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Soil Acidification and its Influence on Growth and Yield of Faba Bean (*Vicia faba* L.) and its Management Options – A Review

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Abstract

Soil acidity associated with major nutrient deficiencies are an impediment to agricultural production in areas where heavy rainfall is common causing nutrient loss by way of leaching and soil erosion. It has a proven negative impact on the growth performance and yield of leguminous crops in greater extent compared with cereals. Despite deficiency of basic plant nutrients, it aggravates disease susceptibility and reduces plant vigour, which leads to overall yield reduction on faba bean crop. This review focuses on causes and impacts of soil acidity on growth performance and yield of faba bean and its management options. Since crop productivity is diminishing year to year, improving the productivity of marginal areas like acidic soils is a major priority as a demand of food and raw materials are increasing rapidly. According to the information gathered from reviewing research findings, the detrimental effects of soil acidity can be mitigated through lime application, breeding acid tolerant crops and integrated use of acid soil management techniques. For instance, application of lime produced 29-53% yield advantages in faba bean production in Ethiopia compared with the control plots. Overall, soil acidity covering about 43% of Ethiopian soil should be reclaimed through application of appropriate liming materials and integrated acid soil management interventions (organic and inorganic ameliorating inputs), which could improve soil health thereby significantly increase in crop yield.

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Keywords

Faba bean, soil acidity, yield, degradation processes.

Introduction

Soil degradation is recognized as a key factor underlying poor agricultural productivity in sub-Saharan Africa (SSA) affecting the livelihoods of farmers and their environment (Amede and Whitbread, 2020). Severely degraded soils account for about 350 million ha (20–25 %) of the total land area, of which about 100 million ha is estimated to be acutely degraded mainly due to improper agricultural activities and the degradation processes vary according to land-use types. Human impact on the productive capacity of agricultural land mainly related to unsustainable soil management, such as total removal of crop residues, application of very low external inputs, following continuous monocropping and shifts to more demanding crops. The consequences are soil acidification, loss of soil organic matter (SOM), nutrient mining and soil erosion. Soil acidity increases with the build-up of hydrogen (H^+) and aluminum (Al^{3+}) cations in the soil or when base cations such as potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and sodium (Na^+) are leached and replaced by H^+ or Al^{3+} (Von Uexküll and Mutert, 1995). It is among the major land degradation problem that affects around 50% of the world's potentially arable soils (Kochian *et al.,* 2004) in areas, where high rainfall is common, due to the deficiencies of N by leaching, P through fixation and low soil OM (Opala *et al.,* 2015).

Soil acidity is a complex process resulting in the formation of an acid soil due to excessive concentration of non-soluble and toxic ions in the soil solution. In the context of agricultural problematic soils, acidic soils are soils in which acidity dominates the problems related to agricultural land use. Consequently, the level of Al^{3+} and H^+ becomes too high causing the soil has negatively charged cation exchange capacity to be overwhelmingly blocked with positively charged H^+ and Al^{3+}, and the nutrients needed for plant growth become unavailable resulting into inhibition of root growth and plant development.

Soil acidity does not just consist of H ions in soil solution but is associated with many components of the soil. Soil components include both inorganic constituents and soil organic matter. Active inorganic constituents involved in soil reaction and acidity are the layer silicate clays and mineral oxides. Silicate clays are the sources of permanent negative charge that is the CEC of the soils. They are composed of one layer of Al-oxide and one or two layers of Si-oxide bonded together by a shared layer of oxygen atoms. The negative charge in the crystal lattice of layer silicate clays arises from the isomorpohous substitution of Al^{3+} by Mg^{2+} or Si^{4+} by Al^{3+} leaving a deficit of positive charge or a net negative charge in the crystalline structure of soil pH, that is, the concentration of H ions in soil solution.

Generally, the most important reactions from the standpoint of crop production are those dealing with solubility of compounds or materials in soils. In this regard, we are most concerned with the effects of soil pH on the availability of toxic elements as Al and Mn are the major causes for crop failure in acid soils. These elements are a problem in acid soils because they are more soluble at low pH.

