.039635	.000	.85835	1.03498
		d	8.877000*	.039635	.000	8.78869	8.96531
copper	a	b	1.110000*	.023465	.000	1.05772	1.16228
		c	-.293333*	.023465	.000	-.34562	-.24105
		d	.740000*	.023465	.000	.68772	.79228
		e	-.186667*	.023465	.000	-.23895	-.13438
	b	a	-1.110000*	.023465	.000	-1.16228	-1.05772
		c	-1.403333*	.023465	.000	-1.45562	-1.35105
		d	-.370000*	.023465	.000	-.42228	-.31772
		e	-1.296667*	.023465	.000	-1.34895	-1.24438
	c	a	.293333*	.023465	.000	.24105	.34562
		b	1.403333*	.023465	.000	1.35105	1.45562
		d	1.033333*	.023465	.000	.98105	1.08562
		e	.106667*	.023465	.001	.05438	.15895
	d	a	-.740000*	.023465	.000	-.79228	-.68772
		b	.370000*	.023465	.000	.31772	.42228
		c	-1.033333*	.023465	.000	-1.08562	-.98105
		e	-.926667*	.023465	.000	-.97895	-.87438
	e	a	.186667*	.023465	.000	.13438	.23895
		b	1.296667*	.023465	.000	1.24438	1.34895
		c	-.106667*	.023465	.001	-.15895	-.05438
		d	.926667*	.023465	.000	.87438	.97895
iron	a	b	.890000*	.026802	.000	.83028	.94972
		c	.173000*	.026802	.000	.11328	.23272
		d	.034667	.026802	.225	-.02505	.09438
		e	.197333*	.026802	.000	.13762	.25705
	b	a	-.890000*	.026802	.000	-.94972	-.83028

		c	-.717000*	.026802	.000	-.77672	-.65728
		d	-.855333*	.026802	.000	-.91505	-.79562
		e	-.692667*	.026802	.000	-.75238	-.63295
	c	a	-.173000*	.026802	.000	-.23272	-.11328
		b	.717000*	.026802	.000	.65728	.77672
		d	-.138333*	.026802	.000	-.19805	-.07862
		e	.024333	.026802	.385	-.03538	.08405
	d	a	-.034667	.026802	.225	-.09438	.02505
		b	.855333*	.026802	.000	.79562	.91505
		c	.138333*	.026802	.000	.07862	.19805
		e	.162667*	.026802	.000	.10295	.22238
	e	a	-.197333*	.026802	.000	-.25705	-.13762
		b	.692667*	.026802	.000	.63295	.75238
		c	-.024333	.026802	.385	-.08405	.03538
		d	-.162667*	.026802	.000	-.22238	-.10295
PH	a	b	-.163333*	.009189	.000	-.18381	-.14286
		c	-.183333*	.009189	.000	-.20381	-.16286
		d	.006667	.009189	.485	-.01381	.02714
		e	-.273333*	.009189	.000	-.29381	-.25286
	b	a	.163333*	.009189	.000	.14286	.18381
		c	-.020000	.009189	.055	-.04048	.00048
		d	.170000*	.009189	.000	.14952	.19048
		e	-.110000*	.009189	.000	-.13048	-.08952
	c	a	.183333*	.009189	.000	.16286	.20381
		b	.020000	.009189	.055	-.00048	.04048
		d	.190000*	.009189	.000	.16952	.21048
		e	-.090000*	.009189	.000	-.11048	-.06952
	d	a	-.006667	.009189	.485	-.02714	.01381
		b	-.170000*	.009189	.000	-.19048	-.14952
		c	-.190000*	.009189	.000	-.21048	-.16952
		e	-.280000*	.009189	.000	-.30048	-.25952
	e	a	.273333*	.009189	.000	.25286	.29381
		b	.110000*	.009189	.000	.08952	.13048
		c	.090000*	.009189	.000	.06952	.11048
		d	.280000*	.009189	.000	.25952	.30048
exchageable acidity	a	b	.296667*	.013663	.000	.26622	.32711
		c	.003333	.013663	.812	-.02711	.03378
		d	.300000*	.013663	.000	.26956	.33044
		e	.196667*	.013663	.000	.16622	.22711

