Ethiop. J. Agric. Sci. 31(2) 13-31 (2021)

Evaluation of Different Agricultural Lime Sources for their Agronomic Effectiveness, Yield of Food Barley and Faba Bean and Acid Soil Properties in the Central Highlands of Ethiopia

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Abstract

The potentials of lime to restore soil health and fertility of the acidic soils is one of the best options of sustainable soil fertility management practices. However, the liming effects depend on its source, composition, purity, and fineness. The study initiated to evaluate the effectiveness of different lime materials produced in Ethiopia. Lime samples collected from different producing factories and were characterized at Holeta Agricultural Research Centre. Following characterization on station and on-farm experiments were conducted to evaluate crop and soil response for the different lime sources. The treatments comprised of four different lime materials and control laid out in randomized complete block design with three replications. The result showed that all lime sources fulfill the standards of agricultural lime. The result also showed that there were significant differences between and among lime sources on soil properties as well as crop yield but highly *significant between the control treatments. This implies that the lime materials can be suitably used nationally to ameliorate soil acidity and increase crop productivity. Thus, the resource-poor farmers dwelling in western, north western, and central highlands who cannot afford to transport the lime sources from far distances can make use of the lime sources near to areas as there is no significant difference.*

Keywords: Agricultural lime, Lime quality, Neutralizing value, pH, Soil acidity**.**

Introduction

In Ethiopia agricultural productivity remains critically low due to several factors which are largely attributed to low and declining soil fertility exacerbated by factors such as soil acidity, soil erosion, continuous cropping and inadequate sustainable soil fertility management (Van Straaten, 2002, Kiiya *et* al., 2006, Crawford and US, 2008).

Soil acidity is caused by high rainfall which exceeds evapotranspiration that cause leaching of basic cations, hence many soils in high rainfall areas is inherently acidic. In addition, the decay of acidic parent materials and organic matter also contributes for soil acidification (Havlin *et al.,* 2005). Soil acidification is a slow process but accelerated by agricultural activity through the use of some acidifying fertilizers, removal basic cations in harvested crop (Fageria and Baligar, 2008).

Several research reports indicated that soil acidity can be easily corrected by liming to increase crop yields of barley (Getachew *et al.,* 2017; Temesgen *et al.,* 2016); potato (Geremew *et al.,* 2015) bread wheat (Mekonen *et al*., 2014), soybean (Derib, 2019). Lime ($CaCO_3$ or its equivalent) is widely known as the effective ameliorant for correcting soil acidity (Anetor and Ezekie, 2007). Although not permanent, the direct effect of lime lasts longer than any other amendment (Fageria and Baligar, 2008), such as organic materials (Osundwa *et al.*, 2013).

Hence, lime application is the most commonly and widely used method to overcome the problem of tropical acid soil infertility worldwide (Osundwa *et al.,* 2013). Its great ameliorative effect makes lime the foundation of crop production in acid soils (Fageria and Baligar, 2008). A farmer in west Wollega, Nedjo area used lime to his teff field on acidic Nitisol observed the improvement of crop yield and called lime used for acidified soil as a remedy 'Anaan', meaning milk in 'afaan oromo', and witnessed on a field day organized in 2014 (personal communication).

Application of lime to acidic soils reduced soil exchangeable acidity, increased soil pH and available phosphorus (Temesgen *et al*.,2016, Geremew *et al*., 2020), raises base saturation, and Ca and Mg contents, (Fageria, and Baligar, 2008; Álvarez *et al.*, 2009), decreases Al^{3+} in the soil solution as well as in the exchange complex (Delhaize *et al.*, 2007; Álvarez *et al.*, 2009), improves soil structure (Crawford and US, 2008; Osundwa *et al.*, 2013), increases yield (Buri *et al.*, 2005; Fageria and Baligar, 2008, and Geremew *et al*., 2020), resulting in increased available P, and p up take and use efficiency (Osundwa *et al.*, 2013 and Geremew *et al*., 2020). Lime application enhances abundances and diversity of earthworms (Bishop, 2003); and improved OM decomposition and nutrient mineralization (Bradford *et al.*, 2002).