In other words, more of the solid form of these elements will dissolve in water when the pH is acid. There is always a lot of Al present in soils because it is a part of most clay particles. Increased acidity is also likely to lead to poor plant growth and water use efficiency because of nutrient deficiencies and imbalance, and or induced Al and Mn toxicity. Because of this major crop like faba bean, did not get essential nutrients, which are valuable for their growth.

Causes of soil acidity

Soil acidification is a complex set of process resulting in the formation of an acid soil. In broadest sense, it is considered as the summation of natural and anthropogenic processes that lower down the pH of soil solution. Inefficient use of nitrogen is one of the causes of soil acidification, followed by the export of alkalinity in produce (Guo *et al.,* 2010). Continuous uses of ammonium-based fertilizers are major contributors to soil acidification where ammonium nitrogen is readily converted to nitrate and hydrogen ions in the soil. Precipitation of acid rain, deposition of sulphur dioxide (SO_2), ammonia (NH_3), nitric acid (HNO_3), continuous application of acidifying fertilizers such as elemental sulphur (S), urea or ammonium (NH_4) salts and the growth of legume crops, removal of basic nutrients through harvest of high yielding crops, root exudates and mineralization of organic matter are the most important cause for soil acidity formation. Therefore, soil acidification is one of the form of land degradation that can be caused by several factors, from the nature of the soil and climatic conditions (mainly rainfall) to anthropogenic factors which are discussed below.

Occurrence of acidic precipitation

Pure rain is usually slightly acid, with a pH of between 5 and 5.6 because of the dissolution of carbon dioxide (CO_2) and the dissociation of the resulting carbonic acid (H_2CO_3). A soil exposed to such rain, but no other acidifying inputs and receiving no lime, would attain the same equilibrium pH as that of the rain. There are, however, very strong localized effects because human activity has increased the acidity of precipitation through emissions of acidifying compounds such as SO_2 and nitrogen oxides from industry and motor vehicles, NH_3 volatilized from manures and fertilizers (RoTAP, 2012).

Mineralization

When microorganisms decompose soil organic matter, they produce CO_2, which dissolves in soil water to form H_2CO_3 in the same way as in rain. Thus, soil and root respiration can result in a large concentration of CO_2 in soil air, but because acidic soil solutions hold very little CO_2, the process is unlikely to cause soil pH to decline below 5 (Bolan *et al.,* 2003).

The decomposition of organic matter produces H^+ ions, which are responsible for acidity (Paul, 2014), but the development of soil acidity from the decomposition of organic matter is insignificant in the short term. Low buffer capacity from clay and organic matter is another source of soil acidity, i.e. contact exchange between exchangeable H^+ on root surfaces and the bases in exchangeable form on soils. Microbial production of nitric and sulfuric acids also occurs, where leaching is limited. The buffering or CEC is related to the amount of clay and organic matter present, the larger the amount, the greater the buffer capacity.

Continuous use acid forming fertilizers and cultivation of legume crops

The most important causes of soil acidification on agricultural soils are the application of ammonium-based fertilizers and urea, elemental S fertilizer and the growth of legume crops without incorporating organic inputs (Tully *et al.,* 2015). Ammonium salts strongly acidify soils through the process of nitrification as follows:

$$NH_4^+ + 2O_2 = NO_3^- + 2H^+ + H_2O \quad \ldots (1)$$

If the nitrate (NO_3^-) is taken up by the crop, there is no net acidification because the NO_3^- takes up protons with it (Marschner, 2012). Acidification only occurs when NH_4^+ is nitrified and the NO_3^- leached. The same is true of urea: there is no net acidification if the crop utilizes the entire N in the urea; acidification only occurs when the urea is converted to NH_4^+, the NH_4^+ nitrified and the NO_3^- leached. In addition, hydrogen is added in the form of ammonia-based fertilizers (NH_4^+), urea-based fertilizers $CO(NH_2)_2$, and proteins (amino acid) in organic fertilizers. Transformation of such sources of N fertilizers into nitrate (NO_3^-) releases hydrogen ions (H^+) to create soil acidity. Besides, N fertiliser increases soil acidity by increasing crop yields, thereby increasing the extent of basic elements being removed. Hence, application of fertilizers containing NH_4^+ to soil can ultimately increase soil acidity and lower pH (Guo *et al.,* 2010). Inefficient use of N is another cause of soil acidification, followed by the export of alkalinity (Guo *et al.,* 2010).

