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Review on Potential of Liming for Sustainable Management Some Selected Soil Chemical Properties and Crop Yield Improved in Tropical Soil

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Abstract:
Acid soils of the tropical soil were greatly responsive to applications of lime fertilizer. Successive applications of lime drastically decreased exchangeable aluminum to the minimum level, and raised soil pH close to the optimum pH requirement of many cereals. Other alternative materials include silicates of calcium or calcium and magnesium, wood ash and several industrial by-products such as slag that can produce modest amounts of other nutrients such as phosphorus and calcium. In order to produce a better crop yield on acid soils, farmers are recommended to apply alkaline materials such as lime (primarily calcium carbonate) to increase the soil pH and thus eliminate Al toxicity, and to apply P fertilizer to increase the bioavailable P in soil. The usual agricultural practice for most crops is to maintain a soil pH of 6.0-6.5 by the addition of lime, applied as calcium carbonate calcium hydroxide or calcium oxide. Traditionally, methods used to raise soil pH include; use of mulch from agro-forestry tree species, burning of sites to give ash and use of animal wastes although such materials are not available in the right amounts desired and, in most cases, they are too bulky. However, in many developing countries, where semi subsistence agriculture prevails, the lack and/or high cost of lime prevent its use. Under such conditions, alternative means of managing soil acidity need to be developed. Research has shown that additions of green manures, FYM, and composts to acid soils can reduce Al toxicity and increase crop yields. So, government should either subsidize the lime or encourage more investors to produce lime in order to decrease the lime cost. The farmers' practice like applying farmyard manure, compost and other organic wastes in backyard which can add organic matter to the soil should be appreciated and encouraged.

Keywords: lime, soil pH, organic matter, alkaline material, soil exchangeable acidity, basic cation

INTRODUCTION

Over half of the world population currently lives in regions dominated by acid soils (Yang *et al.*, 2004) whose productivity is on the decline to meet the food requirements of the ever-increasing population, especially in the tropics (Hartemink, 2002). Soil acidity is a major yield-limiting factor for crop production worldwide. The land area affected by acidity is estimated at 4 billion hectares, representing approximately 30 % of the total ice-free land area of the world (Sumner and Noble, 2003).

In Ethiopia, heavy population pressure has resulted in practically all cultivatable land being farmed, eliminating expansion of cropped area as the main driver of agricultural growth, which had been the case in the 1990s (World Bank, 2007). In the tropics, substantial weathering of soils over millennia has resulted in the leaching of crop nutrient bases (mainly K, Mg and Ca). This is followed by replacement by H, Al and Mn cations that contribute to acid related stresses on crop production (Okalebo *et al*., 2009). Acid soils are phytotoxic as a result of nutritional disorders, deficiencies, or unavailability of essential nutrients such as calcium, magnesium, molybdenum, and phosphorus, and toxicity of aluminum, manganese, and hydrogen activity (Foy, 1984). The solubility of soil compounds and, therefore, nutrient availability to plants is related to soil pH Acid infertility factors limit crop growth and yield as well as soil productivity in highly weathered soils of humid and sub-humid regions of the world due to deficiency of essential nutrient elements (Akinrinade *et al*., 2006). Likewise, feeding the ever-increasing human population is most challenging in developing countries because of soil degradation. For instance, in Sub-Saharan African countries, soil fertility depletion is the fundamental biophysical cause for declining per capita food production (Sanchez *et al*., 1997). This challenge will continue as population pressure increases and degradation of soil resources is aggravated.

According to Angaw and Desta (1988), soil acidity severely affects the yields of many crops in the western, south-western and southern parts of high rainfall areas of Ethiopia. The infertility of soils in these areas is attributed to excessive concentration of aluminum (Al), iron (Fe) or manganese (Mn) on one hand; and to deficiencies of calcium (Ca), magnesium (Mg), phosphorus (P) and molybdenum (Mo) on the other (Mesfin, 1996). Soil acidity is a major constraint to maize (*Zea mays)* production on tropical soils due to toxic levels of aluminium (Al) and the concomitant phosphorus (P) deficiency that hinder plant growth (Kisinyo *et al.,* 2005). To increase crop yields and reduce crop production risks associated with soil acidity, there is need to focus on soil amendment practices that target efficiency of nutrients use in soils especially phosphorus that is made unavailable chemically for plant uptake. Liming acid soils is general practice to reduce aluminum toxicity and is considered to many scientists as the first step towards providing a balanced nutrition for cultivated plants (Essington, 2004).

Thus, low soil pH is considered to be the main cause of yield reduction for all crops in general and acid sensitive crops in particular in tropical soil. Liming improves acid soils' physical, chemical and biological properties and increases plant production. Numerous authors (Havlin *et al*., 1999; Hughes *et al*., 2004; Loncaric *et al*., 2007) reported that liming of acid soils increased crop yield and caused significant changes in soil properties modifying soil acidity and nutrient availability. Soil acidity is now a serious threat to crop production in most high land of tropical soil. Currently, it is estimated that about 40.9% of the total arable land of Ethiopia is affected by soil acidity (Taye Bekele, 2007) which covers 95% of the cropped area and contain almost 85% of the Ethiopian population.

This implies that effort has to be made to improve the fertility and productivity of the acidic and infertile soils of highlands Ethiopia areas and make sure that optimum utilization of same is made to secure the well-beings of the present and future generations. Therefore, the objective of this pepper was to review on potential of liming for sustainable management of some selected soil chemical properties and crop yields in tropical soil.