	b	a	-.296667*	.013663	.000	-.32711	-.26622
		c	-.293333*	.013663	.000	-.32378	-.26289
		d	.003333	.013663	.812	-.02711	.03378
		e	-.100000*	.013663	.000	-.13044	-.06956
	c	a	-.003333	.013663	.812	-.03378	.02711
		b	.293333*	.013663	.000	.26289	.32378
		d	.296667*	.013663	.000	.26622	.32711
		e	.193333*	.013663	.000	.16289	.22378
	d	a	-.300000*	.013663	.000	-.33044	-.26956
		b	-.003333	.013663	.812	-.03378	.02711
		c	-.296667*	.013663	.000	-.32711	-.26622
		e	-.103333*	.013663	.000	-.13378	-.07289
	e	a	-.196667*	.013663	.000	-.22711	-.16622
		b	.100000*	.013663	.000	.06956	.13044
		c	-.193333*	.013663	.000	-.22378	-.16289
		d	.103333*	.013663	.000	.07289	.13378
organic carbon	a	b	.796667*	.004714	.000	.78616	.80717
		c	.750000*	.004714	.000	.73950	.76050
		d	-.013333*	.004714	.018	-.02384	-.00283
		e	.636667*	.004714	.000	.62616	.64717
	b	a	-.796667*	.004714	.000	-.80717	-.78616
		c	-.046667*	.004714	.000	-.05717	-.03616
		d	-.810000*	.004714	.000	-.82050	-.79950
		e	-.160000*	.004714	.000	-.17050	-.14950
	c	a	-.750000*	.004714	.000	-.76050	-.73950
		b	.046667*	.004714	.000	.03616	.05717
		d	-.763333*	.004714	.000	-.77384	-.75283
		e	-.113333*	.004714	.000	-.12384	-.10283
	d	a	.013333*	.004714	.018	.00283	.02384
		b	.810000*	.004714	.000	.79950	.82050
		c	.763333*	.004714	.000	.75283	.77384
		e	.650000*	.004714	.000	.63950	.66050
	e	a	-.636667*	.004714	.000	-.64717	-.62616
		b	.160000*	.004714	.000	.14950	.17050
		c	.113333*	.004714	.000	.10283	.12384
		d	-.650000*	.004714	.000	-.66050	-.63950
total nitrogen	a	b	.036333*	.002076	.000	.03171	.04096
		c	.038000*	.002076	.000	.03337	.04263
		d	.008667*	.002076	.002	.00404	.01329

		e	.041000*	.002076	.000	.03637	.04563
	b	a	-.036333*	.002076	.000	-.04096	-.03171
		c	.001667	.002076	.441	-.00296	.00629
		d	-.027667*	.002076	.000	-.03229	-.02304
		e	.004667*	.002076	.048	.00004	.00929
	c	a	-.038000*	.002076	.000	-.04263	-.03337
		b	-.001667	.002076	.441	-.00629	.00296
		d	-.029333*	.002076	.000	-.03396	-.02471
		e	.003000	.002076	.179	-.00163	.00763
	d	a	-.008667*	.002076	.002	-.01329	-.00404
		b	.027667*	.002076	.000	.02304	.03229
		c	.029333*	.002076	.000	.02471	.03396
		e	.032333*	.002076	.000	.02771	.03696
	e	a	-.041000*	.002076	.000	-.04563	-.03637
		b	-.004667*	.002076	.048	-.00929	-.00004
		c	-.003000	.002076	.179	-.00763	.00163
		d	-.032333*	.002076	.000	-.03696	-.02771
available phosporus	a	b	-.575000*	.031920	.000	-.64612	-.50388
		c	-.530667*	.031920	.000	-.60179	-.45954
		d	-.038667	.031920	.254	-.10979	.03246
		e	.184000*	.031920	.000	.11288	.25512
	b	a	.575000*	.031920	.000	.50388	.64612
		c	.044333	.031920	.195	-.02679	.11546
		d	.536333*	.031920	.000	.46521	.60746
		e	.759000*	.031920	.000	.68788	.83012
	c	a	.530667*	.031920	.000	.45954	.60179
		b	-.044333	.031920	.195	-.11546	.02679
		d	.492000*	.031920	.000	.42088	.56312
		e	.714667*	.031920	.000	.64354	.78579
	d	a	.038667	.031920	.254	-.03246	.10979
		b	-.536333*	.031920	.000	-.60746	-.46521
		c	-.492000*	.031920	.000	-.56312	-.42088
		e	.222667*	.031920	.000	.15154	.29379
	e	a	-.184000*	.031920	.000	-.25512	-.11288
		b	-.759000*	.031920	.000	-.83012	-.68788
		c	-.714667*	.031920	.000	-.78579	-.64354
		d	-.222667*	.031920	.000	-.29379	-.15154