The decline in S deposition noted above has resulted in the need for farmers to apply S containing fertilizer. Inputs of S as elemental S or as SO_2 from the atmosphere produce acidity when they are oxidized as follow:

$$2S + 3O_2 + 2H_2O = 2H_2SO_4 \quad \ldots (2)$$

$$2SO_2 + O_2 + 2H_2O = 2H_2SO_4 \quad \ldots (3)$$

However, SO_4^{2-} produces no acidity because it is not subject to further oxidation. The fixation of atmospheric N_2 by legumes results in the formation of NH_4^+ within the root nodules by nitrogenase enzyme, the uptake of an excess of cations, especially K^+, and therefore a net release of protons to balance the charge (Marschner, 2012).

Removal of basic cations through harvest of high yielding crops

Removal of elements, especially from soils with small reservoir of bases due to the harvest of high yielding crops is responsible for soil acidity. When soils are worked mechanically and crops are grown, the balance is disturbed and the soils become more acid. This is the result of base cations being removed with crops and the simultaneous increase of leaching which takes place when soils are disturbed and worked (Brady and Weil, 2016). Harvest of high-yielding crops plays the most significant role in increasing soil acidity. During growth, crops absorb basic elements such as Ca, Mg, and K to satisfy their nutritional requirements. As crop yields increase, more of these lime-like nutrients are removed from the soil.

Compared to the leaf and stem portions of the plant, grain contains minute amounts of these basic nutrients. Therefore, harvesting high-yielding crops affects soil acidity more than harvesting grain does (Rengel, 2011).

Soil acidifications continues until a balance is reached between removals and replacement of the basic cations such as Ca and Mg that are removed through leaching and crop harvest and replaced due to organic matter decomposition and from weathering of minerals (Regassa and Agegnehu, 2011).

With further increase in rainfall, a point is reached at which the rate of removal of bases exceeds the rate of their liberation from non-exchangeable forms. Hence, wet climates have a greater potential for acidic soils.

Over time, excessive rainfall leaches soluble nutrients such as Ca, Mg and K that prevent soil acidity, which are replaced by Al from the exchange sites (Brady and Weil, 2016)

Nutrient uptake by crops and root exudates

Plant growth and nutrient uptake result in some localized acidification around plant roots through the exudation of acids from the roots. Excluding the particular case of legumes, the contribution of this to bulk soil acidification is small (<10%) when compared with N and S based fertilizer inputs but it has an important influence on the bioavailability of plant nutrients in the rhizosphere (Marschner, 2012).

Effect of soil acidity on availability of plant nutrients

Soil acidity and associated low nutrient availability is the major constraint to crop production on acid soils. One of the detrimental effects of soil acidity is P sorption, which is affected by clay mineralogy, pH, oxides and hydroxides of Fe and Al content of amorphous materials. The mechanism of P sorption is considered to be mainly through replacement of hydroxyl ions on crystal lattices hydrated Fe and Al by phosphate ions (Abebe, 2007).

The P sorption capacity increases with increasing in soil acidity. However, in the case of highly weathered soils, where the dominant minerals are Gibbsite, Goethite, Kaolinite and desilicated amorphous materials, P sorption is high to very high (Sertsu and Ali, 1983). According to Duffera and Robarge (1999), 70–75% of Nitisols in Ethiopian are highly deficient in phosphorus. The solubility and availability of nutrients to plants is closely related to the pH of the soil (Marschner, 2011). Soil acidity converts available soil nutrients into unavailable forms. High soil acidity is related to shortage of available Ca, K, Mg, P and Mo on the one hand (Agegnehu and Sommer, 2000) and excess of soluble Al, Mn and other metallic ions on the other (Rahman *et al.,* 2018).