SOIL ACIDITY IN TROPICS

Soil acidity is a serious agricultural and environmental problem that limits the growth of pasture and crops in many parts of the world including Latin America, North America, Asia, Africa, Europe and Australia (Baligar *et al*., 1993). Vast areas of tropical lands that were once fertile have been rendered unproductive due to continuous cultivation and erosion which has caused physical soil degradation, loss of soil organic matter and a decrease in Cation exchange capacity (CEC) as well as increased Al and Mn toxicity (Mba, 2006). In high rainfall areas of Ethiopia, soil acidity is a severe problem and can lead to decline or complete failure of crop production (Angaw and Desta, 1988). The extent of acidity and mining of soil fertility is believed to increase from year to year due to anthropogenic (man-made) activity. This fact and the peculiarity of tropical soils described above imply that in the tropics, it is wiser to focus on lime application for the correction of Al toxicity instead of trying to bring the soil pH close to neutral. This is why this document focuses on the decrease or suppression of the Al toxicity.

Among biological properties, activities of beneficial microorganisms are adversely affected by soil acidity, which has profound effects on the decomposition of organic matter, nutrient mineralization, and immobilization, uptake and utilization by plants, and consequently on crop yields (Fageria and Baligar, 2008). Although soil acidity is a serious problem in the western and southwestern parts of Ethiopia, no in-depth studies are found on the causes and the extent of acidity. Another important difference between soils from temperate and tropical regions is the nature of soil surface charge. The most common source of surface charge on soil colloids is from structural imperfections in the crystal structure. As a result, its exact extent is difficult to ascertain, but available information indicates that about 40.9% of the Ethiopian total land area is affected by soil acidity. Of this land area, about 27.7% is moderately acidic (pH in KCl) 4.5 -5.5) and about 13.2% is strongly (pH in KCl) < 4.5) acidic (Schlede, 1989). Soil acidity can decrease crop yield, seedling emergence and survival, establishment and persistence, legume nodulation and root growth (Marschner, 2002). In addition, deficiencies of essential nutrient elements such as Ca, Mg, P and Mo may also be involved (Somani, 1996). In the tropics the soil acidity is aggravated by leaching or/and continuous removal of basic cations through crop harvest (Wassie H andShiferaw B 2014). Integrated application of lime and fertilizer gave the highest yield only when NPK and full rate of lime are applied (Wassie H andShiferaw B 2014). If lime application sought to bring significantly appreciable improvement in the yield of crops it has to be with applied balanced application of NPK is a must (Wassie H andShiferaw B 2011).

CAUSES OF SOIL ACIDITY

Soil acidification is a complex set of processes resulting in the formation of an acid soil. The summation of different anthropogenic and natural processes including leaching of exchangeable bases, basic cation uptake by plants, decomposition of organic materials, application of commercial fertilizers and other farming practices produce acid soil (Brady and Weil, 2002). The causes of soil acidity are more easily understood when we consider that a soil is acid when there is an abundance of acidic cations, like hydrogen (H^+) and aluminum (Al^{+++}) present compared to the alkaline cations like calcium (Ca^{++}), magnesium (Mg++), potassium (K^+), and sodium (Na^+) (Johnson, 1914). Acidification of the soil is a slow natural process and part of normal weathering. Many farming activities cause an increase in the rate of acidification of the soil. Changes in soil pHCa under agricultural use are measured in tens or hundreds of years rather than thousands of years as in the natural environment.

Most acidic soils, however, have been developed as a result of leaching losses and crop removal of bases (Somania, 1996). In Ethiopia, soil acidity increase involves climatic factors such as rainfall, temperature, topographic factors and morphological factors (Mesfin, 1998). Even plant growth will contribute to acidification; a major nutrient uptake process is to exchange hydrogen ions at the root surface for needed base ions such as calcium, magnesium, and potassium (Marschner, 2002). In conditions where rainfall exceeds evapotranspiration (leaching) during most of the year, the basic soil cations (Ca, Mg, K) are gradually depleted and replaced with cations held in colloidal soil reserves, leading to soil acidity. Soil acidity is really a high rainfall problem (Slattery and

Hollier, 2002). Once the anions are removed from the soil, the normal neutralization process by oxidation of carboxylate compounds to carbon dioxide and water cannot occur, resulting in long-term acidification of soils (Bohn *et al.*, 2001). In the effects of human activity, when acidifying fertilizers particularly, ammonium sulfate and mono-ammonium phosphate (MAP) are added to soil, nitrification occurs and causes soil acidity (Somani, 1996). Decaying organic matter produces H^+ which is responsible for acidity. The carbon dioxide (CO2) produced by decaying organic matter reacts with water in the soil to form a weak acid called carbonic acid. This is the same acid that develops when CO2 in the atmosphere reacts with rain to form acid rain naturally. Like rainfall, the contribution to acid soil development by decaying organic matter is generally very small, and it would only be the accumulated effects of many years that might ever be measured in a field (Slatter and Hollier, 2002).

