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Soil Acidity and Its Managements: A Review

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Abstract

Acidic soils significantly limit crop production; about 50 percent of the currently arable soils around the world are acidic. Soils tend to become acid because of the leaching mechanism of carbonic acid that is CO_2 dissolved in rainwater. The availability of micronutrients such as aluminum (Al), manganese (Mn) and iron (Fe) increases as the pH decreases. However, basic cations like calcium (Ca) and magnesium (Mg) are removed through leaching and crop harvest but at the same time these bases are replaced due to organic matter decomposition and from the weathering of minerals those are formed by naturally. High rainfall and leaching, acidic parent material, organic matter decay, and harvest of high yielding crops are the major causes for soils to become acidic. Effect of soil acidity are toxicity (aluminum, manganese and hydrogen are toxic at lower pH), nutrient availability (acid soils are strong due to this loss of nutrient like, potassium, calcium and magnesium can be depleted by leaching or removed in products such as hay and grain) and soil microbial activity (reduced microbial activity microbes which fix nitrogen or decompose organic matter are less active in moderately and strongly acidic soils) etc. Soil acidity can be managed by using lime, organic matter and crop systems, use of plant tolerance to soil acidity those all are essential for minimize the soils acidity.

Keywords: Ammonium, Lime, Nutrient, Organic Matter, Soil Acidity

1. Introduction

Bacillary dysentery and enteric fevers continue to be impor-tant causes of morbidity in both developed and developing nations. Shigella cause an estimated >150 million cases of dysentery and enteric fever occurs in >27 million people annually (Bardhan et al., 2010; Crump et al., 2004; Crump and Mintz, 2010; WHO, 2005). Shigellosis and enteric fevers together cause >250,000 deaths annu-ally (Bardhan et al., 2010; Crump et al., 2004), demonstrating a continuing need for novel vaccines to protect against these dis-eases.

Acidic soils significantly limit crop production around the world because about 50 percent of the currently arable soils around the world are acidic. The toxic levels of aluminum (Al) and manganese (Mn), as well as suboptimal levels of phosphorous (P) are the primary limitations on acid soils (Kochian.*et al.,* 2004). Soils tend to become acid because of the leaching mechanism of carbonic acid that is CO_2 dissolved in rainwater. Basic cations like calcium (Ca) and magnesium (Mg) are removed through leaching and crop harvest but at the same time these bases are replaced due to organic matter decomposition and from the weathering of minerals those are formed by naturally (Abebe Mesfin, 2007; Sanchez, 1977). Geologically, soil acidity increases as rainfall increases. The availability of micronutrients such as Aluminum (Al), manganese (Mn) and iron (Fe) increases as the pH decreases. High rainfall and leaching, acidic parent material, organic matter decay, and harvest of high yielding crops are the major causes for soils to become acidic (Eswaran *et al.,* 1997b; Von Uexküll and Mutert, 1995).

Ethiopia is an agrarian society whereby the livelihood of more than 85% of its population is based on subsistence farming. Soil acidity affects about 43% of the cultivated land in humid and sub- humid highlands of Ethiopia. The major factor to increase and sustain crop yields the increasing demand for food and raw materials, soil health and fertility has remained. This told for proper use of knowledge of soil acidity and its amelioration to maximize agricultural productivity (Getachew Agegnehu and Chilot Yirga, 2019). In acid soils, excess Al primarily injures the root apex and inhibits root elongation (Sivaguru and Horst, 1998). The poor root growth leads to reduced water and nutrient uptake, and as a result crops grown on acid soils are constrained with poor nutrients and water availability. The net effect of which is reduced growth and yield of crops (Marschner, 2011; Wang *et al.*, 2006).

