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Soil Acidity in Ethiopia: Its Causes, Effects on Crop Production and Management Experiences So Far- Review

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Abstract
Soil acidity is a serious chemical problem that limits agricultural productivity in most of the highlands of Ethiopia as well as in the western part of the country. These acidic soils, which cover an estimated 41% of the arable land in Ethiopia, are inherently infertile and exhibit aluminium (Al) or manganese (Mn) toxicity, which are generally considered to be the major limiting factor for plant growth in acidic soils. The major factors leading to acid soils in western Ethiopia include erosion of topsoil by heavy rains and high temperatures, which increase the greatest loss of organic matter and leaching of exchangeable basic cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}). Organic matter can be easily degraded and lost through conventional land clearing practices such as burning and direct sun and rain exposure, which is exacerbated by improper agricultural practices. If these soils are not properly managed after clearing, they can quickly lose much of their original fertility and beneficial physical as well as biological properties. It has been suggested that maintaining production on these soils requires an effort far beyond the means of poor farmers. Because low pH affects the availability of nutrients, especially phosphorus and other macronutrients, correcting low pH through liming and/or the application of organic matter (such as compost and vermicompost) is critical to the sustainable management of these acidic soils. The recently introduced technology of organic soil amendment with vermicompost has proven to be a potential resource to significantly improve soil fertility and soil health in various soil types around the globe. Therefore, farmers should be encouraged to increase the productivity of acidic soils through organic amendments such as compost/vermicompost. Vermicomposting, which is still very young and rarely practiced by farmers, should be supported and strengthened by more research and extension than we currently have to produce high quality vermicompost to amend acidic soils of Ethiopia and restore soil life.
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1. INTRODUCTION

In Ethiopia, agricultural productivity remains critically low. Low-yield agriculture is neither profitable nor sustainable, as it leads to soil degradation and land abandonment [1]. The low productivity of the agricultural sector is largely attributed to low and declining soil fertility due to many factors such as soil erosion, continuous cropping, soil acidification, and inadequate sustainable soil fertility management. In addition, Ethiopia has soil types with inherently poor soil quality characteristics that can be problematic for crop production and require special management [2]. Soil acidity is one of the major limiting factors to acid sensitive crop production in the western highland areas Ethiopia [3,4]. It is often developed in regions where excessive rainfall coupled with unfavorable temperature and precipitation is high enough to leach appreciable amounts of exchangeable basic ions like calcium, magnesium, sodium and potassium from the surface of soil. Soil acidity 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 [4]. Acidification occurs with other conditions including eroded topsoil and depleted organic matter, depleted nutrients, alternating drought stress and high rainfall. In moisture-stressed areas, acidification can also be caused by continuous application of acid-forming fertilizers. Approximately 80% of acidic soils are expected to derive from Nitisols [2].

In general, acidic soils are inherently infertile and Al or Mn toxic. Their shallow top soils, the Nitisols particularly, are highly susceptible to erosion. The organic matter can be easily degraded and lost by conventional land-clearing practices, including burning and direct exposure to sun and rain. If not managed properly after clearing, these soils can rapidly lose much of their original fertility and beneficial physical properties. To sustain production on these soils requires inputs far exceeding the means of poor farmers. Unfortunately, there is no such thing as a 'low input' technology for the poor acid soils of the tropics. If poorly managed with no or low input to replace nutrients removed by cropping or erosion, these soils will within a few years be incapable of producing a decent crop. Soil acidity has become a serious threat to crop production in most highlands of Ethiopia in general and in the western part of the country in particular. Currently, it is estimated that about 40% of the total arable land of Ethiopia is affected by soil acidity [3,5]. Out of the total percent of soil coverage in Ethiopia non-acidic occupy 59 %, moderate to weak 28 % and strongly acidic soils 13 % (Fig. 1.).

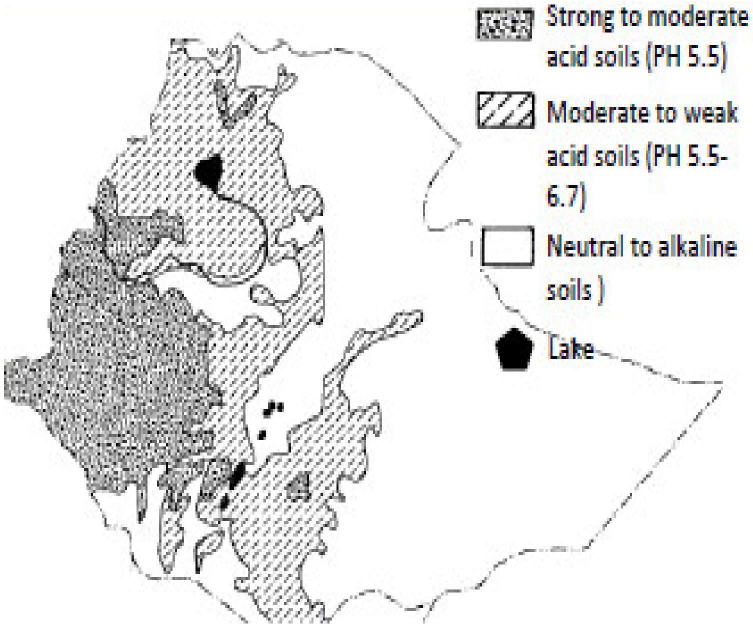

Fig.1. Acidic soil coverage distribution (ATA, 2013).