‘B’ (Soil treated)

Dependent Variable	(I) soil treated	(J)soil treated	MeanDifference (I- J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
sodium	AA	AB	-.854000*	.006296	.000	-.86803	-.83997
		AC	.155667*	.006296	.000	.14164	.16970
		AD	-.983667*	.006296	.000	-.99770	-.96964
		AE	-1.402000*	.006296	.000	-1.41603	-1.38797
	AB	AA	.854000*	.006296	.000	.83997	.86803
		AC	1.009667*	.006296	.000	.99564	1.02370
		AD	-.129667*	.006296	.000	-.14370	-.11564
		AE	-.548000*	.006296	.000	-.56203	-.53397
	AC	AA	-.155667*	.006296	.000	-.16970	-.14164
		AB	-1.009667*	.006296	.000	-1.02370	-.99564
		AD	-1.139333*	.006296	.000	-1.15336	-1.12530
		AE	-1.557667*	.006296	.000	-1.57170	-1.54364
	AD	AA	.983667*	.006296	.000	.96964	.99770
		AB	.129667*	.006296	.000	.11564	.14370
		AC	1.139333*	.006296	.000	1.12530	1.15336
		AE	-.418333*	.006296	.000	-.43236	-.40430
	AE	AA	1.402000*	.006296	.000	1.38797	1.41603
		AB	.548000*	.006296	.000	.53397	.56203
		AC	1.557667*	.006296	.000	1.54364	1.57170
		AD	.418333*	.006296	.000	.40430	.43236

potasium	AA	AB	.660000*	.013499	.000	.62992	.69008
		AC	.106667*	.013499	.000	.07659	.13674
		AD	.633333*	.013499	.000	.60326	.66341
		AE	-.750000*	.013499	.000	-.78008	-.71992
	AB	AA	-.660000*	.013499	.000	-.69008	-.62992
		AC	-.553333*	.013499	.000	-.58341	-.52326
		AD	-.026667	.013499	.076	-.05674	.00341
		AE	-1.410000*	.013499	.000	-1.44008	-1.37992
	AC	AA	-.106667*	.013499	.000	-.13674	-.07659
		AB	.553333*	.013499	.000	.52326	.58341
		AD	.526667*	.013499	.000	.49659	.55674
		AE	-.856667*	.013499	.000	-.88674	-.82659
	AD	AA	-.633333*	.013499	.000	-.66341	-.60326
		AB	.026667	.013499	.076	-.00341	.05674
		AC	-.526667*	.013499	.000	-.55674	-.49659
		AE	-1.383333*	.013499	.000	-1.41341	-1.35326
	AE	AA	.750000*	.013499	.000	.71992	.78008
		AB	1.410000*	.013499	.000	1.37992	1.44008
		AC	.856667*	.013499	.000	.82659	.88674
		AD	1.383333*	.013499	.000	1.35326	1.41341
magnisium	AA	AB	27.453667*	.019904	.000	27.40932	27.49802
		AC	3.995333*	.019904	.000	3.95098	4.03968
		AD	2.268333*	.019904	.000	2.22398	2.31268
		AE	3.231333*	.019904	.000	3.18698	3.27568
	AB	AA	-27.453667*	.019904	.000	-27.49802	-27.40932
		AC	-23.458333*	.019904	.000	-23.50268	-23.41398
		AD	-25.185333*	.019904	.000	-25.22968	-25.14098
		AE	-24.222333*	.019904	.000	-24.26668	-24.17798
	AC	AA	-3.995333*	.019904	.000	-4.03968	-3.95098
		AB	23.458333*	.019904	.000	23.41398	23.50268
		AD	-1.727000*	.019904	.000	-1.77135	-1.68265
		AE	-.764000*	.019904	.000	-.80835	-.71965
	AD	AA	-2.268333*	.019904	.000	-2.31268	-2.22398
		AB	25.185333*	.019904	.000	25.14098	25.22968
		AC	1.727000*	.019904	.000	1.68265	1.77135
		AE	.963000*	.019904	.000	.91865	1.00735
	AE	AA	-3.231333*	.019904	.000	-3.27568	-3.18698
		AB	24.222333*	.019904	.000	24.17798	24.26668
		AC	.764000*	.019904	.000	.71965	.80835