However, quality of liming material is very important characteristics in correcting soil acidity. The source of lime, chemical composition, its fineness and the purity of lime are extremely crucial for effective use of lime (Kemperl and Maček 2009). The efficiency of liming material is determined by its acid neutralising potential, fineness factors of the various particle size fractions, effective neutralizing value (ENV) and its effective calcium carbonate equivalence (ECCE) (Foth and Ellis 1996; Synder and Leep 2007). The materials may differ in neutralizing power and nutrient or other elements associated with the liming agent. The main factors indicating lime quality used were purity and particle size distribution as indicated by (Scott *et al*, 1992).

Chemical and physical properties of agricultural lime quality can vary tremendously depending on the chemical properties and particle size caused by physical grinding of the stone. The chemical characteristic, assessed as percent calcium carbonate equivalence, and the physical as the size of the particles, finally combined into one value that quantifies the effectiveness of the limestone. This value is known as the relative neutralizing value (RNV) which is calculated using the lime purity value (CCE) and fineness value.

Currently, a variety of liming materials are available in Ethiopia. The materials differ in place of origin and parent material they were made from, and the quality of the grinding machine; hence, they may differ with neutralizing power, fineness, nutrients and/or other elements associated with the liming materials. All crushers planted by Ministry of Agriculture (MoA) at different Regional National States produces an excellent fineness quality (Farina, 2011) but, no characterization was done about their elemental content and quality parameters. Knowledge on the effectiveness of various lime sources in correcting soil acidity is lacking due to limited/no previous studies conducted in this area. In view of filling up this technical gap, this experiment was executed to investigate the agronomic effectiveness of the different lime sources, and their effect on yield of food barley and faba bean grown on acid soils in central high lands of Ethiopia.

Materials and Methods

Site description

The study was conducted in Welmera districts at two locations on acidic fields; research field of Holeta Agricultural Research Centre (HARC), situated at 9^0 3.546' N latitude and 38^o 30.36' E longitude at an altitude of 2281 meter above sea level (masl) and farmers' field at Robgebeya which situated 9^o 7.928' N latitude and 38^o 26.670' E longitude at an altitude of 2622 masl.

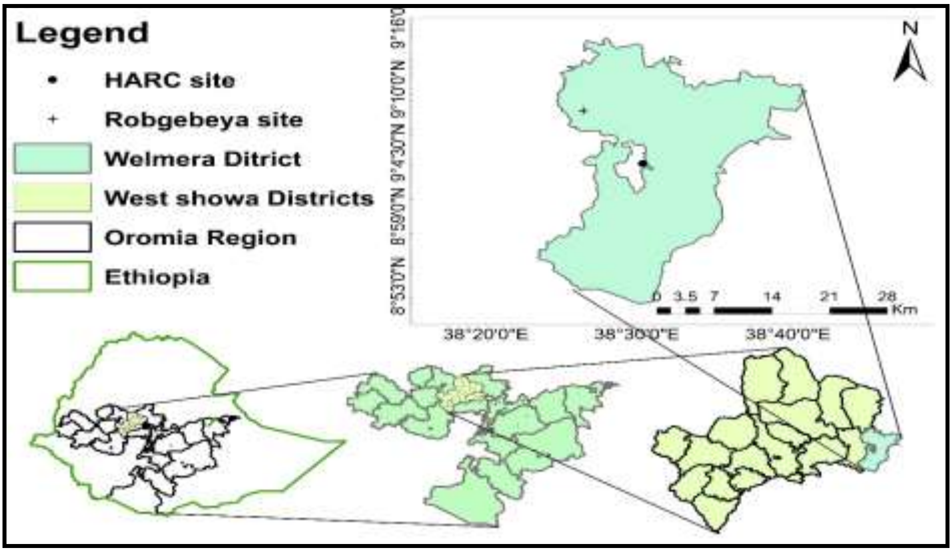

Figure 1. Location map of the Study Area (HARC and Robgebeya)

The average, annual rainfall was about 1100 mm with a peak in July and mean annual temperature fall between 16.06^oc and 22.18 ^{o}c. Soils in HARC are expected to be under human influence for not less than 6 decades. In HARC station where this experiment was executed is a red Nitisol. Farming system practiced at HARC is mostly small seeded cereals with pulse/oil/potato crop rotation. Similarly, a soil of Robgebeya a red Nitisol and the farming system is typically cereal with pulses/oil crop rotation.