Therefore, acidic farmland in Ethiopia accounts for 40% of the total land. Given that the provided data is outdated, there is potential that this situation has worsened over the course of time [3,6]. Haile and Boke [7] also reported soil acidity have also been identified as a key production constraint in the highlands of southern Ethiopia (SNNPR) areas such as Gamugofa, Sidama, Kembata, Hadya, Guragie are sternly affected by soil acidity. Kidanemariam et al. [8] also reported soil acidity problems in some areas of Tigray Regional State (Tsegede District), northern Ethiopia and also Endibir and Awi Zone of the Amahara regional state [2].

Since, Western Ethiopia receives a high mean annual rainfall of above 1300 mm; there is a high loss of soil fertility, through erosion and leaching. In most cases, cereals are produced in mono-crop condition for several consecutive seasons, which has contributed a lot to the degradation of the fertility of the soil. Hence, unless efficient soil fertility management practices are designed and implemented, the productivity of such soils will remain poor [9]. Investigations by several researchers have indicated that soils in Ethiopia have increased in acidity over the years, the rate of which is very alarming. A substantial proportion of agricultural soils nationwide are currently ranging from very slightly to extremely acidic [3]. An inventory was made in 2006 to determine the current status of soil acidity of Nitisols occurring in western and central Ethiopia. The results revealed that all samples were acidic though the degree varied from location to location [5]. These authors opined that soil acidity problem that occurred particularly in eastern and western zones of Oromia was very critical and deserved immediate intervention to amend the soils for crop production. Soil acidity is expanding both in scope and magnitude in Ethiopia, severely limiting crop production. Several efforts have been made by both researchers and farmers to alleviate or control this problem. The present review paper aims to focus on assessing some of the approaches adopted for acid soil amelioration in Ethiopia and the constraints behind. This paper reviews the causes of soil acidity, its effect on crop production and management options and practices used as well as experiences so far and constraints behind using to neutralize soil acidity in Ethiopian condition.

2. Causes of soil acidity

In the tropics, substantial weathering of soils over many years 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 [10]. Thus, the higher the concentrations of these ions in soil solution, the higher the acidity. Most acid soils have been found to be low in fertility, have poor physical, chemical, and biological properties. 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. Crop production on such soils is seriously constrained, particularly in areas where proper management measures have not been put in place [1].

The soil solution not only contains a certain quantity of H^+ ions, but also has the ability to resist pH changes. Generally, soils have natural buffering capacity by which they are able to resist changes in soil pH upon marginal increases in their acidity or alkalinity [11]. This natural buffering ability of soils, however, varies from region to region as the parent materials and the unconsolidated soil strata differ greatly in their physico-chemical properties. The buffering capacity of soils, regardless of the location is, however, attenuated when soils are continuously exposed to processes that lead to soil acidification. Soil acidity develops from a combination of natural and anthropogenic processes. Naturally, soil acidity develops gradually over time as part of the soil development process and other natural phenomena. Both natural and anthropogenic factors cause soil acidity. However, anthropogenic activities in which man, through poor soil and water management and agronomic practices make worse the rate of acidification. Soil erosion followed by long term mono cropping was ranked as the most important causes of low soil fertility problem in western part of the country [9]. Belay [12] also reported that in different regions of Ethiopia there exists various topographic, climatic or agro-climatic and soil conditions. These varying conditions together with socio-economic status of the society, creates various factors that cause soil fertility decline with varying degrees. Acidification occurs with other conditions including eroded topsoil and depleted organic matter, depleted nutrients, alternating drought stress and high rainfall. In moisture-stressed areas, acidification can also be caused by continuous application of acid-forming fertilizers. Approximately 80 percent of acidic soils are expected to derive from Nitisols [2].

Generally, causes of soil acidity can be summarized as reported by Craswell and Pushparajah [1] most of which are attributable to high rainfall and temperatures include:

- High rates of weathering of soils;
- High rates of leaching of nutrients from soils;
- Very rapid destruction of usually shallow topsoil, especially its organic matter and structure;
- Quick and severe erosion of the topsoil;
- Acute drought stress after less than one week without rain

Only exposed soils, which have lost their protective cover of vegetation or leaf litter during land clearing and burning, are susceptible to these disadvantages [1].

2.1 Weathering of soils and leaching nutrients

Usually, the parent rocks or materials from which soils are formed are the main provenance for both essential and non-essential plant nutrient elements. If the parent material is acidic, there will be acidifying effect and alkaline effect on the hand will manifest if the parent material is basic. In the tropics, accelerated chemical and biological processes and high rainfall result in the loss of most nutrients by leaching. A highly acidic solum therefore develops, dominated by the end products of mineral weathering: kaolinite and the oxides and hydrous oxides of iron and Al [13]. During weathering both acidic and basic cations are released into the soil. Acid soils are highly weathered and contain large quantities of Al and Fe hydrous oxides that have the ability to adsorb major elements onto their surfaces such that much of added nutrients are fixed instead of being made available for crop use [14]. The influx of these nutrient elements to the soil is, however, annulled through leaching, where most of the basic cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) that would counteract the acidity effects of the acidic cations (mainly H^{+} and Al^{3+}) are removed from the soil, resulting in the preponderance of these acidic cations which give rise to soil acidity [15]. Soils, especially, in the humid tropics, become acidic when basic cations are removed through leaching, plant uptake and plant harvest. The older and more weathered soils are generally more acidic than younger soils [16]. Haque and Jutzi [17] also reported large areas of African soils with serious nutrient limitations are essentially acid and tend to become more so under cultivation, especially in heavy rainfall areas. This process is very effective in areas where there is high temperature and where precipitation exceeds evaporation and plant transpiration to induce weathering and leaching. Most highlands of Ethiopia in general and in the western part of the country in particular are naturally highly weathered and leached rendering them acidic and less fertile [18].