EFFECTS OF LIME ON CHEMICAL PROPERTIES OF ACID SOILS

Soil Reaction (pH) and Its Management

Soil reaction is one of the most important physiological characteristics of the soil solution. It affects nutrient availability and toxicity, microbial activity, and root growth. Soil reaction is expressed in terms of pH indicating whether the soil is acidic, alkaline or neutral. Human activity can change the pH of a soil too; the addition of most nitrogen fertilizers and organic nutrient sources (compost and manure) leads to formation of nitric acid (HNO3) and/or sulfuric acid (H_2SO4). Both are strong acids that cause an increase in soil acidity (i.e., a decrease the pH of the soil). Solubility of many essential elements for plants and nutrient uptake rates are pH dependant. Generally, anions like nitrate and phosphate are taken up at a faster rate under slightly acid conditions whereas the cation uptake rates seem to be faster around the more neutral pH range (Rorison, 1980). It could be attributed to reduction of $Al3^+$ ions concentration in soil solution and in exchangeable sites because of lime and manure application (Pearce and Sumner, 1997). Wong and Swift, (2003) in their findings also reported that addition of organic manures to acid soils increased soil pH, decreased Al saturation, and thereby improved conditions for plant growth.

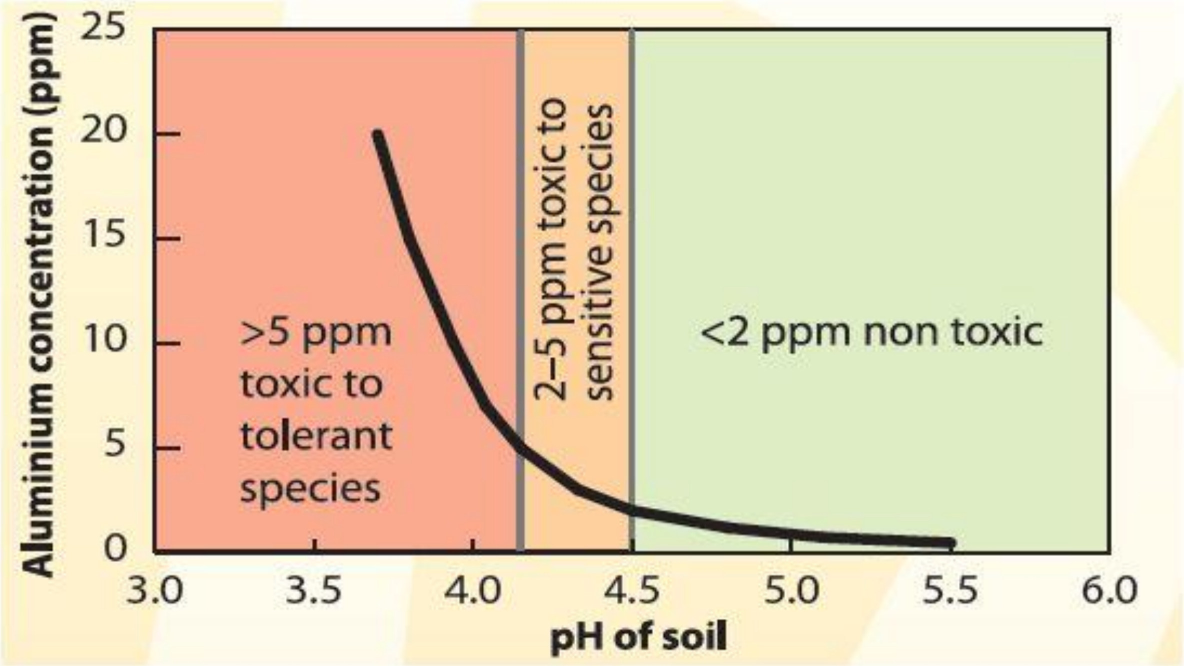

Figure 1. Effects of aluminum concentration on soil pH.
Source: https://www.agric.wa.gov.au/soil-acidity/effects-soil-acidity

Available Phosphorus

Acid soils, present mostly in humid tropical and subtropical areas of the world, are characterized by having excess H^+, Mn^{2+}, and $A1^{3+}$, with deficiencies of Ca^{2+}, Mg^{2+}, and $PO4^{3-}$. Additionally, sulfur dioxide and other air pollutants cause acid soil stress in areas other than the tropics (Foy, 1984). Total phosphorus (P) gives an indication of the total reserve of the nutrient in the soil. However, it is a poor indicator of the availability level since most of the soil P may be fixed. Phosphorus deficiency problems are compounded by widespread high phosphorus fixation capacity of acid soils (Somani, 1996). Soluble aluminium immobilises phosphorus in the soil and the plant, causing symptoms of phosphorus deficiency, that is, small and dark-green or occasionally purple leaves. The symptoms become more pronounced as the aluminium level increases. Lime can be used to improve the availability of native and/or added P by increasing soil pH because mineral oxide binding of P decreases as the pH increases from 4–7 (Haynes 1982). Rapid increases in available P following the reaction of added lime to desorb fixed P have been termed the *P spring effect* (Mike and Nanthi 2003). The increase in the agronomic yields and P uptake of wheat due to lime and wood ash may be attributed to the increases in soil pH, reduction in the toxicity of Al^{3+} and Mn^{2+} and reduction in nutrient deficiency (Ca, P or Mo) as well as due to indirect effect of better physical condition of the soil (Haynes,1984). Wood ash was more effective than lime in increasing the dry shoot biomass and the P uptake of the wheat (Asmare.M, *et al*,.2015). Magdoff et al. (1984) also evaluated land application of wood ash and limestone in a greenhouse and laboratory research project. Two soils were mixed with wood ash; limestone and a lime stone-wood ash mix (90:10). Plant growth, nutrient uptake, and soil chemical changes were measured during the growth of maize. Ash gave better response than limestone. The effect of over-liming was reduced when ash was added with the limestone.