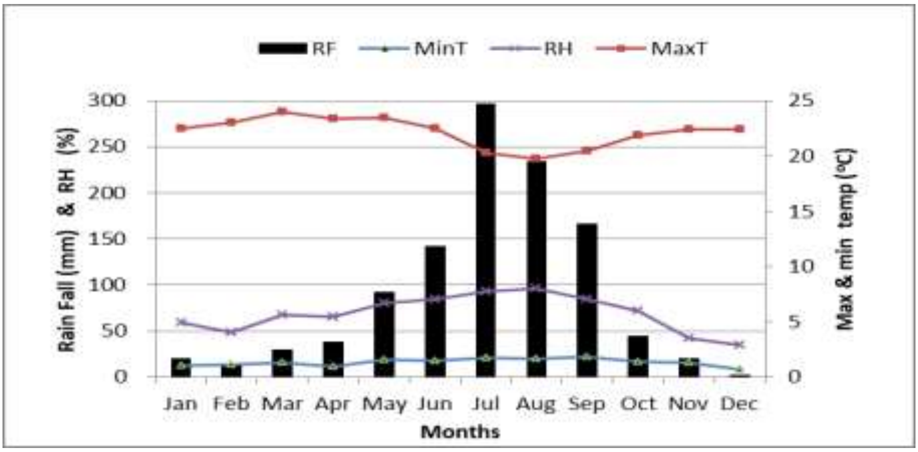

Figure 2: Monthly rainfall, Relative humidity and minimum and maximum temperature during crop growing seasons at Holeta Agricultural Research Centre (2014-2016).

Characterization of Liming Materials and their Quality Parameters

Lime materials collection

The lime materials were collected from the existing lime crushing industries found in Ethiopia. Awash calcite and Awash dolomite from Awash 7 kilo "MEDROC company" lime factory", Senkele lime from Guder area (Oromia Regional National State) and Dejen lime from Gojam (Amhara Regional National State). The lime materials were packed and taken to Holeta Agricultural Research Center laboratory for physical and chemical analysis.

Determination of Calcium Carbonate Equivalence

Calcium Carbonate equivalence (CCE) of lime materials was determined as described by Effiong *et al*. (2009) and percentage CCE was calculated as:

$$CCE(\%) = 2.5\left(\frac{VHCL - VNaOH}{2 * Tv}\right) x\ 100 \qquad (1)$$

where: Tv - total volume of aliquot

Fineness

Fineness was determined as described by (Conyers *et al.*, 1995) and its percentage was calculated as:

$$Pass\ 10\ mesh\ P1\ (\%) = \frac{Mp1}{Wts} x\ 100 \qquad (2)$$

$$Pass\ 50\ mesh\ P2\ (\%) = \frac{Mp2}{Wts} x\ 100 \quad (3)$$

$$Pass\ 100\ mesh\ P3\ (\%) = \frac{Mp3}{Wts} x\ 100 \quad (4)$$

$$Fineness\ (\%) = \frac{P1+P2+P3}{3} \quad (5)$$

where: Mp1-mass pass through 10 mesh, Mp2-mass pass through 50 mesh, Mp3-mass pass through 100 mesh

Determination of Relative Neutralizing Value

The relative neutralizing value (RNV) was determined from CCE and the fineness % using the formula;

$$\text{RNV} = \frac{CCE}{100} * Fineness\ \% \quad (6)$$

Determination of Calcium Carbonate

The lime; calcium carbonate ($CaCO_3$), was determined as described by Jackson, 1970 and percentage $CaCO_3$ was calculated as:

$$\text{CaCO3}\ (\%) = \text{MNaOH}\ \left(\frac{(\text{a}-\text{b}) * 50 * \text{mcf}}{\text{Weight of sample (g)}}\right) \quad (7)$$

Where: a-blank, b-sample used for back titration, mcf-moisture correction factor, M-morality NaOH, 50- equivalent weight of $CaCO_3$.

Determination of total Calcium and Magnesium in Lime materials

The lime materials were analysed for their chemical composition by wet acid digestion procedure allowed for the determination of calcium (Ca) and magnesium (Mg) oxide contents, and subsequently their acid neutralizing values, in terms of calcium carbonate equivalent as described by (FAO-UNDP, 1979).

Total Ca and Mg content were calculated as:

$$\text{Total (Ca / Mg)}(\%) = \frac{(\text{R}-\text{B}) * \text{Tv} * \text{Df}}{\text{Wt} * 10{,}000} \quad (8)$$

Where: R-sample reading, B-blank reading, Df- dilution factor, Wt-weight of sample, Tv-total volume of the extracted sample.