2.2 Loss of Organic Matter

The roles of organic matter in the productivity of mineral soils are still grossly underestimated and neglected in most tropical African countries [17]. Craswell and Pushparajah [1] listed nine major benefits of organic matter, the most important being increased available nutrient supply, reduced surface temperature, improved water relations (conservation, infiltration), and reduced soil erosion and surface water runoff. Because of the small percentage of organic carbon in the tropical soils, every effort should be made during land clearing to save as much of the carbon in the above-ground biomass as possible. This can best be accomplished by maintaining a cover on the soil at all times. Soil organic matter provide the primary driving force for many chemical and biochemical processes and thus affect nutrient cycling, soil fertility, and carbon cycling [19]. Generally, organic matter contains reactive substances such as carboxylic and phenolic groups which behave as weak acids. The dissociation of these groups results in the release of H^{+} ions which are responsible for acidity [17]. Decaying organic matter also produces CO_2 which reacts with H_2O to form weak carbonic acids. The conversion of organic N to mineral N through nitrification can also increase soil acidity. Brady [20], however, indicated that the contribution to acid soil development by decaying organic matter is generally very small. It was estimated that half of the Ethiopian highlands' arable lands are moderately to severely degraded and nutritionally depleted due to over cultivation, over grazing, primitive production techniques, and over dependent on rainfall [2]. Organic matter has been highly depleted in Ethiopian soils across a wide coverage of the nation; Ethiopia's highlands, covering ~40% of the nation, historically have extremely low soil carbon content. Recent data shows there is a need to improve the soil organic matter content in soils of Ethiopia [6], especially through replenish back organic materials into the soil.

2.3 Acid Rain

Rainfall is characteristically acid and it is made so by oxides of sulfur and nitrogen fed into the atmosphere from the internal combustion engines, the burning of coal and agricultural activities. The acidity of the rain which can have a pH value between 4.0 and 4.5 [20] is imparted to the soil through precipitation. The quantity of H_2SO_4 and HNO_3 that is brought to the earth in acid precipitation globally is enormous but the amount falling on a given hectare in a year which can induce any significant changes in pH is somewhat low, particularly in the less industrialized countries like Ethiopia. With time, however, the cumulative effects of acid precipitation can influence both soils and plants that grow in them [20].

2.4 Crop Production and Residue removal

The distribution of organic carbon is about equally divided between soil and above-ground biomass in a temperate forest ecosystem, but is concentrated almost entirely in the biomass (over 85%) will very little in the soil in a tropical forest ecosystem due to long term mismanagement that is imbalance between nutrient input and removal in the harvested crop [21]. Depletion of vegetation cover and soil organic matter (farmers remove all crop biomass from the fields and use less farmyard manure) are problem in the highlands of Ethiopia with dynamic rapid changes that increasingly render agro-ecosystems vulnerable to uncertainty [2]. Obviously, the main aim of any agricultural production system is to produce saleable products. However, this often saddled with some problems such as soil acidification. Crops absorb basic cations such as Ca^{2+}, Mg^{2+} and K^+ and also NH_4^+ from the soil solution for their nutrition. Consequently, there is a release of H+ from the plants in order for electrical balance to be established, particularly when plants absorb nutrient in the form of NH_4^+. The release of these H^+ ions has an acidulating effect in the soil [22]. When these crops are subsequently harvested from the field, or burnt and washed away via surface run-off, these basic cations which are responsible for counteracting the acidity developed by other processes are lost and the net effect is increased acidity [14]. The amount of these nutrients removed by cropping, however, depends on the type of crop grown, the part of crop harvested, and stage of growth at harvest. The leaves and stem portions of the plant contain larger amounts of these basic nutrients than the grains. Therefore, high-yielding forages such as Bermuda grass, hay and alfalfa have a larger effect on soil acidity than grains when harvested.

2.5. Application of acid forming fertilizers

Generally, as a result of high temperatures and other natural phenomena such as, precipitation and incessant leaching of nutrients, there is deterioration of the soils inherent capacity to support crop production. The continuous use of agricultural lands without appropriate management measures to ensure their rejuvenation has also given rise to many infertility problems. The levels of organic matter and most of the essential plant nutrients, particularly nitrogen and available phosphorus are low in most Ethiopian soils [2]. By reason of this intrinsic poverty of most of the soils, most farmers depend on external sources of fertilization to replenish the soil of its fertility. The reliance on chemical fertilizers far surpasses that of organic amendments for soil fertility replenishment in Ethiopia because the use of organic matter in the form of manure and compost is constrained due to farmers use animal manure and crop residues widespread as fuel and animal feed, respectively [23]. The problem of soil acidity on cultivated land is further aggravated by the use of acid-forming chemical fertilizers. The amount of acidification that results from using nitrogenous fertilizers depends on the fertilizer type. Fertilizers that contain nitrogen as ammonium, for example ammonium sulfate, acidify the soil within weeks after application [24]. In particular, the predominant inorganic fertilizers used in Ethiopia are urea and diammonium phosphate (DAP) [3]. Both these fertilizers increase soil acidity when converted to nitrate nitrogen by releasing hydrogen ions [15]. There is no denying the fact that significant successes in terms of crop yields have been recorded in so many places via the use of such chemical fertilizers. Even though these fertilizers are vital for high yields, their use is saddled with many consequences such as soil acidification.