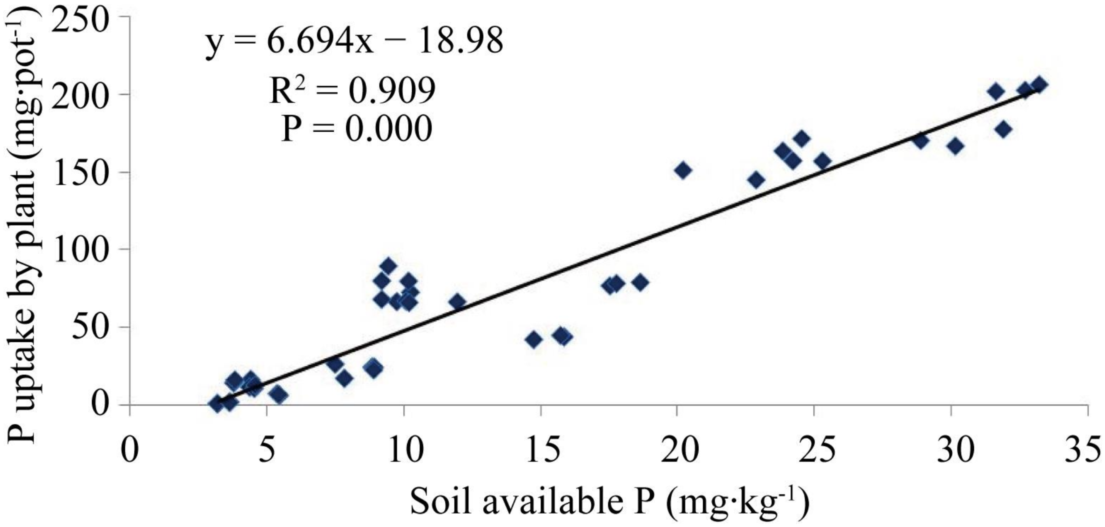

Figure 2. Correlations of available P with P uptake by In- dian spinach

Source: Ashoka S, *et al* 2014

Exchangeable Acidity

Exchangeable acidity consists of any mono-meric aluminum or iron, as well as any exchangeable H that may be present in the exchange sites (Bohn *et al.*, 2001). Exchangeable acidity in soils is almost entirely due to mono-meric Al^{3+} ions (Thomas and Hargrove, 1984). This is because only Al^{3+} is a common exchangeable cation in moderately to strongly acidic soils (Bohn *et al.*, 2001). Liming with the highest rate (3750 kg $CaCO3$ ha-1) recorded the minimum value of exchangeable acidity and exchangeable almunium which reduced them to 0.36 cmol (+) Kg-1 and 0.24 cmol (+)

kg-1 respectively (Adane B.2014). This decrease may be ascribed to the increased replacement of Al by Ca in the exchange site and by the subsequent precipitation of Al as Al (OH)3, as the soil was limed. Soil exchangeable acidity is the total amount of the Cation Exchange Capacity (CEC) of a soil that is due to H^+ and Al^{3+} ions (FAO, 1995). It indicates soil disturbances due to high Al concentrations (which are toxic to plants and soil organisms). Exchangeable acidity is measured only if the pH value drops under 7 because only then does the concentration of exchangeable H+ and Al^{3+} ions become significant.

Cation Exchangeable Capacity

The cation exchange capacity (CEC) of a soil represents the total quantity of negative charge available to attract cations in the soil solution. It is one of the most important chemical properties of soils as it strongly influences nutrient availability (Havlin *et al*., 1999). Numerically the mean values of soils exchangeable Ca $^{2+}$ ion and CEC of each land use type showed increments with the increase of applied lime rates and soil pH. High CEC values are usually associated with humus compared to those exhibited by the inorganic clays, especially kaolinite and Fe, Al oxides (Brady and Weil, 2002). The increase in CEC due to liming could be attributed to the change in pH and the release of the initially blocked is omorphous and interlayer substitional negative charge by deprotonation of the variable charge minerals and functional groups of humic compounds caused by $Ca^{2+.}$ The greater amount of negative charge available on the surfaces of these minerals results in the increase in CEC (Pionke HB, Corey RB 1967). The colloids of highly weathered soils have a constant surface potential, which is mainly a characteristic of kaolinite, Al-interlayerd chlorites, hydrous-oxides of Fe and Al, and Alorganic matter complexes (Gillman and Bell, 1978). As result, the CEC of highly weathered soils is pH dependant, and it is a function of the constituent minerals and organic matter. Under such soil, the CEC is increased as the pH of the soil increased by liming. This is because not only the permanent charge but also the pH dependant charge is operative when the pH is adjusted to a value higher than the point of zero charge (PZC) with buffered salt solutions (Mesfin, 1996). Liming acidic soils indirectly increases the effective cation exchange capacity (ECEC) of soils that contain organic matter or variably charged clay minerals (Bohn *et al*., 2001). Thomas and Hargrove (1984) found that the ECEC of acidic soils increased slowly at pH values of around 5.0 but increased very rapidly at pH 8.0. Haynes and Ludecke (1981) reported that the influence of lime addition on CEC was not consistent although increased P addition generally increased measured CEC values. However, the CEC determined after maize harvest in western Ethiopia (Alemayehu, 1999) and six weeks incubation periods in Nigeria (Adetunji and Bamiro, 1994) showed a sharp increase due to application of lime. These effects of lime and P addition in increasing the ECEC of the soil might have been caused by the increase in the exchangeable basic cation (particularly Ca, Mg and K) contents of the soil. Similarly, Thomas and Hargrove (1984) also found very rapid increase in ECEC of acidic soils as the pH of the soil increased by liming. However, the direct relationships between pH, exchangeable Ca and CEC with the increase of the lime rates is attributed to the applied lime which enhances the concentration of Ca^{2+} and thereby increases the soil pH due to the dissociation of agricultural lime and replacement of H^+ and Al^{3+} from the soil solution and soil exchange complex.