Determination of available phosphorus in lime materials

Available phosphorus was determined by Olsen and Sommers, (1982) extraction method.

Experimental Design, Procedure and Treatment Set up

At both sites, the experiment was conducted on fixed plots with lime applied in the 1st year of the experiment. The experiment was laid out in randomised complete block design (RCBD) in three replications. The treatments were four lime materials (Dejen lime, Awash Dolomite ($CaMg(CO_3)_2$), Awash Calcite ($CaCO_3$), Senkele lime and control). For all lime materials, the amount of lime to be applied was calculated on the basis of the exchangeable acidity, bulk density and 15 cm plough depth (equation 9). It was assumed that one mole of exchangeable acidity would be neutralized by an equivalent mole of $CaCO_3$ (adopted from Kamprath, 1984).

$$LR, CaCO_3 (kg / ha) = \frac{cmolEA / kg \ of \ soil * 0.15 \ m * 10^4 \ m^2 * B.D.(Mg / m^3) * 1000}{2000} \quad (9)$$

Where: LR- Lime requirement; EA- Exchangeable acidity; B.D- Bulk density
The experimental plot size used was 3*4 m^2. The lime rates were adjusted to their respective 100 % calcium carbonate equivalence, the amount of lime treatments received at HARC and Robgebeya were Dejen lime 1535.62 and 2094.10 g per $12m^2$, Awash dolomite 1545.27and 2107.18 g per $12m^2$, Awash calcite 1554.30 and 2119.53 g per $12m^2$ and Senkele lime 1616.23 and 2203.96 g per $12m^2$, respectively. Land preparation, planting, weeding and harvesting were undertaken according to the crop agronomic requirement.

Lime was broadcasted uniformly by hand and incorporated into the soil a month before planting ones at the beginning of the experiment. The amount of lime applied per plot was calculated on the basis of the exchangeable acidity. Urea and Di-ammonium Phosphate (DAP) were used as the source of N and P fertilizers. The recommended rate of nitrogen (72 kg ha^{-1}) and phosphorus (P_2O_5 150 kg ha^{-1}) fertilizers was applied uniformly to all treatments. Urea split application was done for barley and DAP was applied at planting for both test crops. The test crops were barley *(Hordeum vulgare L.)* variety HB 1307 and faba bean *(Vicia faba L.)* variety Dosha. Crop data on yield and yield components were collected following each crop agronomic data measurement procedures.

Soil sampling and analysis

Before the execution of the experiment a representative soil samples were taken from each experimental field randomly and composited to one sample for soil characterization. Treatment based composite soil samples were collected after two- and three-years harvest from HARC and Robgebeya respectively. The collected soil samples were analysed for their selected chemical properties (pH, total N, available P (Pav.), Soil Organic carbon (SOC), cation exchange capacity (CEC), exchangeable cations (Ca. Mg, K, Na), exchangeable acidity (Al^{+3} + H^+), Al and extractable Zn, Cu, Fe, and Mn. The pH of the soil is determined with the potentiometric method (1:2.5 Soil: Water) as described by Chopra and Kanwar (1976). Available phosphorus was determined following Bray II procedure (Bray and Kurtz, 1945). Soil OC was determined as described by Walkley-Black (1934) while TN was determined the Kjeldahl method (Rainst *et al.*, 1999). Exchangeable acidity (Al^{+3} and H^{+1}) and exchangeable Al were determined by saturating the soil samples with 1N KCl solution and the filtrate was titrated with 0.02N NaOH and 0.02N HCl, respectively, as described by Rowell (1994).

Data analysis

Analysis of variance (ANOVA) was done using statistical analysis software (SAS, 2004) and means were compared using least significant difference (LSD).

Results and Discussions

Characterization of different lime materials produced in Ethiopia

The physico-chemical properties of liming materials were indicated in Table 1. The reaction of Dejen lime, Awash calcite and Awash dolomite were strongly alkaline, while lime from Senkele was very strongly alkaline. Both Awash limes (calcite and dolomite) had showed better P content while the P content of Senkele lime was trace. All lime materials have nearly equal percent of $CaCO_3$. All lime materials have above 90% calcium carbonate equivalent (CCE) and this indicated that at least 90% of the material could dissolve and neutralize soil acidity. This finding is in agreement with the report of (University of Kentucky College of Agriculture, 1960*)* which reported the minimum CCE to qualify as ground agricultural limestone is 80%. This means that at least 80% of the material could dissolve and neutralize soil acidity.