		AD	-.963000*	.019904	.000	-1.00735	-.91865
calcium	AA	AB	-5.436000*	.209290	.000	-5.90233	-4.96967
		AC	-1.656667*	.209290	.000	-2.12299	-1.19034
		AD	-3.333333*	.209290	.000	-3.79966	-2.86701
		AE	-.146333	.209290	.500	-.61266	.31999
	AB	AA	5.436000*	.209290	.000	4.96967	5.90233
		AC	3.779333*	.209290	.000	3.31301	4.24566
		AD	2.102667*	.209290	.000	1.63634	2.56899
		AE	5.289667*	.209290	.000	4.82334	5.75599
	AC	AA	1.656667*	.209290	.000	1.19034	2.12299
		AB	-3.779333*	.209290	.000	-4.24566	-3.31301
		AD	-1.676667*	.209290	.000	-2.14299	-1.21034
		AE	1.510333*	.209290	.000	1.04401	1.97666
	AD	AA	3.333333*	.209290	.000	2.86701	3.79966
		AB	-2.102667*	.209290	.000	-2.56899	-1.63634
		AC	1.676667*	.209290	.000	1.21034	2.14299
		AE	3.187000*	.209290	.000	2.72067	3.65333
	AE	AA	.146333	.209290	.500	-.31999	.61266
		AB	-5.289667*	.209290	.000	-5.75599	-4.82334
		AC	-1.510333*	.209290	.000	-1.97666	-1.04401
		AD	-3.187000*	.209290	.000	-3.65333	-2.72067
cation exchageable capacity	AA	AB	2.320000*	.993188	.042	.10704	4.5396
		AC	4.113333*	.993188	.002	1.90037	6.32629
		AD	1.890000	.993188	.086	-.32296	4.10296
		AE	.936667	.993188	.368	-1.27629	3.14963
	AB	AA	-2.320000*	.993188	.042	-4.53296	-.10704
		AC	1.793333	.993188	.101	-.41963	4.00629
		AD	-.430000	.993188	.674	-2.64296	1.78296
		AE	-1.383333	.993188	.194	-3.59629	.82963
	AC	AA	-4.113333*	.993188	.002	-6.32629	-1.90037
		AB	-1.793333	.993188	.101	-4.00629	.41963
		AD	-2.223333*	.993188	.049	-4.43629	-.01037
		AE	-3.176667*	.993188	.010	-5.38963	-.96371
	AD	AA	-1.890000	.993188	.086	-4.10296	.32296
		AB	.430000	.993188	.674	-1.78296	2.64296
		AC	2.223333*	.993188	.049	.01037	4.43629
		AE	-.953333	.993188	.360	-3.16629	1.25963
	AE	AA	-.936667	.993188	.368	-3.14963	1.27629
		AB	1.383333	.993188	.194	-.82963	3.59629