3. EFFECTS OF SOIL ACIDITY ON CROP PRODUCTION

Soil acidity has been shown to have detrimental effects on plant growth by affecting plant nutrient availability and plant development. Acid soil related fertility problems are common throughout Africa in the humid and sub humid tropical regions, particularly Ethiopia. Soils are naturally acid or become acid and the acid soil-related infertility problem is accentuated under intensified agriculture production system in Ethiopia [2,3]. The acid soil-related infertility problem is complex and involves complex interactions of pH, toxicities of Al and Mn and deficiencies of P, Ca and Mg. It is often difficult to separate these effects under field experiment It has, however, been established that P deficiency is the major nutrient constraint on soils affected by acid soil-related infertility problems [25]. As mentioned above, soil acidity is usually associated with H^+ and Al^{3+}. Surprisingly, however, not so much deleterious effects on plant growth as a result of increased activity of H^+ ions under acidic conditions have been documented compared to that of Al [13]. Soluble aluminum in the soil causes most of the problems associated with acidic soils. The principal effects on plant growth from soluble aluminum in the soil solution is increased acidity via Al hydrolysis and reduced root proliferation and function, which is generally observed in the roots on the field as stunted, club shaped. This reduces the ability of plants to extract water and other nutrients in the soil. Several studies have also shown that when Al is in abundance, P is fixed as aluminum phosphate which is insoluble, hence making it unavailable for plant uptake [26]. This is one of the main problems in Ethiopian farmers, particularly in south western part, are faced with concerning acid soils. With the exception of molybdenum, the availability of micro-nutrients generally increases as soil acidity increases. Since micro-nutrients are needed by the plants in only minute quantities, plant toxicity and other detrimental effects occur with excess amounts. Generally, soil acidity (Al toxicity) resulted with indication such as stunted or shallow root growth in crops and pastures and poor nodulation in legumes or ineffective nodules that is acidity reduces the activity of beneficial soil micro-organisms. It is recognized that the nitrogen fixation by *Rhizobia spp*. on legume roots is retarded in acid soils, resulting in lower nitrogen availability and reduced production [24].

4. MANAGEMENT OF SOIL ACIDITY

The preceding sections have shown that soil acidity is an ongoing natural process which can be increased via anthropogenic activities. However, with appropriate management practices, soil acidity and its deleterious effects can be mitigated or prevented. Studies have shown that a wide array of possibilities exist for mitigating the effects of soil acidity. Some of the methods commonly used in Ethiopia include liming, the use of acid tolerant crops [18] and also organic material addition.

4.1 Liming

Several liming materials such as crushed limestone ($CaCO_3$), dolomitic lime ($CaMgCO_3$), slaked lime ($Ca(OH)_2$), quick lime (CaO) etc., can be used to reduce soil acidity. In general, limestone, dolomite, marl and marble are some of the major liming materials currently being produced in different parts of Ethiopia for use within the country [8]. They can be used either singly or in combined form. Studies have shown that apart from reducing the acidity of the soil by counteracting the effects of excess H^+ and Al^{3+} ions [26], liming also has several other benefits including, its ability to reduce the toxicity effects of some micro elements by lowering their concentrations while increasing the availability of plant nutrients such as Ca, P, Mo, and Mg in the soil [24] and reducing the solubility and leaching of heavy metals. Crops absorb most of these nutrient elements particularly Ca, P, and Mg in substantial amounts and therefore by increasing their amounts in soil crop yields can be significantly improved. Application of lime is, however, affected by factors such as quality of the liming material, soil texture, soil fertility, crop rotation, conservation tillage, crop species and the use of organic manure [26]. Several studies have been conducted to buttress the beneficial effects of liming in Ethiopia. Hirpa et al. [18] conducted an experiment on improving the fertility of some acid and impoverished soils in Ethiopia by liming. The study revealed yield responses showed that the grain yield was significantly affected by lime application. In general, the researchers found that liming resulted in a mean improvement in grain yield for all genotypes over no lime application. The magnitude of increase in grain yield and total dry biomass yield due to liming was 25.7 and 27.6 %, respectively over the no lime treatment. In a similar experiment conducted by Zerihun and Abera [27] increased lime application rates resulted with a linear increase in grain yield of faba bean and considerably improve the nutrient availability, particularly phosphorus, since it improves soil pH under which maximum availability of the nutrient may be obtained.

4.2 Application of organic materials

For simplicity, the use of organic materials herein represents all forms of organic materials from both plants and animal origins. It has long been established that apart from improving the fertility, structure and some biological properties of the soil, organic materials have the capacity to reduce soil acidity and Al saturation. Plant materials generally contain excess cations, and the balance between cations and anions is maintained by synthesis of organic acid anions such as oxalate, citrate and malate [20]. During microbial decomposition of plant materials, theses organic acid anions are decarboxylated in the process of plant residue decomposition which requires a proton for this reaction to be complete. By consuming a proton, the hydroxyl ions increase and this results in an increase in alkalinity. Thus, the greater the content of cations in plant material, the greater will be this effect. The use of organic fertilizers such as farm yard manure, compost, green manure and transferred biomass of leguminous trees is an alternative to inorganic fertilizers to improve soil fertility [7]. Plant materials such as legume residues (soybean, red clover, and acacia) were observed to have a substantially higher Ca, Mg, and total basic cation contents than the non-legumes (maize and sorghum), and consequently, ash alkalinity values were also higher. Anetor and Akinrinde [28] found that organic anions present in the residue may have a positive effect on preventing P fixation on sorption sites, predominantly available in weathered, sesquioxide (Fe and Al oxides)-rich soils. Organic soil amendments such as animal manures composts, green manures, cover crops, crop residues, straws, etc. has been helpful in the enhancement of the microbial biomass than non-amended soil or inorganic fertilizers and could led to sustainable agriculture [29]. Recently, Gebrehana et al. [30] reported that vermicomposting a process used to produce a nutrient-rich and microbially active vermicompost has been used to neutralize acidic soils and restore soil fertility and health in Ethiopia. Vermicompost is a nutrient-rich organic amendment with diverse microbial community generated from organic waste through the combined action of earthworms and microorganisms [31].