Dejen lime has better fineness percentage (92.41 microns) while Senkele lime has the least fineness percentage (86.91 microns). This finding is in agreement with the report of (Conyers et al., 1995) who reported that particle size analysis on limestone's undertaken using dry sieves do not extend reliably to < 50 micron or 0.05 mm. Awash calcite has better Ca content than the other lime materials. Awash dolomite has better Mg content while Senkele lime has less Mg content. Senkele lime had less relative neutralizing value (79.57%) when compared with other lime materials. Similar finding was reported by (Soil Survey Division Staff, 1993).

Lime as a soil conditioner, improves some acid soil parameters, hence, it is recommended to use these lime materials along with recommended fertilizers in order to attain optimum grain yield. All Lime materials have high alkaline concentration, hence showed high pH and this benefited to attain and maintain a suitable soil pH for the growth of crop. These lime materials have nearly equal percent $CaCo_3$, CCE and fineness, hence they might have equivalent capacity to enhance the physical, chemical and biological properties of soil through its direct effect on the amelioration of soil acidity and its indirect effect on the mobilization of plant nutrients (P, Ca and Mg) and immobilization of toxic heavy metals (Al, Mn and Fe) as reported by (Ligeyo and Gudu, 2005).

Table 1. Characterization of different lime materials produced in Ethiopia

No.	Lime type	Parameters							
		pH	Pav (ppm)	% $CaCO_3$	% CCE	Fineness (micron)	% RNV	% Ca	% Mg
1	Dejen lime	8.7	3.12	11.90	96.70	92.41	89.36	37.58	0.75
2	Awash – Dolomite	9.0	4.62	11.79	96.10	87.31	83.31	13.96	4.10
3	Awash-Calcite	8.5	4.34	11.82	95.54	89.56	85.57	40.29	0.57
4	Senkele lime	10.0	0.0	11.68	91.88	86.91	79.57	22.22	0.29

Pav - available phosphorous, %CCE- percent calcium carbonate equivalent, %RNV - percent neutralizing value

Soil chemical properties before planting and after harvest

The nutrient content of initial soil samples analysed for the study sites are indicated in Table 2. Soil from HARC was very strongly acidic while Robgebeya soil was strongly acidic. Available P of HARC and Robgebeya was very low and medium respectively as rated by Jones (2003). Total nitrogen content of both sites soil was high (Tekalign, 1991). Calcium content of both sites soil was medium according to (FAO, 2006). The soil magnesium content of HARC and Robgebeya was medium and low respectively; based on FAO (FAO, 2006). Similarly, potassium content of both sites was high FAO (FAO, 2006). According to Jones, (2003) the micronutrient (Cu, Zn, Fe and Mn) at both sites falls in the range of medium to high.

Table 2. Soil chemical properties before application of lime

Site	**pH**	**EA**	**Al**	**P**	**N**	**OC**	**CEC**	**Ca**	**Mg**	**K**	**Cu**	**Fe**	**Zn**	**Mn**
HARC	4.43	1.1	0.54	6.23	0.15	1.36	19.57	6.4	1.17	1.21	3.01	44.16	0.6	47.5
RG	4.5	1.5	0.89	17.95	0.2	2.09	17.25	5.26	0.56	1.03	3.19	96.7	2.25	2.2

HARC- Holeta Agricultural Research Centre, RG- Robgebeya, EA-exchangeable acidity

Soil pH, Exchangeable Acidity and Exchangeable Aluminium

Soil pH, exchangeable acidity and exchangeable Al which are used as diagnostic tools for the prediction of Al toxicity have been grouped together for both sites and their result after final crop harvest were presented in Figures 3a and3b.

At HARC site soil initial pH was extremely acidic (4.43) and was improved to very strongly acidic (4.83 and 4.84) after application of Senkele lime and Awash dolomite, respectively. Exchangeable acidity was 1.1 $cmol_{(+)}$ kg^{-1}soil before lime application and improved to 0.56 $cmol_{(+)}$ kg^{-1}soil after the application of Awash dolomite. Similarly, it decreased Al content of the soil from 0.54 to 0.3 $cmol_{(+)}$ kg^{-1}soil.