		AC	3.176667*	.993188	.010	.96371	5.38963
		AD	.953333	.993188	.360	-1.25963	3.16629
Iron	AA	AB	1.243333*	.206064	.000	.78419	1.70247
		AC	-.106667	.206064	.616	-.56581	.35247
		AD	-2.633333*	.206064	.000	-3.09247	-2.17419
		AE	1.182333*	.206064	.000	.72319	1.64147
	AB	AA	-1.243333*	.206064	.000	-1.70247	-.78419
		AC	-1.350000*	.206064	.000	-1.80914	-.89086
		AD	-3.876667*	.206064	.000	-4.33581	-3.41753
		AE	-.061000	.206064	.773	-.52014	.39814
	AC	AA	.106667	.206064	.616	-.35247	.56581
		AB	1.350000*	.206064	.000	.89086	1.80914
		AD	-2.526667*	.206064	.000	-2.98581	-2.06753
		AE	1.289000*	.206064	.000	.82986	1.74814
	AD	AA	2.633333*	.206064	.000	2.17419	3.09247
		AB	3.876667*	.206064	.000	3.41753	4.33581
		AC	2.526667*	.206064	.000	2.06753	2.98581
		AE	3.815667*	.206064	.000	3.35653	4.27481
	AE	AA	-1.182333*	.206064	.000	-1.64147	-.72319
		AB	.061000	.206064	.773	-.39814	.52014
		AC	-1.289000*	.206064	.000	-1.74814	-.82986
		AD	-3.815667*	.206064	.000	-4.27481	-3.35653
manganes	AA	AB	1.410000*	.023548	.000	1.35753	1.46247
		AC	-1.172333*	.023548	.000	-1.22480	-1.11987
		AD	-.136333*	.023548	.000	-.18880	-.08387
		AE	1.883000*	.023548	.000	1.83053	1.93547
	AB	AA	-1.410000*	.023548	.000	-1.46247	-1.35753
		AC	-2.582333*	.023548	.000	-2.63480	-2.52987
		AD	-1.546333*	.023548	.000	-1.59880	-1.49387
		AE	.473000*	.023548	.000	.42053	.52547
	AC	AA	1.172333*	.023548	.000	1.11987	1.22480
		AB	2.582333*	.023548	.000	2.52987	2.63480
		AD	1.036000*	.023548	.000	.98353	1.08847
		AE	3.055333*	.023548	.000	3.00287	3.10780
	AD	AA	.136333*	.023548	.000	.08387	.18880
		AB	1.546333*	.023548	.000	1.49387	1.59880
		AC	-1.036000*	.023548	.000	-1.08847	-.98353
		AE	2.019333*	.023548	.000	1.96687	2.07180
	AE	AA	-1.883000*	.023548	.000	-1.93547	-1.83053

		AB	-.473000*	.023548	.000	-.52547	-.42053
		AC	-3.055333*	.023548	.000	-3.10780	-3.00287
		AD	-2.019333*	.023548	.000	-2.07180	-1.96687
copper	AA	AB	-.747333*	.005002	.000	-.75848	-.73619
		AC	-1.059000*	.005002	.000	-1.07015	-1.04785
		AD	-.935333*	.005002	.000	-.94648	-.92419
		AE	-.263000*	.005002	.000	-.27415	-.25185
	AB	AA	.747333*	.005002	.000	.73619	.75848
		AC	-.311667*	.005002	.000	-.32281	-.30052
		AD	-.188000*	.005002	.000	-.19915	-.17685
		AE	.484333*	.005002	.000	.47319	.49548
	AC	AA	1.059000*	.005002	.000	1.04785	1.07015
		AB	.311667*	.005002	.000	.30052	.32281
		AD	.123667*	.005002	.000	.11252	.13481
		AE	.796000*	.005002	.000	.78485	.80715
	AD	AA	.935333*	.005002	.000	.92419	.94648
		AB	.188000*	.005002	.000	.17685	.19915
		AC	-.123667*	.005002	.000	-.13481	-.11252
		AE	.672333*	.005002	.000	.66119	.68348
	AE	AA	.263000*	.005002	.000	.25185	.27415
		AB	-.484333*	.005002	.000	-.49548	-.47319
		AC	-.796000*	.005002	.000	-.80715	-.78485
		AD	-.672333*	.005002	.000	-.68348	-.66119
Zink	AA	AB	.362533*	.069643	.000	.20736	.51771
		AC	.372600*	.069643	.000	.21743	.52777
		AD	.499600*	.069643	.000	.34443	.65477
		AE	.651600*	.069643	.000	.49643	.80677
	AB	AA	-.362533*	.069643	.000	-.51771	-.20736
		AC	.010067	.069643	.888	-.14511	.16524
		AD	.137067	.069643	.077	-.01811	.29224
		AE	.289067*	.069643	.002	.13389	.44424
	AC	AA	-.372600*	.069643	.000	-.52777	-.21743
		AB	-.010067	.069643	.888	-.16524	.14511
		AD	.127000	.069643	.098	-.02817	.28217
		AE	.279000*	.069643	.002	.12383	.43417
	AD	AA	-.499600*	.069643	.000	-.65477	-.34443
		AB	-.137067	.069643	.077	-.29224	.01811
		AC	-.127000	.069643	.098	-.28217	.02817
		AE	.152000	.069643	.054	-.00317	.30717