Soil acidity occurs mainly due to application of N fertilizers or manure, especially those having high concentrations of ammonium or urea because nitrification releases hydrogen ions. Soil pH decreases as the acidity increases because pH expresses acidity as the negative logarithm of concentration of H^+ (Pagani, 2011). Soil pH is used to determine soil acidity limits crop growth but does not directly estimate lime requirement (LR) (Pagani, 2011). Soil pH is a measure of soil solution number of hydrogen ions. However, the actual concentration of H^+ in the soil solution is actually quite small (Donahue and Auburn, 1999). Hence, the aim of this review paper is focused on soil acidity, cause of soil acidity, effect of soil acidity and management of the soils acidity.

2. Soil acidity and its management

2.1. Soil Acidity

Soil acidification is a gradual process resulting from intensive crop production over a long period of time. By management, the soil acidification rate can be that. Adjusting applied nitrogen and sulfur to crop needs may reduce the cost of input while reducing acidification (Martha Mamo and Shapiro, 2015).

In Ethiopia, soil acidity is a problem that has not been addressed in depth. It is found that most of these soils have high rainfall in the highlands (Paoulos, 2001).

The Ethiopian highlands are one of the hotspots on the African continent with regard to food production and in the struggle to preserve the natural resource base (FAO, 2004 cited in Balesh *et al.*, 2005, FAO, 2005).

2.1.1 Characteristics of Acid Soils

The pH is low, highly exchangeable H and Al, the characteristics of acid soils are low CEC and high base unsaturated; adverse effects are caused by toxic Al, Mn and Fe accumulation and Ca and Mg deficiency; acid soils in usable P are weak and have a high capacity for fixing P; Except for molybdenum, the available micronutrient status is adequate; Population of bacteria and actinomycetes is lower and those of fungi higher (Chilot Yirga *et al., 2019).*

2.1.2. Class of Soil Acidity

Soil acidity is estimated by pH measurement. Soil pH is an index of active acidity. Active acidity is the concentration of hydrogen ions in the soil solution and is measured in a soil and water mixture. Soil pH is a general indicator of nutrient availability, the presence of free lime (calcium carbonate), and excessive availability of some ions, including sodium, hydrogen, aluminum, and manganese (Getachew Agegnehu and Chilot Yirga., 2019).

2.1.2.1 Active Acidity

Active acidity measured as in soil pH; it is the concentration of hydrogen ions in the soil solution. This occurs because of H^+ ion concentration of the soil solution that is attributable to carbonic acid (H_2CO_3), water soluble organic acids and hydrolytically acid salts. It can be determined by measuring the pH value of a water suspension or extract from a soil. It bears directly on the development of plants and soil microorganisms (Pankova *et al*., 2009).

2.1.2.2 Exchange Acidity

The H and Al ions adsorbed on soil colloids. There exists an equilibrium between the adsorbed and soil solution ions (i.e. active and exchange acidity), permitting the ready movement from one form to another form. It is the acidity caused by hydrogen and aluminum that are easily exchangeable in a simple salt solution such as KCl (Getachew Agegnehu and Chilot Yirga, 2019).

2.1.2.3 Reserve Acidity

It is the concentration of hydrogen ions attached to clay and organic matter and is measured as buffer pH in a buffer solution the adsorbed H and Al ions pass into the soil solution and its acidity is also known as potential or adsorbed or reserve acidity. In an acid soil, most of the H^+ present is absorbed by the soil (reserve acidity) (Thomas, 1996).

There is the relationship between the acidity of the active and reserve. But the relationship between the soils is not constant. The type and quantity of clay and the amount of organic matter and free lime in the soil determined it. The reserve-to-active acidity ratio refers to the soil's buffer potential or the soil's ability to resist pH change as the soil's clay and organic matter content increases. Thus, a sandy soil's buffer capacity, or reserve acidity, is much lower than that of a soil that contains more clay, like a silt loam. When the soil pH is 6.3 or lower, the pH buffer is measured to determine the amount of lime needed to neutralize a substantial part of the reserve acidity (Somani, 1996).

2.1.3. Causes of Soil Acidity

Soil acidification is a complex set of process resulting in the formation of an acid soil. In the broadest sense, it can be considered as the total of natural and anthropogenic processes that lower down the pH of soil solution (Krug and Frink, 1983).