4.3 Use of acid tolerant crops

Although this approach is not able to reverse acidic soil conditions, the constraints of acid soil to crop production can be alleviated by growing acid tolerant crops in such areas with limited inputs such as lime. Quite a variety of crops have been found to thrive well in acid soils because of their varying degrees of tolerance to acidity. Cassava and rice and other cereal are some of the successful crops so far used in this regard [13]. Hirpa et al. [18] found that soil acidity tolerant germplasm of common bean which are adapted to acid soil condition in circumstances where other soil amendment strategies are not readily practical. Soil acidity problems for common bean production can be overcome by growing genotypes which are adapted to acid soil condition in circumstances where other soil amendment strategies are not readily practical. However, this is not possible until these tolerant genotypes are developed. This study revealed that common bean genotypes differ in tolerance to soil acidity. Although some genotypes exhibited an outstanding performance in terms grain yield and yield related traits, soil fertility improvement through liming would still be very important if economical bean production is to be produced in places with strong acid soil as the one used in this study. Moreover, the great variability of 25 common bean genotypes exhibited a good potential to screening large germplasm of common bean for soil acidity tolerance and develop a cultivar that are tolerant to soil acidity with potential and quality grain on such acid soils in the future. In addition, research should focus on improving crop genetics for tolerance to soil acidity and Al toxicity which can be complementary to or independent of soil liming [5]. According to Upjohn et al. [24] reported acid tolerant species can help farmers to reduce the impact of soil acidity by:

- Maintaining cash flow if limestone cannot be applied when required
- Maintaining or increasing production on soils with acidic subsurface layers that are too deep to be limed economically, or are on non-arable land
- Slowing the rate of acidification with more efficient use of nitrate nitrogen and soil moisture; particularly by replacing annual winter grasses with vigorous, perennial grasses that have some summer growth
- Allowing crop and pasture rotation sequences to match the typical decline of soil pH during a 10–15-year liming cycle
- Increasing water use and ground cover and thus reducing the downstream impacts.

Acid tolerant plants may slow the acidification of the soil but will not prevent it. Eventually the soil will become so acidic that only the most tolerant species can grow, and then with reduced production. Where the soil is very acidic and sowing acid tolerant species is not practical then retiring land from agriculture may well be the best option for the farm and the environment.

5. CONSTRAINTS FOR AMELORATION OF ACID SOILS

5.1 Constraints for liming

Management and/or amelioration options of acid soils like liming and application of organic materials are constrained by several factors as discussed below.

5.1.1 Availability, high cost and incorporation of lime

In the tropics, most acid soils have a strong buffering capacity against amendments of lime [13]. Hence, large amount of lime is needed to normalize the pH. Most resource-poor farmers in the tropics are constrained by unavailability, transport, and the high cost of the large volumes of lime needed to treat the soils [23]. In addition, 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 [24]. Due to this reason its mechanical incorporation in to the subsoil is also often difficult for small-scale farmers without tractors and subsoil rippers. Consequently, when surface soils are amended with lime, it fails to increase the pH of the sub-soil, resulting in restricted root growth and, therefore, poor plant growth [3,13, 23]. On the other hand, the use of inorganic fertilizer has remained very difficult for most subsistence farmers of developing countries, due to high price of fertilizer, which is beyond the purchasing capacity of farmers in the region [9].

5.1.2 Liming with nutrient supply

Agricultural liming material is the most common soil management practice whose addition to agricultural soil in moderate amounts may be beneficial as plant nutrients, minimize soil acidification. Measuring lime requirement and estimating the level of acid saturation together with exchangeable acidity are the most common methods to alleviate soil acidity constraints to crop production and to modify soils fertility status. As Gete et al. [2] reported Ethiopia has soil types with inherent characteristics which can be problematic for crop production and need special management. However, liming only will not be a solution to address because liming without replenishing of nutrients whether through inorganic fertilizer or organic materials could be worthy in nutrient depleted soils like Ethiopia, especially acidic soils of south western part. Different soil researchers in Ethiopia come up with liming and nutrient application is the best option in ameliorating acid soils and discussed as follows: Abush et al. [9] also reported low crop productivity, mainly caused by low soil fertility and absence of efficient and sustainable soil fertility management practices is a major constraint contributing to food shortage in Ethiopia. Though several limitations restrict its use by small scale farmers, the use of inorganic fertilizers and lime have been suggested as one of the best approaches to address those problem. Abdenna et al. [5] also reported that in East Wollega zone of south western Ethiopia farmers are reporting yield decline despite application of nitrogen and phosphorus fertilizers in the form of DAP and Urea. There are also reports that shows acidic cations are toxic and basic cation such as calcium, magnesium and potassium are deficient. Without liming application of inorganic fertilizers could not result with increase in plant growth because soil acidity may be one of the factors that limit yield and growth responses of crops to applied fertilizers [8]. Mesfin et al. [32] also found that application of lime might contributed in releasing some amount of fixed P to be available for the crop. But application of lime alone could not help haricot bean production to be increased. This also indicates that deficiency of P cannot be replaced by lime. As a result, in acidic soils which are deficient in Available P, OC and TN are important to apply P together with lime to increase crop production. Similarly, Haile and Boke [7] also found application of lime alone did not increase the yield of potato in both locations of the experiment and suggesting that the soils in both locations were severely depleted of essential nutrients. In the experiment conducted by Kidanemariam et al. [8] to improve wheat crop production on acidic soils of the Tsegede highlands, Tigray, Ethiopia. Acidic soils received combined application of NP and lime and showed significant grain yield increment as well as higher N and P uptake over those separately applied N and P fertilizers and lime levels. Moreover, significant wheat yield response and NP uptake were also observed due to application of only lime over the non-limed soils.