	AE	AA	-.651600*	.069643	.000	-.80677	-.49643
		AB	-.289067*	.069643	.002	-.44424	-.13389
		AC	-.279000*	.069643	.002	-.43417	-.12383
		AD	-.152000	.069643	.054	-.30717	.00317
PH	AA	AB	-.133333*	.006325	.000	-.14743	-.11924
		AC	.016667*	.006325	.025	.00257	.03076
		AD	.113333*	.006325	.000	.09924	.12743
		AE	.100000*	.006325	.000	.08591	.11409
	AB	AA	.133333*	.006325	.000	.11924	.14743
		AC	.150000*	.006325	.000	.13591	.16409
		AD	.246667*	.006325	.000	.23257	.26076
		AE	.233333*	.006325	.000	.21924	.24743
	AC	AA	-.016667*	.006325	.025	-.03076	-.00257
		AB	-.150000*	.006325	.000	-.16409	-.13591
		AD	.096667*	.006325	.000	.08257	.11076
		AE	.083333*	.006325	.000	.06924	.09743
	AD	AA	-.113333*	.006325	.000	-.12743	-.09924
		AB	-.246667*	.006325	.000	-.26076	-.23257
		AC	-.096667*	.006325	.000	-.11076	-.08257
		AE	-.013333	.006325	.061	-.02743	.00076
	AE	AA	-.100000*	.006325	.000	-.11409	-.08591
		AB	-.233333*	.006325	.000	-.24743	-.21924
		AC	-.083333*	.006325	.000	-.09743	-.06924
		AD	.013333	.006325	.061	-.00076	.02743
Exchageable acidy	AA	AB	.013000*	.002765	.001	.00684	.01916
		AC	.002333	.002765	.418	-.00383	.00849
		AD	-.023000*	.002765	.000	-.02916	-.01684
		AE	.018000*	.002765	.000	.01184	.02416
	AB	AA	-.013000*	.002765	.001	-.01916	-.00684
		AC	-.010667*	.002765	.003	-.01683	-.00451
		AD	-.036000*	.002765	.000	-.04216	-.02984
		AE	.005000	.002765	.101	-.00116	.01116
	AC	AA	-.002333	.002765	.418	-.00849	.00383
		AB	.010667*	.002765	.003	.00451	.01683
		AD	-.025333*	.002765	.000	-.03149	-.01917
		AE	.015667*	.002765	.000	.00951	.02183
	AD	AA	.023000*	.002765	.000	.01684	.02916
		AB	.036000*	.002765	.000	.02984	.04216
		AC	.025333*	.002765	.000	.01917	.03149