The major causes for soils to become acid are Rainfall and leaching, Acidic parent material, Organic matter decay, Harvest of high yielding crops, Nitrification of ammonium, and Low buffer capacity from little clay and organic matter (Zhang, 2013). Soil acidity are easily under-stood when we consider that a soil is acid when there is an richness of acidic cations, like hydrogen (H^+) and aluminum (Al^{3+}) present compared to the alkaline cations, like calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+) and sodium (Na^+) (Wolf and Snyder, 2003).

2.1.3.1. Rainfall and Leaching

Excessive rainfall is an effective agent for removing basic cations over a long period of time. With an increase in rainfall, the contents of soluble salts are reduced to a low level, and any calcium carbonate and gypsum present are removed. When a lot of water flows through the soil quickly, runoff is most effective in causing soils to become acidic. Sandy soils are often the first to become acidic as water percolates quickly, and sandy soils only have a small base reservoir (buffer capacity) due to low levels of clay and organic matter (Wolf and Snyder, 2003). Excessive rainfall leaches the soil profile's basic elements (Ca, Mg, Na, and K) and that increase soil acidity (Foy, 1984). High rainfall leaches soluble nutrients such as Ca and Mg which are specifically replaced by Al from the exchange sites (Brady and Weil, 2016).

2.1.3.2 Acidic parent material

Soils will become acidic after different lengths of time due to differences in the chemical composition of parent materials. Soil from granite rock is likely to be more acidic than soil from calcareous shale or calcareous stone (Guo *et al.,* 2010; Hue, 1992).

Rocks containing an excess of quartz or of silica as compared to their content of basic materials or of basic elements are categorized as acid rocks; granite and rhyolite are examples of acid rocks. When rocks that are deficient in bases are disintegrated or decomposed in the process of the accumulation of soil material is acidic, despite no loss of base during the process of soil formation.

It is possible that soils that derive from weathered granite are more acidic than those that drive from shale or limestone. There are large areas created from acid parent rocks of silica and sandy soils that have always required lime (Yilmaz, 1989). However, most acid soils have been developed as a result of leaching losses and crop removal of bases (Brady and Weil, 2016).

The pH value below 4 the soil is strong acidic, the pH values in the majority of soils are in the range of 4.5 to 6.5. Soils found in high altitude areas of the country are most of the time acidic in reaction, poor in exchangeable cations and low in base saturation (Bekele Tekelye and Hofner, 1993; Waken Regassa and Getachew Agegnehu, 2011).

2.1.3.3 Organic matter decay

Hydrogen ion, responsible for acidity, is created by decaying organic matter. The carbon dioxide (CO_2) formed by decaying organic matter reacts with soil water to form a weak acid known as carbonic acid. This is the same acid that happens when CO_2 reacts naturally with rain in the atmosphere to form acid rain. By decaying organic matter, many organic acids are also formed, but they are also weak acids. The contribution of decaying organic matter to acid soil development is usually very small like rainfall, and it would be only the cumulative effects of several years that could ever be measured in a field. (Prochnow, 2014).

Soil organic matter or humus contains reactive carboxylic, enolic and phenolic groups that behave as weak acids. During their dissociation they release H^+ ions. In addition, the formation of CO2 and organic acids during the decomposition also result in replacement of bases on exchange complex with H+ ions (Somani *et al.*, 1996).

2.1.3.4 Harvest of high yielding crops

Removal of elements is responsible for soil acidity, particularly from soils with a small reservoir of bases due to the harvest of high yield crops. High-yield crop harvesting plays the most important role in increasing soil acidity. In order to meet their nutritional requirements, crops absorb basic elements such as Ca, Mg, and K during growth. Compared to the portion of the plant's leaves and roots, grain produces minutes of these essential basic nutrients. Therefore, harvesting high-yielding forages such as Bermuda grass and alfalfa affects soil acidity more than harvesting grain does (Fageria and Baligar, 2008; Rengel, 2011). Changes in land use and management practices regularly amend most soil physical, chemical and biological properties to the extent reflected in agricultural productivity (Heluf Gebrekida and Wakene Negassa, 2006). Such practices result in an increase in bulk density, decline in soil organic matter (SOM) content and CEC (Conant *et al.,* 2003), which in turn reduce the fertility status of a certain soil type. In addition, change in land use associated with deforestation, continuous cultivation, overgrazing, and mineral fertilization can cause significant variations in soil properties and reduction of output (Kang and Juo, 1986; Lemenih *et al.,* 2005).