5.1.3 Availability of quality lime in Ethiopia

Although, liming material contains Ca and Mg compounds that are capable of neutralizing soil acidity, it is often difficult to distinguish the quality of one liming material from the other by visual inspection. Thus, parameters such as calcium carbonate equivalence (CCE), moisture factor, fineness factor and relative neutralizing value are principal quality standards used to differentiate liming materials from one another. The relative neutralizing value, effective neutralizing value and agricultural index are also synonymous terms used to describe the quality index of a liming material based on purity and fineness of the materials. However, even if liming materials have not the same chemical composition, they all follow the same process to neutralize soil acidity [24]. Therefore, major liming materials currently being produced in different parts of Ethiopia for use within the country should be pass through the above lime quality parameters for effective amelioration of acid soils.

5.2 Constraints for application of organic materials

There was emphasis by African farmers on organic mulching which was particularly interesting, considering that most of them do not have access to fertilizer supplies but still practical use of the organic materials is low in African countries, especially in Ethiopia. Abate et al. [23] also reported that the use of compost, manure and other organic fertilizer sources are recommended to cope with problem of soil acidity. However, these options are constrained by several factors which include; Animal manure and crop residues have widespread used by farmers of Ethiopia as fuel and animal feed, respectively. Therefore, large-scale use of this option is not common. On the other hand, there is evidence to show that use of manure is still unpopular among the farmers despite demonstrated advantages in the literature. Reasons could be the limited availability which they, high labor costs involved in transporting manure to fields, and low nutrient content due to poor storage (knowledge gap on preparing and storage of manure and compost). Addition of organic materials was and is still one of the cheapest alternatives but most farmers are not getting in to practicing this.

6. DISCUSSION

The acidity problem of the soil can be partly improved by the application of lime. However, lime application alone without the application of inorganic fertilizers at the right time and rate cannot solve the fertility problem of the soil [9]. The following list gives details to be checked to ensure that a response to liming is likely. This is particularly important when putting in a lime trial or test strip.

- The soil is acidic as determined using a soil test.
- The crop or pasture being limed is sensitive to acidity.
- The growth of crop or pasture is not restricted by some other factors such as poor soil structure, disease or a nutrient deficiency.
- The acidity of the subsurface soil will not restrict the productivity and persistence of the crop or pastures to be sown.
- The limestone to be used is sufficiently fine and with a high neutralizing value, or is the most cost-effective product available.
- The lime rate is sufficient to correct the problem

Indeed, the use of animal and household manure may increase the efficiency of inorganic fertilizer by providing micro-nutrients not present in the inorganic fertilizer or alleviating other constraints to crop production. There is evidence to show that use of manure is still unpopular among the farmers despite demonstrated advantages in the literature. Reasons could be the limited availability which they, high labor costs involved in transporting manure to fields, and low nutrient content due to poor storage. But Nigussie and Kissi [33] gave the conclusion, management practices such as increase input of plant residues, nitrogen rich organic materials like manure and compost are required. Moreover, application of lime, micronutrients-based fertilizers should be introduced in order to boost the crop productivity of the study area.

The use of chemical inputs including lime in agriculture declined because the resource poor farmers were unable to afford them, and most of them were also not readily available as all chemical substances used the time were imported. The need for alternatives that were relatively cheap and locally available became of paramount importance. Addition of organic materials was and is still one of the cheapest alternatives but most farmers are not getting in to practicing this.

Regardless of the rate of the lime applied, its effects on both soil acidity and crop yields could not be substantiated. On the contrary significant effects of FYM was observed on both soil pH and crop yield, while also reducing the levels of exchangeable Al in the top 20 cm of the soil. It is therefore possible to infer that significant savings can be made by using these organic materials. Nonetheless, the rapid rate of decomposition of organic matter due to high temperatures and incessant rainfall can result in rapid wearing out of its effects. The relatively large amounts required to neutralize acidity can also make its usage somewhat cumbersome and prevented. The creation of a free and efficient marketing system for the timely delivery of chemicals of good quality and in adequate quantity to farmers would probably ease the fertilizer problem in Ethiopia especially nonacid forming fertilizers and chemicals. For example, heavy application of P in the form of TSP fertilizers could be another alternative to achieve sustainable wheat crop production on acidic soils of the Tsegede highlands as well as elsewhere with similar agro-ecology areas of Ethiopia [8].

Several studies indicated that some rhizobia strains for different legume crops are acid tolerant when grown in acidic laboratory medium [34]. Different studies suggested that little research attentions have been given to acid tolerant rhizobia and evaluation of their symbiotic performance under acidic conditions [35]. Hence, selection of acid tolerant together with effective *Rhizobial* strains is important to improve the production of different legumes on acid soils of Ethiopia. Currently, there are carrying out research on various areas of soil and water management, fertilizer recommendations, management of problematic soils and other relevant areas in Ethiopia. However much of this knowledge is specific to particular areas selected for study and currently cannot be compiled, compared, or accessed at a national level to enable policymakers and other stakeholders to draw conclusions on the status of soil in Ethiopia and its implications for food production [2]. Many technologies (such as vermicomposting) that can be used to make Ethiopia's acidic, infertile soils productive and profitable in the long term and sustainably are already known, but need to be adapted and applied locally. This the recent and rarely practiced vermicomposting technology at farmers level should be supported and strengthen with much more research and extension education than we have at present.