IMPACT OF SOIL ACIDITY TO ROOT DEVELOPMENT AND SOIL MICROORGANISMS

Soil microbiological properties can serve as soil quality indicators because soil microorganisms are the second most important (after plants) biological agents in the agricultural ecosystem (Fageria, 2002). Soil microorganisms provide the primary driving force for many chemical and biochemical processes and thus affect nutrient cycling, soil fertility, and carbon cycling (He et al., 2003). Acid soils affect plants in several ways. For instance, Al prevents plant root elongation due to its direct effect on metabolism or indirectly by rendering the phosphate in the soil unavailable by binding it to form aluminium phosphates thereby leading to overall low crop yields (Mora et al., 2005). Plant species and varieties differ, in their sensitivity to the conditions in acid soils (Wild, 1993). Toxic levels of aluminum harm the crop by "root pruning." that is, a small amount of aluminum in the soil solution in excess of what is normal causes the roots of most plants to either deteriorate or stop growing. As a result, the plants are unable to absorb water and nutrients normally and will appear stunted and exhibit nutrient deficiency symptoms, especially those for phosphorus. The final effect is either complete crop failure or significant yield loss. Maize lies in the medium tolerance range and would do well in the 5.5-6.0 pH range. Acidity produces complex interactions of plant growth-limiting factors involving physical, chemical, and biological properties of soil. Among biological properties, activities of beneficial microorganisms are adversely affected by soil acidity, which has profound effects on the decomposition of organic matter, nutrient mineralization, and immobilization, uptake and utilization by plants, and consequently on crop yields (Huber, 2006). Soil microorganisms especially bacteria and fungi have been shown to be sensitive to organic amendments and lime application (Magdoff, 2001). Organic amendments are known to increase the abundance of various components of the soil food web, including the soil fungal and bacterial communities (Forge et al., 2008 The availability of Phosphorus for plant uptake can therefore be increased by treatment with mineral acids, organic acids, and a mixture of organic materials, biological treatment, etc. Incorporating organic manures and P materials has been shown to enhance the solubility (Sharif et al., 2011).

PROBLEMS OF PLANT NUTRITION IN ACID SOILS

The effects of soil acidity, acidification, and liming can be classified into three main categories that cannot always be sharply distinguished: the availability of nutrients and toxic elements, biological activity, and soil structure. The first category will be treated here. The availability of essential plant nutrients is affected by soil pH. In acid soils, there are problems of both plant nutrient deficiencies and toxicities of three elements (Al, Mn, and H) (Baragengana, R.1990). Water is essential for plant life as soil solution because it carries all plant nutrients through mass flow and/or diffusion to the roots. N, after hydrogen and oxygen, is the element needed in greatest quantity from the soil for plant growth. Plants absorb most N in the nitrate (NO_{3-}) form, but they also absorb N in the ammonium form (NH_4^+). The latter is preferentially absorbed at high pH (Adams, 1984). Nitrate-N can be more available than ammonium-N, because NO_{3-}-N is mobile in soils and can move to plant roots with soil water, since it is negatively charged. Ammonium-N, on the other hand, is relatively immobile, being attracted to negatively charged surfaces of the soil's CEC. The optimum range of oxidation of NH_4^+ nitrogen to NO_3^- is between pH 5 and 8. In acid soils below pH 5, nitrification is severely reduced. The result is that N in the soil becomes less available to plants. At soil pH <5, both nitrification and mineralization (conversion of N from organic molecules into inorganic forms by microbial activity) are diminished, making N less available to plants. Liming of soils of pH less than 5 results in increased heterotrophic microbial activity, resulting in greater availability of mineral forms of N (NH_4^+ and NO_3^-) for uptake by plants.