2.1.3.5 Application of Ammonium Fertilizers

Soil acidity can be increased by continuous application of inorganic fertilizer without soil test. The use of N fertilizers in ammonia form is a source of acidification (Fageria and Nascente, 2014; Guo *et al.,* 2010). When ammonium fertilizers are applied to the soil, acidity is produced, but the form of N removed by the crop is similar to that found in fertilizer. Hydrogen is added in the form of ammonia-based fertilizers (NH4), urea-based fertilizers [(CO (NH2)2], and as proteins (amino acid) in organic fertilizers. Transformation of such sources of N fertilizers into nitrate (NO3) releases hydrogen ions (H^+) to create soil acidity. In reality, N fertilizer increases soil acidity by increasing crop yields, thereby increasing the number of basic elements being removed. Hence, application of fertilizers containing NH4 or even adding large quantities of organic matter to a soil can ultimately increase soil acidity and lower pH (Getachew Agegnehu and Chilot Yirga, 2019).

2.1.3.6. Low Buffer Capacity from Little Clay and Organic Matter

Another cause of soil acidity is the exchange of interaction between the exchangeable root surfaces hydrogen and the soil bases in exchangeable form. Where leaching is limited, microbial production of nitric and sulfuric acids also occurs. The acid soil lime requirement is related not only to the pH of the soil but also to the buffer or the CEC. The buffering or CEC is related to the amount of clay and organic matter present, the larger the amount, the greater the buffer capacity. Soils with higher buffer capacity (clayey, peats), if acid, have high lime requirement. Coarse textured soils with little or no organic matter will have low buffer capacity and, even if acid, will have low lime requirement. The indiscriminate use of lime on coarse textured soil could lead to over-liming injury (Krull, *et al*., 2004).

3.1.4. Effects of Soil Acidity

Poor plant growth and reduced productivity of plants which are sensitive to acidity will reduce in growth and productivity allowing weeds to increase or reduce soil cover which can lead to soil erosion (Mcfarland *et al.*, 2001).

Aluminum toxicity in the subsurface soil is the major problem for soils acidity (Gebregziabher *et al*., 2016). Low pH in top soils primarily affects nutrient availability and decreases nodulation of legumes and nitrogen fixation in pastures. These problems are minimized if the topsoil pH is maintained above (ContChris Gazey and Stephen Daviesents, 2009).

3.1.4.1 Toxicity

Aluminum, manganese and hydrogen are toxic at lower pH. Plants do not tolerate excessive amount of these elements. Phosphorus and Molybdenum combines with free aluminum and iron released in acid soils and becomes less available to plants. Toxic levels of aluminum and manganese are released into soil solution as pH (CaCl2) drops below 5.0.