At Robgebeya site all lime materials brought insignificant pH improvement. Exchangeable acidity was 1.5 $cmol_{(+)}kg^{-1}$soil before lime application and improved to 1.05 $cmol_{(+)}kg^{-1}$soil and 1.10 $cmol_{(+)}kg^{-1}$soil after the application of Awash calcite and Awash dolomite respectively. This shows that all lime materials reduced Al concentration in small range.

The raise of soil pH and decline of the soil exchangeable acidity might be due to reduction in Al^{+3} and H^{+} ions concentration in the soil solution by buffering ability of applied lime. In other saying, application of lime increases the replacement of Al by Ca in the exchange site and by the subsequent precipitation of Al as $Al(OH)_3$. This finding is in agreement with the report of many authors (Caires *et al.*, 2008, Sadiq and Babagana, 2012, Chimdi *et al.*, 2012) who reported the increase of soil pH after lime application and the reduction of exchangeable Al and Aluminium saturation to adequate levels following application of lime in acidic soil.

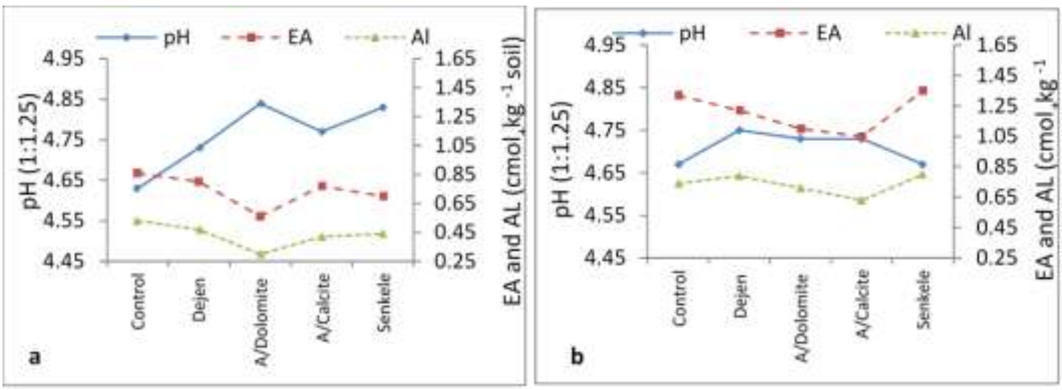

Figure 3. Influence of lime application on soil pH, exchangeable acidity and aluminium content of the soils at HARC (a) and Robgebeya (b) sites.

Available Phosphorus, Total Nitrogen and Organic Carbon

Soil chemical properties such as total nitrogen, available P and OC after lime treatment are presented in Figure 4. At HARC phosphorus content of the soil was improved from 6.23 to 13.71 ppm with application of Awash calcite. Similarly, at Robgebeya phosphorus content of the soil was improved from 17.95 to 20.01 ppm with Awash dolomite. Hence, at both sites P fixed by Al/Fe was released by calcite and dolomite. This finding is in agreement with the report of (Fageria *et al*., 2007) which indicated that liming acid soil increases soil pH, thus increases soil phosphorus due to release of P ions from Al/ Fe oxides, which are responsible for P fixation. At both sites (HARC and Robgebeya) total N and organic carbon content of the soil never showed a significant difference among treatments.

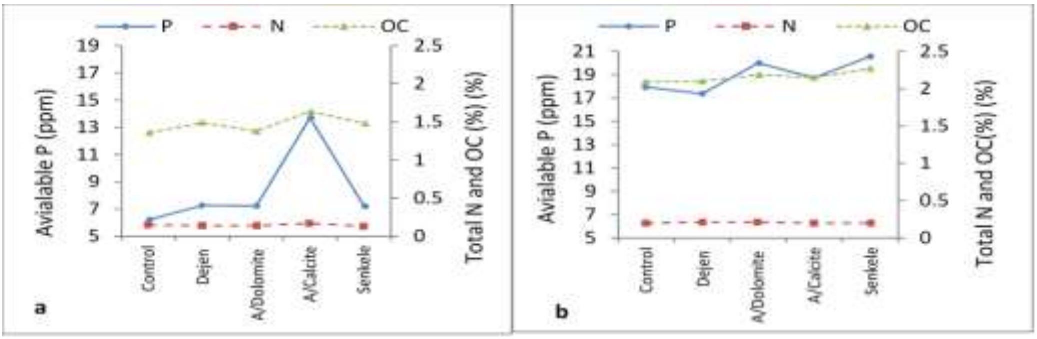

Figure 4. Influence of lime application on soil available P, total N and organic C content of the soils HARC (a) and Robgebeya (b) sites.