EFFECTS OF LIME ON PLANT YIELD IMPROVEMENT IN TROPICAL SOIL

Tolerance to Al toxicity or acidic soils differs greatly among cereal species, and barley is usually considered the most susceptible member of the Poaceae (Garvin and Carver, 2003). Aluminium causes extensive root injury, leading to poor ion and water uptake (Barcelo & Poschenrieder, 2002). The acidic soils are naturally deficient in total and plant available phosphorus. This is because significant portions of applied P are immobilized due to precipitation of P as insoluble Al phosphate. The liming of acidic soils results in the release of P for plant uptake; this effect is often referred to as "P spring effect" of lime (Bolan *et al.*, 2003). Root tips have been found to be the primary site of aluminum injury, and the distal part of the transition zone has been identified as the target site in maize (Zea mays) (Sivaguru& Horst, 1998). The Al tolerance order as reported is maize> rye> triticale> wheat> barley (Polle and Konzak, 1985), rye> oats> millet> bread wheat> barley> durum wheat (Bona et al., 1993). Aluminum is known to induce a decrease in mitotic activity in many plants, and the aluminum-induced reduction in the number of proliferating cells is accompanied by the shortening of the region of cell division in maize (Panda, 2007). Plant growth improvement in acid soil is not due to addition of basic cations (Ca, Mg), but it is due to increasing pH that reduces toxicity of phytotoxic levels of Al (Fageria and Beligar, 2008). Past laboratory and field studies conducted to determine how phosphorus availability responds to lime addition reported that liming enhances P uptake by alleviating Al toxicity and thereby improving root growth (Haynes, 1982). Wood ash was more effective than lime in increasing the dry shoot biomass and the P uptake of the wheat, (Asmare M. et al,.2015). Shiferaw B. 2014 reported highest barley grain and biomass yields were obtained from applications of full lime rate + NPK in.

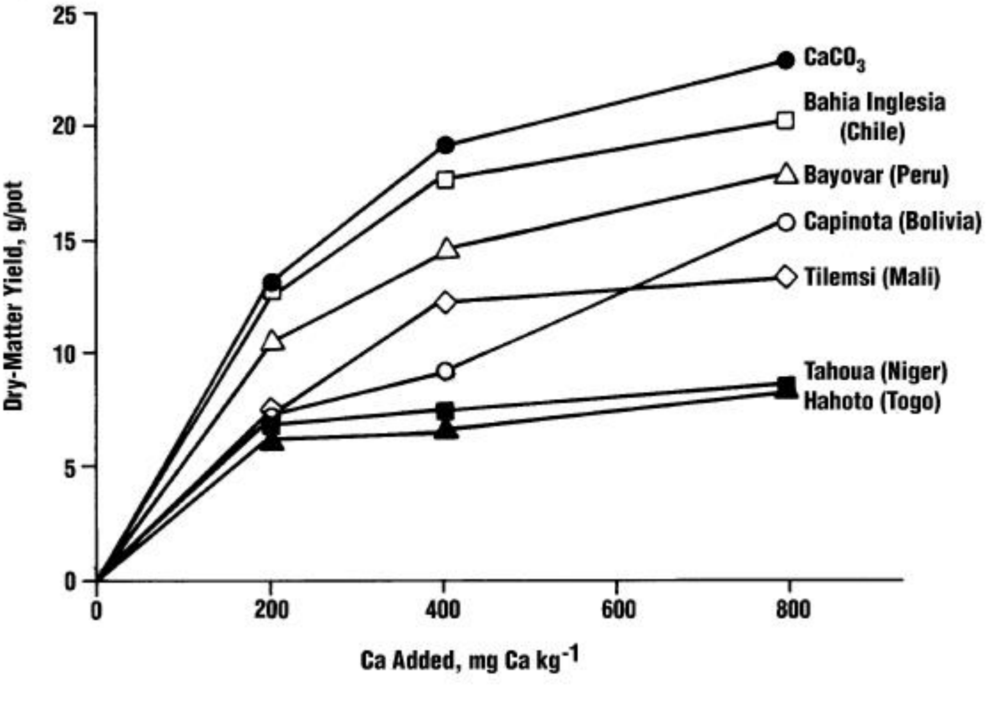

Fig.3. Maize dry matter yield response to PR source and Caco$_3$ ultisols

Source: Hellunss. D.T *et al.*,1989

MANAGEMENT OPTION OF SOIL ACIDITY PROBLEMS

Liming as Soil Acid Management Strategy

In order to produce a better crop yield on acid soils, farmers are recommended to apply alkaline materials such as lime (primarily calcium carbonate) to increase the soil pH and thus eliminate Al toxicity, and to apply P fertilizer to increase the bioavailable P in soil. Many studies report the beneficial Ca effects in different crops growing in acid soils (Mora *et al.*, 2002). According to Sanchez *et al.*, (1997), soil fertility reduction on the smallholder farms remains the central cause of decline in per capita food production in Africa, a situation that threatens food security. The rising rural poverty and the price fluctuations on fertilizer and other farm inputs has led to decline in capacity of farmers in Sub-Saharan Africa to put through necessary fertility measures

(Borlaugh, 2003). The modern agriculture production requires the implementation of efficient, sustainable, and environmentally sound management practices (Fageria and Baligar, 2008). Traditional methods of managing acidic soils for agriculture in the humid tropics, such as slash-and-burn agriculture practiced in its various forms, also rely on the "application" of carbonates in this case in the form of ashes produced by the burning of woody and vegetative materials (Juo and Manu, 1996). Ashe contains a large proportion of the carbonates of mineral cations (K, Ca, &Mg) originally present in the vegetation. In this context, liming is an important practice to achieve optimum yields of all crops grown on acid soils. Adequate liming eliminates soil acidity and toxicity of Al, Mn, and H; improves soil structure (aeration); improves availabilities of Ca, P, Mo, and Mg, and N_2 fixation; and reduces the availabilities of Mn, Zn, Cu, and Fe and leaching loss of cations. For several crops, liming results in some chemical changes in the soil such as, increase in pH, effective cation exchange capacity (ECEC), and exchangeable Ca, decrease in toxic elements for example Al^{3+} and Mn^{2+} and changes in the proportion of basic cations in CEC sites (Ezekiel, 2006). Lime requirement refers to the amount of lime required to neutralize all or part of the acidity in soil (both solution and reserve) from an initial level to a desired or target less acid condition. The target level of soil acidity depends both on the soil and the crop. The crop affects the LR through its level of tolerance to acid soil conditions. Lime also makes phosphorus that is added to the soil to be more available for plant growth and increases the availability of nitrogen by hastening the decomposition of organic matter (Donald, 2011**).** Lime is usually added to acid soils to increase soil pH. Its addition not only replaces hydrogen ions and raises soil pH, thereby eliminating most major problems associated with acid soils but it also provides two nutrients, calcium, and magnesium to the soil. Over-liming, however, can significantly reduce the bioavailability of micronutrients (Zn, Cu, Fe, Mn and B), which decrease with increasing pH (Fageria *et al.*, 2002).