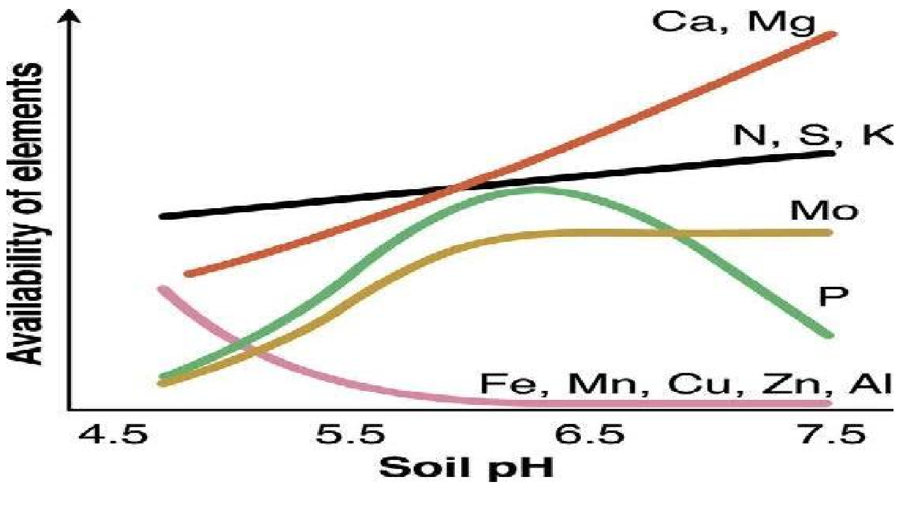
Aluminum (Al) toxicity is a problem when soil extractable Al levels are >2mg/kg or exchangeable Al is >5%. Toxic levels of aluminum and manganese affect root growth and the soil biota. Increased risk of soil erosion by the reduced amount of soil cover and increased runoff with subsequent water pollution and deposition in streams (Mcfarland *et al.*, 2001).

Aluminum is present in soils in a variety of forms and bound to the soil constituents, particularly clay particles and organic matter. When soil pH drops, Aluminum becomes soluble and the amount of Aluminum in the soil solution increases. As a rule of thumb, soil Aluminum concentration between 2 and 5 ppm (mg/kg) is toxic to the roots of sensitive plant species, and above 5 ppm is toxic to tolerant species. In general, the topsoil contains enough organic matter so that aluminum can remain bound and does not become harmful to plant roots even though it can be removed in laboratory study (Hargrove and Thomas, 1981). In the soil solution toxic levels of Aluminum affect root cell division and the ability of the root to elongate. The root tips are deformed and brittle. Root growth and branching is reduced. Poor crop and pasture growth, yield reduction and smaller grain size occur due to inadequate water and nutrition. The result of aluminum toxicity is most evident in dry-finish seasons. Root are unable to grow effectively through acidic subsurface soil that forms a barrier and limits access for grain filling to stored subsoil water. (ContChris Gazey and Stephen Daviesents, 2009)

2.1.4.2 Nutrient Availability

Acid soils are strong due to this loss of nutrient like, potassium, calcium and magnesium can be depleted by leaching or removed in products such as hay and grain. A lack of calcium can also contribute to soil structural problems. Nutrient tie-up as soil acidity increases nutrients such as phosphorus and manganese can become unavailable (Mcfarland *et al.*, 2001).

The availability of nutrients to plants is affected by soil pH. In acidic soils, the availability of the major plant nutrients nitrogen, phosphorous, potassium, sulfur, calcium, manganese and also the trace element molybdenum is reduced and may be insufficient (figure 1). Liming is to raise the pH of acidic soil will increase the availability of these nutrients. There is an improved abundance of iron, manganese, copper, zinc and aluminum in acidic soils (Ngoune, *et al*., 2018). Pollution of groundwater and surface water are increased due to leaching of nitrate, other nutrients and heavy metals from the soil profile. (Mcfarland *et al.*, 2001).



Plants go hungry for some nutrients
Nutrients can be lost to environment
Al and Mn reach toxic levels

Figure 1 : Relationship between soil pH and nutrient availability, in acidic soils
Source: - Gov. W. Australia, Dept. Ag and Food At low soil pH (Nelson, and Su, N, 2010).

➢ Relationship between soil pH and nutrient availability some nutrients may not be adequately available in acidic soils for optimum plant growth and aluminum may become toxic (Clark *et al.*, 2001).

2.1.4.3 Soil microbial acidity

Reduced microbial activity microbes which fix nitrogen or decompose organic matter are less active in moderately and strongly acidic soils. Declining land values by loss of productive capacity due to acidity can reduce land values (Mcfarland, *et al.*, 2001).