Soil acidity and Al toxicity limit soil enzyme activities resulting in suppressed microbial mediated nutrient are cycling, that Al toxicity, and a reduced availability of organic matter due to Al and Fe binding may protect a substantial pool of organic carbon from microbial degradation in acidic soils (Kunito *et al.,* 2016). Soil acidity also affects the movement of soil organisms that are important for plant health. If pH of a soil is less than 5.5, phosphate can readily be rendered unavailable to plants as it is the most immobile of the major plant nutrients (Agegnehu and Sommer, 2000), which results in low crop yield. The quantity of P in soil solution needed for optimum growth of crops ranges in between 0.13 and 1.31 kg P ha^{-1} as growing crops absorb about 0.44 kg P ha^{-1} per day. The labile fraction in the topsoil layer is in the range of 65-218 kg P ha^{-1}, which could replenish P in soil solution (Mengel *et al.,* 2001).

Faba bean (*Vicia faba* L.) is among the oldest and the earliest domesticated food legumes in the world, probably in the late Neolithic period (Singh *et al.,* 2013). In Ethiopia faba bean is mainly cultivated in the mid to high altitude areas, characterized with elevations of between 1800 to 3000 m.a.s.l. (Mussa and Gemechu, 2006). Its production is totally rain-fed on Nitisols and Cambisol type of soils and currently on Vertisols (Tadel, 2019). It is an important source of protein for subsistence farmers in the developing countries like Ethiopia (Asnakech *et al.,* 2016). Furthermore, it is a source of cash to the farmers and foreign currency to the country, serves as “break” crop to pests, and restores soil fertility when grown in rotation with cereals and other crops (Tadel, 2019). Despite its diverse benefits and availability of more than 30 high yielding improved varieties, in Ethiopia the national average yield of faba bean is 2.11 t ha^{-1} (CSA, 2017/18) which has remained too poor in production compared to Egypt and United Kingdom 3.47 and 3.83 t ha^{-1}, respectively (FAOSTAT, 2018). Even within the country, currently the average yield of faba bean becomes decreasing due to its susceptibility to biotic and abiotic stresses (soil acidity and others) (Gemechu *et al.,* 2016).

Soil acidity is a serious threat to crop production in Ethiopia that strong soil acidity affects 28 % of the entire country and 43% of the agricultural land mostly in the highlands of Ethiopia mostly in Oromia, Amhara and Southern Nation Nationalities and Peoples region (Tegbaru, 2015). It limits the productivity of legumes in more extent compared to cereals (Fageria *et al.,* 2012). Therefore, improving the productivity of acid soil is major priority as a demand of food and raw materials are increasing rapidly. The use of lime is a potential option for sustainable management soils than other options for restoring soil health and fertility. It is more effective and widespread practice to improve crop yields on acid soils and it make the soil environment better for leguminous plants and associated microorganisms as well as increase concentration of essential nutrients by raising soil pH and precipitating exchangeable aluminum (Kisinyo *et al.,* 2012). Impact assessment of soil acidity on performance of faba bean is very important to design remedial measures. Therefore, this review was done with the objective to assess the impacts of soil acidity on growth performance and yield of faba bean and its management options.

Major Production Constraints of Faba Bean in Ethiopia

Although faba bean has diverse benefits and high production potential, the productivity has remained very low in Ethiopia which is 2.11 t ha^{-1} (CSA, 2017/18) compared to Egypt and United Kingdom 3.47 and 3.83 t ha^{-1}, respectively (FAOSTAT, 2018). The major production constraints that attributed to lower productivity includes biotic and abiotic stresses, coupled with poor crop management practices (Gemechu *et al.,* 2016)

The biotic factors that limits faba bean production include diseases like chocolate spot, rust, black root rot, foot rot and "faba bean gall'', insect pests such as African bollworm, bean bruchids and broad-leaved weeds. Whereas, abiotic factors comprise water logging, moisture stress, soil acidity and poor cultural practices (Gemechu *et al.,* 2016). Among the abiotic factors, soil acidity associated with low nutrient availability is one of the major production constraints of faba bean in the highlands of Ethiopia (Endalkachew *et al.,* 2018 and Mesfin *et al.,* 2019).