7. CONCLUSION

As a natural process, soil acidification may only be reduced and not completely eliminated on already-made-acid-soils. Preventive measures can, however, be adopted for the remaining which have not yet been overwhelmed by this menace by ensuring a balance in removal and input of soil nutrients. In this review, however, it is inferred that a combination of lime and inorganic fertilizer and lime and organic materials are effective considering their merits and demerits and the case of Ethiopia. Soil fertility management in Ethiopia should begin to shift toward integrated approach. Further, the phenomenon of soil acidity has not been adequately investigated. Then, there is a need to quantify the status and extent of these soils with reflection on their current and future potentials. Lime application may not be feasible for poor resourced farmers. However, the complementary benefits (liming and nutrient supply) of organic fertilizers and rock phosphates could sufficiently ameliorate acid soil conditions and greatly reduce P fertilizer cost for effective and sustainable soil fertility management. Acid forming fertilizers such as ammonia nitrate UREA and DAP have negative effect on crops growing in acidic soils due to acidifying nature of these fertilizers, therefore none acidifying, alternative sources of fertilizers should be tested and demonstrated which cannot considered to be scarce and expensive, particularly for resource poor farmers, but whenever available, it can be a good substitute. Especially, the recently introduced high-value organic fertilizer (vermicompost) production through vermicomposting earthworms should be the future promising mechanism to alleviated soil acidity and restore soil biochemical properties.

In addition, research on evaluation of different crops and crop varieties for acidity tolerance should be strengthening from the past. Currently, there are carrying out research on various areas of soil and water management, fertilizer recommendations, management of problematic soils and other relevant areas in Ethiopia. But lack of effective links between research, extension, education and farmers a fundamental enabler for transfer of knowledge and skills from theory into widespread practice is still in the track. Therefore, more is expected at a national level to enable policymakers and other stakeholders to draw conclusions on the status of soil in Ethiopia and its implications for food production.

REFERENCES

[1] Craswell E.T. and Pushparajah E. Management of Acid Soils in the Humid Tropics of Asia.Australian Centre for International Agricultural Research Monograph No.13 (MSRAM Monograph No.1), 118 p. 1989.
[2] Gete Z., Getachew A., Dejene A. and Shahidur R. 2010. Fertilizer and Soil Fertility Potential in Ethiopia: Constraints and Opportunities for Enhancing the system, International Food Policy Research Institute, working paper. pp.20. 2010.
[3] Mesfin A."Nature and Management of Acid Soil in Ethiopia". Haramaya University. Haramaya, Ethiopia.99pp. 2007.
[4] Achalu C., Heluf G., Kibebew K. and Abi T. "Effects of Liming on Acidity-Related Chemical Properties of Soils of Different Land Use Systems in Western Oromia, Ethiopia''. World Journal of Agricultural Sciences, 8 (6): 560-567. 2012.
[5] Abdenna D., Negassa C.W. and Tilahun G. Inventory of Soil Acidity Status in Crop Lands of Central and Western Ethiopia. "Utilization of diversity in land use systems: Sustainable and organic approaches to meet human needs"Tropentag, Witzenhausen. 2007.
[6] ATA. "Status of soil resources in Ethiopia and priorities for sustainable management". GSP for Eastern and Southern Africa. Mar 25-27, 2013, Nairobi, Kenya. 2013.
[7] Haile W. and Boke S. "On-Farm Verification of Lime and NPK Fertilizers Effects on the Tuber Yield of Irish Potato (*Solanum Tuberosum*) on Some Acidic Soils of Southern Ethiopia". Journal of the dry lands, 4(1): 283-288. 2011.
[8] Kidanemariam A., Gebrekidan H., Mamo T. and Tesfaye K. "Wheat Crop Response to Liming Materials and N and P Fertilizers in Acidic Soils of Tsegede Highlands, Northern Ethiopia". Agriculture, Forestry and Fisheries, 2(3): 126-135. 2013.
[9] Abush T., Githiri M., Derera J. & Tolessa D. "Subsistence farmers' experience and perception about the soil, and fertilizer use in Western Ethiopia". Ethiop. J. Appl. Sci. Technol. 2(2): 61 – 74. 2011.
[10] Okalebo J.R., Othieno C.O., Nekesa A.O., Ndungu-Magiroi K.W. and Kifuko-Koech M.N. "Potential for agricultural lime on improved soil health and agricultural production in Kenya". African Crop Science Conference Proceedings, 9, 339 – 341. 2009.
[11] Ritchie G.S.P. "Soil Acidity and Plant Growth-The Chemical Behaviour of Aluminium, Hydrogen and Manganese in Acid Soils". Academic Press Australia. ISBN 0125906552. 1989.
[12] Belay Y. "Integrated soil fertility management for better production in Ethiopia". International journal of soil science, 10(1): 1-16. 2015.
[13] Rao I.M., Zeigler R.S., Vera R. and Sarkarung S. "Selection and Breeding for Acid-Soil Tolerance in Crops". BioScience, 43: 454-465. 1993.
[14] Akinrinade, E.A., Iroh I., Obigbesan, G.O., Hilger T., Romheld, V., and Neumann, G. "Response of cowpea varieties to phosphorus supply on an acidic alumi-haplic-Acrisol from Brazil". Nigerian Journey of Soil Science, 16: 115-120. 2006.
[15] Redmon L. A., McFarland M. L., Haby V. A. and Bade D. H. "Soil Acidity and Liming". Department of Soil and Crop Sciences, SCS-2001-06, Texas Agricultural Extension Service. 2001.
[16] Helyar K.R. and Porter W.M. "Soil Acidity and Plant Growth -Soil Acidification, its Measurement and the Processes Involved". Academic Press Australia ISBN 0125906552. 1989.
[17] Haque I. and Jutzi S. "Nitrogen fixation by forage legumes in sub-Saharan Africa: Potential and limitations". Up-dated version of a synthesis paper presented at the First Conference of the African Association for Biological Nitrogen Fixation. Nairobi, Kenya. 1984.
[18] Hirpa L., Nigussie D.R., Setegn G., Geremew B. and Firew M. "Response to Soil Acidity of Common Bean Genotypes (*Phaseolus vulgaris* L.) Under Field Conditions at Nedjo, Western Ethiopia". Science,