In acidic soil most microbial processes are reduced because growth and reproduction of the soil microbes, primarily bacteria and fungi, are reduced and breakdown of organic matter and cycling of nutrients is reduced. The rate of mineralization of nutrients by soil microbes into plant-available forms is slower, potentially limiting plant uptake. Nitrogen-fixing rhizobia bacteria under favorable conditions form a symbiosis with crop and pasture legumes in root nodules. Species of rhizobia bacteria differ in their resistance to soil acidity, for example medicinal rhizobia are very susceptible and do not continue (Howieson and Ewing, 1986). Grass-dominated pastures can result from the failure of pasture legumes to thrive in acidic soil (ContChris Gazey and Stephen Daviesents, 2009).

Low pH can affect microbial activity in top soils, most notably decreasing nodulation of the legumes (Quilliam *et al*., 2013). Reddening of stems and petioles on pasture legumes or yellowing and death of the oldest leaves on grain legumes may indicate the resulting nitrogen deficiency (Yazie, 2020). Rhizobia bacteria are greatly reduced in acidic soils. According to the inability of reduced rhizobia populations to successfully nodulate roots and establish a working symbiosis, some pasture legumes may fail to survive (Unkovich, 2013).

3.2. Management of Soil Acidity

The management of acid soils should aim at improving the production potential by the addition of amendments to correct the acidity and manipulate the agricultural practices to obtain optimum crop yields (Getachew Agegnehu and Chilot Yirga, 2019).

3.2.1. Using Lime

Liming is a major and effective practice to overcome soil acidity constraints and improve crop production on acid soils. The foundation of crop production or ‘‘workhorse’’ in acid soil is called lime (Fageria and Baligar, 2008). Liming the soil can easily corrected soil acidity, or adding basic materials to neutralize the acid present. The most economical liming materials and relatively easy to manage are calcitic or dolomitic agricultural limestone (Pilbeam and Morley, 2007; Rengel, 2011). Modern agriculture production requires the implementation of efficient, sustainable, and environmentally sound management practices. In order to achieve optimum yields for all crops grown on acidic soils, liming is an essential method (Fageria *et al*., 2007). Liming is the most widely used long-term method of soil acidity amelioration (Fageria and Baligar, 2008).

The most economical method of ameliorating soil acidity is liming. The amount of lime needed will depend on the pH profile of the soil, the nature of the lime, the type of soil, the farming method and rainfall (Goulding, 2016).

Lime sand, from coastal dunes, crushed limestone and dolomitic limestone are the main sources of agricultural lime. Carbonate from calcium carbonate and magnesium carbonate is the component in all of these sources that neutralizes acidic soil. The key factors of lime quality are neutralizing value and particle size. The neutralizing value of the lime is expressed as a percentage of pure calcium carbonate which is given a value of 100 %. With a higher neutralizing value, less lime can be used, or more area treated, for the same pH change. Lime with a higher proportion of small particles will react quicker to neutralize acid in the soil, which is beneficial when liming to recover acidic soil (Anderson *et al*., 2013).

The advantages of liming are that it decreases the risk of toxicity of Mn^{2+} and Al^{3+} and improves microbial activity; physical condition (better structure); symbiotic legume fixation of nitrogen; forage palatability; provides an inexpensive source of Ca^{2+} and Mg^{2+} when these nutrients are deficient at lower pH; enhances the abundance of nutrients (the availability of P and Mo increases as pH increases at 6.0 – 7.0 but the availability of other micronutrients increases as pH increases).

The amount of lime to be added to the soil depends on: **-** (1) The change in the pH required (2) the buffer capacity of the soil (resistance of the soil for change in pH) depends upon CEC and clay content. The higher CEC and clay content, the larger lime content required. (3) The fineness of the liming material. 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. If the soil is coarse, the reaction would be slight; but if fine, the reaction will be extensive. Therefore, for materials such as calcium oxide and calcium hydroxide that are by nature powdery, no problem of fineness is involved. On the other hand, limestone is entirely a different matter since its reaction is related to particle size (Taye Bekele, 2008). In contrast, with crushing machinery now available, liming materials or limestone can be ground to any degree of fineness. Such ground marble, limestone, and dolomite found in the country (Sanchez, 1976) could easily be made available fairly quickly and thereby make the process cheaper.