Currently it is a worldwide problem and it associated with high availability of Al^{3+} besides the simple matter of low soil pH (Atemkeng *et al.,* 2011). As soils become more acidic, particularly when the soil pH drops below 4.5, it becomes increasingly difficult to produce food crops; because the supply of most plant nutrients decreases while aluminum and a few micronutrients become more soluble and toxic to plants. Moreover, it hinders legume production more than any other crops as it affects the complex nitrogen fixation process (Graham, 1992). As faba bean is acknowledged sensitive to soil acidity and its sensitivity limits the usage of faba bean in some cropping systems. Most legumes prefer at pH > 5.0 at least in a depth of 20cm and layers below 5cm adversely affect root growth, nodulation, plant vigour and N_2-fixation potential (Burns *et al.,* 2017). Faba bean grows best in soils with pH ranging from 6.5 to 9.0 (Jensen *et al.,* 2010) and poorly perform at a pH values of $\leq$ 5 (French and White, 2005). In Ethiopia, lower yield of faba bean (0.68 to 1.03 t ha^{-1}) than national average (1.52 t ha^{-1}) were reported at pH 5.1 on different varieties (Degife and Kiya, 2016). Due to soil acidity a mean yield reductions of 32.34% were recorded on faba bean genotypes at soil pH of 4.49 to 4.96 in the central highlands of Ethiopia (Mesfin, 2019). Several adverse effects such as loss of crop diversity, decline in crop yield, lack of response to N and P fertilizers, and complete failure of crops were reported. For example, growth and yields of faba bean was extremely low, even under application of optimum rate of N fertilizers on acid soils of Anded district (unpublished) due to low pH. Some N-fixing strains of the bacteria do not thrive at pH values below 6, thus pH 6 or above is best for the legumes that require particular strains of bacteria. The pH of soils for best nutrient availability and crop yields is considered to be between 6.0 and 7.0, which is the most preferred range by common field crops (Duncan, 2002). For instance, faba bean yield have shown strong positive relationship with soil pH level since it is sensitive to soil acidity, implying that an ideal soil pH is a prerequisite for attaining optimum yield of the crop, but with the application of other crop management practices.

In general, soil pH is the most important chemical property of the soil, which plays a significant role in plant growth. Soil acidity, at pH 5.5 or lower, can inhibit the growth of sensitive plant species (eg. Faba bean), though it has little effect on insensitive species even at pH lower than 4. Therefore, faba bean grow well on neutral to mildly acid to neutral soils (at pH 6 -7). Poor plant vigour, uneven crop growth, poor nodulation, stunted root growth, persistence of acid-tolerant weeds, increased incidence of diseases and abnormal leaf colors are major symptoms of increased soil acidity on legume crops which may lead to reduced yields (Marschner, 2011).

Management options of soil acidity

Acid soil management is becoming one of the major strategies to achieve food and nutrition security in SSA even it has its own challenge. An in-depth analysis and knowledge are required to design, adopt and scale up a suitable acid soil management approach.

The management of acid soils should aim at improving the production potential by the addition of amendments to correct the acidity and manipulate agricultural practices to obtain optimum crop yields. The soil's acid/alkali balance (measured by pH) is very important in maintaining optimum availability of soil nutrients and minimizing potential toxicities. For example, at a very low soil pH Al may become more soluble and taken up by roots - becoming toxic, P may become unavailable and Ca levels can be low. At high pH, Fe and other micronutrients except Mo becomes unavailable since they are locked up as insoluble hydroxides and carbonates (Somani, 1996).

To improve production and productivity of faba bean in acidic soils, different strategies needs to be implemented: use of acid tolerant genotypes for sustainable production, using appropriate soil management practices, use of integrated biological and appropriate soil management practices such as liming coupled with organic and inorganic nutrient inputs.

Application of Lime

Management of acid soils should aim at improving the production potential of soils by applying amendments to correct the acidity and obtain optimum crop yield. Liming is a major and effective practice to overcome soil acidity constraints and improve crop production on acid soils. According to the finding of Fageria and Baligar (2012) lime is called the foundation of crop production or ''workhorse'' in acid soils. Liming acid soil make the soil environment better for leguminous plants and associated microorganisms as well as increase concentration of essential plant nutrients by raising its pH and precipitating exchangeable aluminum (Kisinyo *et al.,* 2012). Nevertheless, the amount of lime needed to achieve a certain pH depends on soil pH and the buffering capacity of the soil. The buffering capacity is again related to cation exchange capacity of the soil. Soils with a high buffering capacity require larger amounts of lime to increase the pH than soils with a lower buffering capacity (Derib, 2014).