		AE	.041000*	.002765	.000	.03484	.04716
	AE	AA	-.018000*	.002765	.000	-.02416	-.01184
		AB	-.005000	.002765	.101	-.01116	.00116
		AC	-.015667*	.002765	.000	-.02183	-.00951
		AD	-.041000*	.002765	.000	-.04716	-.03484
organic carbon	AA	AB	.186667*	.008692	.000	.16730	.20603
		AC	.120000*	.008692	.000	.10063	.13937
		AD	.116667*	.008692	.000	.09730	.13603
		AE	.060000*	.008692	.000	.04063	.07937
	AB	AA	-.186667*	.008692	.000	-.20603	-.16730
		AC	-.066667*	.008692	.000	-.08603	-.04730
		AD	-.070000*	.008692	.000	-.08937	-.05063
		AE	-.126667*	.008692	.000	-.14603	-.10730
	AC	AA	-.120000*	.008692	.000	-.13937	-.10063
		AB	.066667*	.008692	.000	.04730	.08603
		AD	-.003333	.008692	.709	-.02270	.01603
		AE	-.060000*	.008692	.000	-.07937	-.04063
	AD	AA	-.116667*	.008692	.000	-.13603	-.09730
		AB	.070000*	.008692	.000	.05063	.08937
		AC	.003333	.008692	.709	-.01603	.02270
		AE	-.056667*	.008692	.000	-.07603	-.03730
	AE	AA	-.060000*	.008692	.000	-.07937	-.04063
		AB	.126667*	.008692	.000	.10730	.14603
		AC	.060000*	.008692	.000	.04063	.07937
		AD	.056667*	.008692	.000	.03730	.07603
total carbon	AA	AB	.060667*	.001282	.000	.05781	.06352
		AC	.021333*	.001282	.000	.01848	.02419
		AD	.048667*	.001282	.000	.04581	.05152
		AE	.035667*	.001282	.000	.03281	.03852
	AB	AA	-.060667*	.001282	.000	-.06352	-.05781
		AC	-.039333*	.001282	.000	-.04219	-.03648
		AD	-.012000*	.001282	.000	-.01486	-.00914
		AE	-.025000*	.001282	.000	-.02786	-.02214
	AC	AA	-.021333*	.001282	.000	-.02419	-.01848
		AB	.039333*	.001282	.000	.03648	.04219
		AD	.027333*	.001282	.000	.02448	.03019
		AE	.014333*	.001282	.000	.01148	.01719
	AD	AA	-.048667*	.001282	.000	-.05152	-.04581
		AB	.012000*	.001282	.000	.00914	.01486

		AC	-.027333*	.001282	.000	-.03019	-.02448
		AE	-.013000*	.001282	.000	-.01586	-.01014
	AE	AA	-.035667*	.001282	.000	-.03852	-.03281
		AB	.025000*	.001282	.000	.02214	.02786
		AC	-.014333*	.001282	.000	-.01719	-.01148
		AD	.013000*	.001282	.000	.01014	.01586
available phosparus	AA	AB	-2.108333*	.013054	.000	-2.13742	-2.07925
		AC	-1.569333*	.013054	.000	-1.59842	-1.54025
		AD	-4.866000*	.013054	.000	-4.89509	-4.83691
	AB	AA	2.108333*	.013054	.000	2.07925	2.13742
		AC	.539000*	.013054	.000	.50991	.56809
		AC	.539000*	.013054	.000	.50991	.56809
		AD	-2.757667*	.013054	.000	-2.78675	-2.72858
		AE	-1.577667*	.013054	.000	-1.60675	-1.54858
	AC	AA	1.569333*	.013054	.000	1.54025	1.59842
		AB	-.539000*	.013054	.000	-.56809	-.50991
		AD	-3.296667*	.013054	.000	-3.32575	-3.26758
		AE	-2.116667*	.013054	.000	-2.14575	-2.08758
	AD	AA	4.866000*	.013054	.000	4.83691	4.89509
		AB	2.757667*	.013054	.000	2.72858	2.78675
		AC	3.296667*	.013054	.000	3.26758	3.32575
		AE	1.180000*	.013054	.000	1.15091	1.20909
	AE	AA	3.686000*	.013054	.000	3.65691	3.71509
		AB	1.577667*	.013054	.000	1.54858	1.60675
		AC	2.116667*	.013054	.000	2.08758	2.14575
		AD	-1.180000*	.013054	.000	-1.20909	-1.15091

*Means significant different.