Placement*:* For both direct and indirect effects on soils and plants, since lime particles do not move readily in soils. Consequently, it must be placed where needed and completely mixed with the soil to ensure uniform distribution. For instance, lime applied on the surface of an acid sub- soil could lead to transitory effects since it does not readily and substantially move to effectively bring about the intended soil reaction change for fertility improvement. This means that deeper plowing would be necessary for through blending with the soil (Taye Bekele, 2008). (4) The chemical composition of the liming material.

3.2.2. Organic Matter and Crop Systems to Reduce Acid Soils

Soil organic matter maintenance and management are central to the sustainability of soil fertility in the tropics (Swift and Woomer, 1993; Womer *et al*., 1994). In low input agricultural systems in the tropics, soil organic matter helps retain mineral nutrients in the soils and makes them available to plants in small amounts over many years as soil organic matter in mineralized. 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. 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 (Martha Mamo, 2015).

Organic Fertilizers applying animal manure may either increase or decrease the soil acidity. Some soil acidity is generated by decomposition of organic matter in manure, resulting in the production of organic and inorganic acids. However, manure often contains enough basic cations and carbonate ions to neutralize this acidification effect as well as some existing soil acidity. Manure samples can be analyzed to determine the liming value (Martha Mamo and Shapiro, 2015).

3.2.3. Use of Plant Tolerance to Soil Acidity

Using tolerant species or varieties of crops and pasture will decrease the impact of soil acidity if soil pH is low (Rorison, 1972). This is not a permanent solution because the soil will continue to acidify without liming treatment. The rate of soil acidification can be minimized through a variety of management activities (Goulding, 2016).

Management of nitrogen fertilizer input to reduce nitrate leaching is most important in high rainfall areas. Product export can be reduced by feeding hay back onto paddocks from where it has been cut. Less acidifying selections will also aid in rotations, e.g. replace legume hay with a less acidifying crop or pasture. Cultivated crops vary in their tolerance to soil acidity. Therefore, selecting and growing species and variety adaptable to acidic soils is one solution (Scott *et al.*, 1997). Perhaps more relevant as a strategy of last resort, where soil pH has fallen to values less than six, plant breeding or biotechnology to improve resistance of plants and microbes to acidity is warranted. For example, recent research indicates the existence of genes for Al tolerance in plants and bacteria such as rhizobia. 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 the root apices are the target site of Al toxicity (Bennet and Breen, 1991; conyer *et al.*, 2005).

4. Conclusion

Problems of soil acidity are increase in Ethiopian highland regions. Various studies verified this and indicated that lime is necessary but must be complemented with balanced plant nutrients in order to obtain adequate crop yields in acid-prone areas Sustainable soil management practices and the maintenance of soil quality are central issues to agricultural sustainability. Soil acidity and associated low nutrient availability are among the major constraints to crop production. The practice of liming acid soils to mitigate soil acidity and reduce phytotoxic levels of Al and Mn has been recognized as necessary for optimal crop production in acid soils. It is not an end goal by itself to achieve potential yield. Overall, liming should be considered as a soil amendment to raise soil pH to the level that is suitable for maximum nutrient availability, plant growth, and crop yield.

The rate of soil acidification can also be reduced through integrated soil and crop management. Residual effects of organic sources on crop production and soil properties may last for several years and hence, their profitability could not be precisely estimated in the short-term, and rather their effect is clearly seen in the long term. Application of organic residues not only increases the nutrient content of soils but also improves their physical and biological properties. Other practices involve choosing fewer acidifying fertilizers or improving time of application although such practices may increase input and management costs. When considering changes those costs need to be weighed against an eventual reduction in the cost of lime application.

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