Moreover, lime requirement refers to the amount of lime required to neutralize all or part of the acidity in soil from an initial level to a desired or targeted less acid condition. The target level of soil acidity depends both on the soil and crop type. Thus, neutralization of soil acidity involves not only neutralization of H^+ in soil solution but also all or part of the soil's reserve acidity.

According to the finding of Agegnehu *et al.,* (2006), application of lime at the rates of 1, 3 and 5 t ha^{-1} resulted significantly in linear response with mean faba bean seed yield advantages of 45, 77 and 81% compared with the control (Figure 1). With regard to mitigating Al toxicity, Desalegn *et al.,* (2017) reported that application of 0.55, 1.1, 1.65 and 2.2 t lime ha^{-1} decreased Al^{3+} by 0.88, 1.11, 1.20 and 1.19 mill equivalents per 100g of soil, and increased soil pH by 0.48, 0.71, 0.85 and 1.1 units, respectively. Agegnehu *et al.,* (2006) also indicated that soil pH consistently increased from 4.37 to 5.91 as lime rate increased. Conversely, the exchangeable acidity was significantly reduced from 1.32 to 0.12 cmol (+) kg^{-1} because of lime application. Yield increments showed direct relationship with the soil pH values and inverse relationship with exchangeable acidity, i.e. as the pH increased the yield also increased, but as the exchangeable acidity decreased the yield of faba bean increased and vice versa.

A report on faba bean evaluated with and without lime application on acid soil showed that liming significantly influenced all the growth parameters; particularly pronounced for plant height and pod number.

Application of lime enhances nutrient use efficiency of both P and K, which is reflected by increase in pod number per plant. Thus, application of lime and mineral fertilizers together further increase grain yield (Ouertatani *et al.,* 2011). In general, legumes are more sensitive in soil acidity than cereal crops and the potential yield is obtained in between soil pH values of 5.7 and 7.2 (Mahler *et al.,* 1988). Liming has significantly improved the response of faba bean to P fertilizer application, which is otherwise immobilized due to P fixation in acidic soils (Alemu *et al.,* 2017). For example, Agegnehu *et al.,* (2006) reported that addition of lime at the rates of 1–5 t ha^{-1} resulted in faba bean seed yield increments of 45–81% over the control.

Improving soil organic matter

Enriching soil with organic matter (SOM) is one of the key approaches of current agricultural research and development is to motivate farmers to make better use of organic west resources to enhance fertility, alleviate elemental toxicity and protect the soil (Amede *et al.,* 2021). Green manuring, application of compost, farmyard manure (FYM), biochar and retention of crop residues are the most important organic inputs used to improve soil organic matter content and recycle nutrients to the soil. Studies have shown that organic matter promotes microbial activity, improves soil structure, aeration, nutrient retention and water holding capacity (Agegnehu and Amede, 2017; Amede *et al.,* 2021). Crop residues can recycle nutrients removed from the soil by crops, while green manures contribute substantial amount of N to subsequent crops and at the same time protect the soil against erosion. Use of organic matter in the form of crop residues, green manures, FYM, compost or biochar could also reduce the effects of toxic elements by extracting them from the soil solution and incorporating them into organic compounds (Cornelissen *et al.,* 2018). However when organic inputs are applied, the quality, quantity and types of nutrients supplied by them should be considered as they are bulky.

Table.1 Amount of P sorbed by some Ethiopian soils at the standard solution P of 0.2 ppm.