Fig.4: Effects of limed and unlimed on plant roots

Source: https://www.agric.wa.gov.au/soil-acidity/effects-soil-acidity

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Quality of Lime:

Lime quality is an important consideration. The most effective liming products are those that have a high neutralising value (i.e., greater than 80%) and a small particle size. Lime is a good investment to maintain the soil pH as well as soil health and to maintain production and profitability. Millar *et al.* (1958) who reported that, fineness through various treatments (calcination, crushing, sieving) of limestone, increases the solubility of limes. The amount of particle sizes and their efficiency factors affect fineness factor of limes which could compromise its effectiveness with time. Halvin *et al*. (2005) reported that the efficiency factor of one (for lime with smaller particles < 0.2mm) is an indication of high solubility (degradability) and efficiency of lime in changing soil properties.

Fineness:

Liming resources are valued for their capacity to ameliorate soil acidity and to maintain the availability of calcium and magnesium for crops. There are a number of liming materials and each liming material has a specific composition and capacity to neutralize acidity. There are two benefits to fineness. The finer particles in a liming material react more quickly in the soil as they have a greater surface area to react with acids. Secondly, they will be better distributed through the soil after incorporation. There is a compromise between fineness and the cost of production, so there are practical limits on fineness (Brett *et al*., 2005). The quality of the materials depends on their mineralogy, purity, and on the size of the particles (Heckman 2000). The standard for measuring purity is calcium carbonate equivalence (CCE) (Spies and Harms, 2004) so that the CCE value for pure calcium carbonate is 100 % (Whitney and Lamond, 1993). Along with other inputs, acid soils can be ameliorated with lime to make them highly productive on sustainable bases. In this connection, the good news is that there are vast lime resources within Ethiopia and these can be systematically exploited (Schlede, 1989). The degree of fineness is equally important in the selection of a liming material since the speed with which the various materials will react is dependent on the surface area that is in contact with the soil. On the other hand, limestone is entirely a different matter since its reaction is related to particle size (Taye Bekele, 2008). The fineness of liming materials is important because the surface area usually affects dissolution rate (Whitney and Lamond 1993). Small particles dissolve quickly and so decrease soil acidity quickly, whereas coarse particles may react very slowly and are of reduced value in managing soil acidity (Spies and Harms 2004).

Comparing Liming Materials Information:

These include calcite ($CaCO_3$), burnt lime (CaO), slaked lime ($Ca\ (OH)_2$), dolomite ($CaMg\ (CO_3)_2$) and slag ($CaSiO_3$). On the label will allow a comparison of the particle sizes and the neutralising value of liming products. A spreadsheet has been developed by some of the limestone crushers to assist in comparing liming products using this data. The acid neutralizing value of liming materials is expressed in terms of calcium carbonate equivalent (CCE), defined as the acid neutralizing capacity of a liming material expressed as a weight percentage of pure CaCO3.

A comparative evaluation of lime, gypsum and PG demonstrated that lime treatment ($CaCO_3$ 2500 kg ha-1) increased exchangeable Ca and decreased exchangeable Al in the 0-5 cm soil layer, but no significant changes were observed below 5 cm, which suggested limited lime leaching **(**Meriño-Gergichevich *et al*., 2010**).**

Applying and Incorporating Lime:

For the quickest and maximum effect, limestone should be finely crushed, evenly spread and incorporated into the soil to 10 cm (Brett U et al,.2005). Pavan *et al*. (1984) reported that gypsum was more effective in lowering Al concentration within the 100 cm depth profile, while lime effects were observed only in the upper 20 cm. Caires *et al*. (2006) showed that gypsum ameliorate subsoil pH and Al-toxicity, increasing Ca and S level in wheat leaves.

Because limestone moves very slowly down through the soil, incorporation should be to the depth of the acidity problem (or as deep as practicable) for the most effective and speedy response. his means that deeper plowing would be necessary for through blending with the soil (Taye bekele, 2008). However, the deep lime incorporation requires the implementation of specific equipment and results in higher costs, which makes it unfeasible for use by small farm (Carvalho and van Raig, 1997).