Technology and Arts Research Journal 2(3): 03-15. 2013.
[19] He Z., Yang X., Baligar V. C. and Calvert D. V. "Microbiological and biochemical indexing systems for assessing quality of acid soils". *Advances in Agronomy,* 78: 89–138. 2003.
[20] Brady N.C. "The Nature and Properties of Soils". Macmillan Publishing Company. New York. 2001.
[21] Lefroy R.D.B. "Improved the Management of infertile acid soils in Southeast Asia: The approach of the IBSRAM acid-soils network". In: FAO/IAEA. 2000. Management and conservation of tropical acid soils for sustainable crop production., Vienna, Austria. 2000.
[22] Tisdale J. and Nelson W.L. "Soil Fertility and Fertilizers". Macmillan Publishing Co. Inc. pp 398. 1975.
[23] Abate E., Hussein S., Laing M and Mengistu F. "Quantitative responses of tef [*Eragrostis tef* (Zucc.) Trotter] and weeping love grass [*Eragrostis curvula* (Schrad.) Nees] varieties to acid soil". Australia Journal of Crop Science 7(12):1854-1860. 2013.
[24] Upjohn B., Fenton G. and Conyers M**. "**Soil acidity and liming**"**. State of New South Wales, Department of Primary Industries. Agfact AC.19, 3rd edition. AGDEX 534. 2005.
[25] Sahrawat K.L. Abekoe M.K. and Diatta S. "Application of inorganic phosphorus fertilizer". Soil science society of America and America Society of Agronomy, 677S.Segoe Rd., Madison. WI 53711, USA. 2001.
[26] Fageria N.K. and Baligar, V.C. "Fertility management of tropical acid soils for sustainable crop production". In: Z. Rengel, Editor, Handbook of soil acidity, Marcel Dekker, New York, pp. 359–385. 2003.
[27] Zerihun A. and Abera T. "Yield Response of Faba bean to Fertilizer Rate, Rhizobium Inoculation and Lime Rate at Gedo Highland, Western Ethiopia". Global Journal of Crop, Soil Science and Plant Breeding, 2 (2):134-139. 2014.
[28] Anetor M.O. and Akinrinde E.A. Response of Soybean [*Glycine max* (L.) Merrill] to Lime and Phosphorus Fertilizer Treatments on an Acidic Alfisol of Nigeria. Pakistan Journal of Nutrition, 5 (3): 286-293. 2006.
[29] Ansari R.A., Sumbul A., Rizvi R., Mahmood I. "Organic Soil Amendments: Potential Tool for Soil and Plant Health Management". In: Ansari R., Mahmood I. (eds) Plant Health Under Biotic Stress. Springer, Singapore. 2019.
[30] Gebrehana Z.G., Gebremikael M.T., Beyene S. Wim M. L. Wesemael and De Neve S. "Assessment of trade-offs, quantity, and biochemical composition of organic materials and farmer's perception towards vermicompost production in smallholder farms of Ethiopia". J Mater Cycles Waste Manag 24**,** 540–552. 2022.
[31] Domínguez, J., Aira, M., Kolbe, A.R. Gómez-Brandón M., Pérez-Losada M. "Changes in the composition and function of bacterial communities during vermicomposting may explain beneficial properties of vermicompost". Sci Rep 9, 9657. 2019.
[32] Mesfin K., Belay Y. and Abera H. "Liming effect on yield and yield component of haricot bean (*Phaseolus vuglaris* L.) varieties grown in acidic soil at Wolaita zone, Ethiopia". Int. J. Soil Sci. 9 (2), 67–74. 2014.
[33] Nigussie A. and Kissi E. Physicochemical Characterization of Nitisol in Southwestern Ethiopia and Its Fertilizer Recommendation Using NuMaSS. Global Advanced Research Journal of Agricultural Science, 1(4): 066-073. 2012.
[34] Jida M. and Assefa F. Phenotypic and plant growth promoting characteristics of *Rhizobium leguminosarum bv. viciae* from lentil growing areas of Ethiopia. African Journal of Microbiology Research (5): 4133-4142. 2011.
[35] Jida M. and Assefa F. Effects of Acidity on Growth and Symbiotic Performance of *Rhizobium leguminosarum* bv. *viciae* Strains Isolated from Faba Bean Producing Areas of Ethiopia. Science, Technology and Arts Research Journal, 3(2): 26-33. 2014.