Soil origin	Soil type	Sorbed P		pH	Fe_2O_3 (%)	Exch.Al (cmol(+)kg^{-1})	Amorphous material (%)	Gibbsite and Goethite (%)
		mg kg^{-1}	kg ha^{-1}					
Chencha	Alisol	1200	2400	4.5	11.7	0.40	51	10
Nedjo	Nitisol	950	1900	4.4	16.1	6.16	32	12
Indibir	Nitisol	800	1600	4.8	11.7	1.69	61	0
Melko	Nitisol	600	1200	5.2	15.8	0.37	ND	ND
Bako	Nitisol	400	900	6.6	14.4	0.02	41	15
Melkassa	Andosol	150	300	7.8	0.20	Trace	ND	ND

Source: Regassa and Agegnehu (2011), ND: Not determined.

Figure.1 Faba bean mean seed yield as influenced by application of lime in the form of calcium carbonate at Holleta (1998-2000) (Source: Agegnehu *et al.,* (2006).

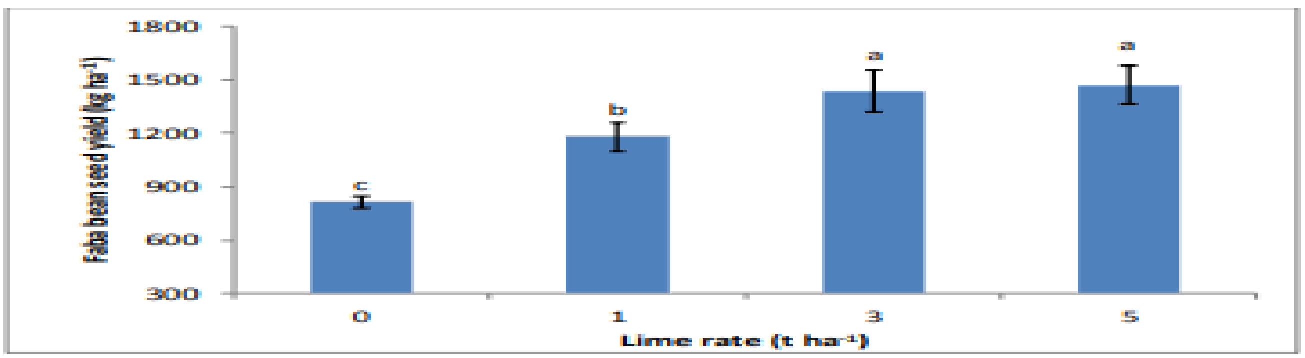

Figure.2 Growth performance of faba bean under limed and un-limed condition on acidic soils.

Integrated soil fertility management options (ISFM)

Integrated soil fertility management (ISFM) is an approach that has viable agricultural practices sufficient for sustainable production in agriculture that is adapted to local conditions to utilize efficiency water use and supply of nutrients as well as improved agricultural productivity. It is one of the approaches to manage and improve soil health and fertility status (Agegnehu and Amede, 2017) which is one of the component to manage acid soils.

Farmyard manure and crop residues are among organic plant nutrient sources, which could ameliorate the physical and chemical properties of soils. For example, Lal (2009) indicated that returning crop residues to soil as amendments is essential for recycling plant nutrients (20–60 kg of N, P, K, Ca per Mg of crop residues) amounting to 118 million Mg of N, P, K in residues produced annually in the world (83.5% of world's fertilizer consumption). In acid soils, where P fixation is a problem application of FYM releases a range of organic acids that can form stable complexes with Al and

Fe thereby blocking the P retention sites, and as a result, the availability and use efficiency of P is improved (Agegnehu and Amede, 2017).

Management of acid soils through integrated soil fertility and plant nutrient management not only improve the yields of crops but also the chemical properties of soils. Regular applications of organic residues can induce a long-term increase in SOM and nutrient content.

According to Haynes and Mokolobate (2001), complexation of Al by the newly formed organic matter tends to reduce the concentrations of exchangeable and soluble Al. As organic residues decompose, P is released and can be adsorbed to oxide surfaces. This can reduce the extent of adsorption of subsequently added P thus increasing P availability.