Effect of Organic Matter Application on Soil Acidity Management Strategy

Soil organic matter maintenance and management are central to the sustainability of soil fertility in the tropics (Womer *et al*., 1994). It has been perceived for a long time that animal manure lowers soil pH as some commercial nitrogen fertilizers do (Hailin, 1998). Organic matter has been found to increase the soil's ability to hold and make available essential plant nutrients and to resist the natural tendency of soils to become acidic (Reis and Rodella, 2002). Working on a long-term field and greenhouse studies using animal manure as an ameliorating agent on acid and neutral soils, Hailin (1998) found that soil pH was higher by 0.5 units to a depth of 2 feet under littered soils than in un-littered soils. Soil organic matter increases the soil flora and fauna (associated with the soil aggregation, improved infiltration of water, and reduced soil erosion), complex toxic Al^{3+} and Mn^{2+} ions (leading to better rooting), increases the buffering capacity of low activity clay soils, and increases water holding capacity (Woomer *et al.*, 1994). Although the use of liming materials is the most effective way of managing and correcting soil acidity, numerous studies reviewed by Wong and Swift (2003) have shown that the application of organic matter such as compost, manure, and un decomposed plant residues can ameliorate the effect of soil acidity on crop growth. The main reason why manure raises soil pH is due to the presence of calcium and magnesium elements in it and its buffer capacity because of forming complexes with Al and Fe in acid soils (Tang *et al.,* 2007). As such, applying manure to acid soils not only supplies the much-needed nutrients and organic colloids for plant growth but also reduces soil acidity, thus improving phosphorus availability and reduces aluminium toxicity (Hailin, 1998). Returning organic amendments in form of livestock manures and crop residues to soil could be important in supplying crop nutrients as well as improving soil moisture conditions and increasing availability of P by stimulating microorganisms that solubilize soil P (Fankem *et al.,* 2008). However, organic amendment in the longer term as they decompose, have an acidifying effect on soils. Nevertheless, for farmers who do not have access to agricultural liming materials either because of they are unavailable or too costly, these materials may be useful as a partial short-term solution to soil acidity.

Use of Plant Tolerant to Soil Acidity

Cultivated crops vary in their tolerance to soil acidity. Therefore, selecting and growing species and variety adaptable to acidic soils is one solution n (Scott *et a., 1997*). Acidity in the surface soil can be corrected by applying agricultural lime. When the subsoil layers are acidic, amelioration of the surface layer will not allow the plant roots to penetrate the acid layer and reach critical water and nutrient supplies below it. Selection and development of genotypes with enhanced tolerance to acid soils and toxic levels of Al is the only reasonable solution to this problem. For chromosome manipulation in wheat and triticale breeding, it is important to know which wheat and rye chromosomes carry genes for aluminum tolerance (Aniol and Gustafson, 1984).

For example, recent research indicates the existence of genes for Al tolerance in plants and bacteria such as rhizobia (Eshetu Lemma 2011). Furthermore, alternative means to chelate Al to reduce its toxic effect in the rhizosphere of plants would be the selection of crop or pasture cultivars excreting organic acids, such as citrate, gluconate, malate or oxalate. Such resistance has been further described in wheat where the root apices are the target site of Al toxicity (Conyers *et al.,* 2005). The use of tolerant plants is important where sub soil acidity exists; particularly as the amelioration of acidity in the subsoil (i.e., below the volume where the lime has been incorporated) after liming is slow (Coventry *et al.*, 1997). The choice of species /variety with better yield potential is obviously important for economic reasons (Eshetu Lemma 2011). However, the choice of species or variety is also an important as a management strategy to offset acidification, as plant s tolerant to soil acidity are more likely to be using water through a better root growth and be reaching more NO_3^- deeper in the soil profile (Eshetu Lemma 2011).

CONCLUSION

Low soil pH is considered to be the main cause of yield reduction for all crops in general and acid sensitive crops in particular in tropical soil. Liming improves acid soils' physical, chemical and biological properties and increases plant production. Numerous authors (Havlin *et al.*, 1999; Hughes *et al.*, 2004; Loncaric *et al.*, 2007) reported that liming of acid soils increased crop yield and caused significant changes in soil properties modifying soil acidity and nutrient availability. Soil acidity is now a serious threat to crop production in most high land of tropical soil. Major constraints to crop production in acid soils are toxicities of Al and Mn and deficiencies of Ca/Mg (Jackson, 1967). In order to produce a better crop yield on acid soils, farmers are recommended to apply alkaline materials such as lime (primarily calcium carbonate) to increase the soil pH and thus eliminate Al toxicity, and to apply P fertilizer to increase the bioavailable P in soil. Lime requirement refers to the amount of lime required to neutralize all or part of the acidity in soil (both solution and reserve) from an initial level to a desired or target less acid condition. The target level of soil acidity depends both on the soil and the crop. The acidic soils are naturally deficient in total and plant available phosphorus. This is because significant portions of applied P are immobilized due to precipitation of P as insoluble Al phosphate. The liming of acidic soils results in the release of P for plant uptake; this effect is often referred to as ‘‘P spring effect’’ of lime (Bolan *et al.,* 2003). Acid soils can be managed in two ways, i.e., either by growing suitable crops for a particular soil pH or by ameliorating the soils through application of amendments, which counteract the soil acidity (Biswas and Mukherjee, 1994). However, in many developing countries, where semi subsistence agriculture prevails, the lack and/or high cost of lime prevent its use. Under such conditions, alternative means of managing soil acidity need to be developed. Research has shown that additions of green manures, FYM, and composts to acid soils can reduce Al toxicity and increase crop yields (Tejada *et al.,* (2006).

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