The practical implication of these processes is that organic residues may be used as a strategic tool to reduce the rates of lime and fertilizer P required for optimum crop production on acidic, P-fixing soils. Agegnehu and Bekele (2005b) found that the application of 4 and 8 t FYM ha^{-1} with 26 kg P ha^{-1} on acid Nitisols of Holleta, Ethiopia, increased faba bean seed yield by 97 and 104%, respectively, compared to the control. The same rates increased soil pH from 4.5-5.0, N from 0.09-0.15%, P from 4.2-6.0 mg kg^{-1}, and K, Ca and Mg from 1.25-1.45, 4.77-7.29 and 0.83-1.69 cmol (+) kg^{-1}, respectively.

Use of soil acidity tolerant crops

Over the past decade, several researchers around the world have focused their efforts on identifying and characterizing the mechanisms employed by crop plants that enable them to tolerate Al toxic levels in acid soils. The two distinct classes of Al tolerance mechanisms are those that operate to exclude Al from the root apex and those that allow the plant to tolerate Al accumulation in the root and shoot symplasm (Kochian *et al.,* 2004).

Although there has been considerable speculation about a number of different Al tolerance mechanisms, most of the experimental evidence has focused on root Al exclusion based on Al-activated organic acid (OA) exudation from the root apex. The use of acid tolerant crops is a low cost input that is easily adopted and can often change the cost portion to value more favorable for initiating lime use.

Study on soil acidity stress tolerance on faba bean is scanty. Nevertheless, wide diversity exists among faba bean landraces for agro-ecological adaptation (French and White, 2005), for biotic and abiotic stress resistance (Khazaei *et al.,* 2013). So far in Ethiopia lime based managements of acid soil were conducted in different location with different legume crops soybean (Workneh, 2013), haricot bean (Adane, 2014) and faba bean (Endalkachew *et al.,* 2018). These authors reported that, the limitation of lime application with its wider utility is that the amount of lime needed per hectare is in tons and the cost is not affordable by small-scale farmers.

The use of acid tolerant varieties remains the first option and low cost if the use of lime is beyond the reach of smallholder farmers. Therefore, use of soil acidity tolerant crops in acid prone areas is eco-friendly and economically feasible alternative when considered as a management option.

Previous efforts to identify soil acidity tolerant faba bean genotypes showed that, there were great variation among genotypes with acidity tolerance level ranging from 3 % to 40 % hindrance in taproot growth at pH 4.5 (Kiflemariam *et al.,* 2017). This information indicates the need to evaluate faba bean genotypes for soil acidity stress tolerance and the chance of getting tolerant genotypes from existing genetic resources.

Therefore, in areas where soil acidity is a problem, faba bean production can be increased by growing adapted genotypes to acid soil condition in circumstances where other soil amendment strategies are not readily practical.

Conclusion

Nowadays soil acidity and associated low nutrient availability are among the major constraints to agricultural productivity in the highlands of Ethiopia. Ethiopian population is increasing while cultivated land is shrinking due to urbanization and low soil fertility.

Thus, to feed the ever-increasing population it needs transformation in the field of agriculture in either using modern technologies or using marginal areas like soil acidity prone areas.

Thus, improving the productivity of acid soil is a major priority as a demand of food and raw materials are increasing rapidly. Lime application is a potential option for sustainable soil managements than other options for restoring soil health and fertility despite the high amount of lime required and unaffordable cost for low-income farmers.

However, application of lime should be considered as an approach to optimize soil pH and nutrient availability for better plant growth and yield. Liming should be combined with the applications of optimum rates of inorganic and organic fertilizers inputs. There is also a need for identifying areas where lime application brings significant change and benefit in crop yield.

The extent of soil acidification can also be mitigated through integrated soil and crop management practices. Integrated soil fertility management approach can enhance soil fertility and crop yield. Application of organic residues enhances buildup of nutrients in the soil and after successive years of application, the dose of nutrients to be applied as inorganic or organic forms will gradually decrease. Matching applied nitrogen and sulfur with crop needs may also reduce input costs while reducing acidification.

In general conserving soil health in a sustainable way is the basis of the productivity of farming systems, the food and nutrition security of ever-increasing population, and the improvement of livelihoods and poverty alleviation in Ethiopia. It needs strategic research, integrating soil and water management with improved crop varieties to generate prototypes and environmentally friendly technologies for sustainable crop production.

Conflict of interest

The author declares that there is no conflict of interest.

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