Exchangeable Bases (Ca, Mg and K) and Cation Exchange Capacity

At HARC initial Ca content of the soil was 6.40 $cmol_{(+)}kg^{-1}$soil, and after treatment of the soil with lime materials showed a very small improvement in Ca content. At Robgebeya site the initial Ca content of the soil was 5.26 $cmol_{(+)}$ kg^{-1}soil, and it was improved to 8.44 $cmol_{(+)}$ kg^{-1} soil with application of Dejen lime. Exchangeable Ca increment due to liming could be attributed to the precipitation of Al ions and the deprotonation of the Al-hydroxyl groups by the added base (Ca) and the subsequent increase in the negative charges in the soil exchange complex that retain nutrient cations. In line with this, Ligeyo and Gudu, (2005); Brown and Stecke, (2003) pointed out that lime increases Ca and Mg availability in acidic soils.

At HARC initial Mg content of the soil was 1.17 $cmol_{(+)}kg^{-1}$soil and it was improved to 1.56 $cmol_{(+)}kg^{-1}$soil after the application of Awash dolomite. At Robgebeya the initial Mg content of the soil was 0.56 $cmol_{(+)}kg^{-1}$soil and improved to 0.65 $cmol_{(+)}kg^{-1}$soil after the application of Awash dolomite. This Mg content improvement at both sites was due to Mg content of the dolomite lime ($CaMg(CO_3)_2$). It could be generalized as lime application to the acidic soils increases soil pH, calcium and magnesium content of the soil. This finding is in agreement with the report of (Anetor and Akinrinde, 2006).

At HARC initial K content of the soil was 1.21 $cmol_{(+)}kg^{-1}$soil and improved to 1.67 $cmol_{(+)}kg^{-1}$soil after the application of Dejen lime. On the other hand, at Robgebeya the K content of the soil never showed an improvement among treatments. At both sites, CEC of the soil never showed a significant difference among treatments. The probable reason for this condition was all lime materials might have nearly equal mineralogical content to act on soil CEC.

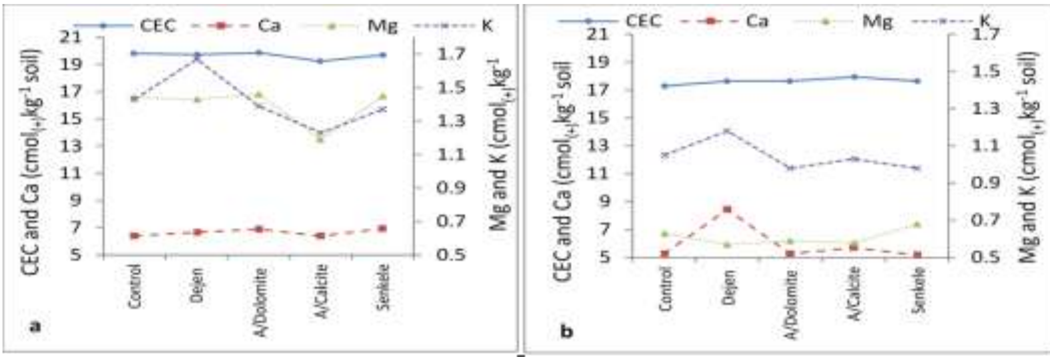

Figure 5. Influence of lime application on Calcium, Magnesium, Potassium and Cation Exchange Capacity of the soils HARC (a) and Robgebeya (b) sites.

Micro nutrients (Fe, Mn, Cu and Zn)

Though occurring in soil in small amounts than major plant nutrient, micronutrients are equally essential for crop growth. Micro nutrient (Fe, Mn, Cu and Zn) analysed after the third-year final crop harvest were presented on Figure 6. At both sites, all lime materials never showed a significant improvement in micronutrients contents even but a decreasing tendency was observed after lime application. The reduction in the concentrations of Fe, Mn, and Zn with increasing rates of liming could be attributed to the reduction of their solubility due to increase in soil pH, as was also reported by Havlin et al. (1999).

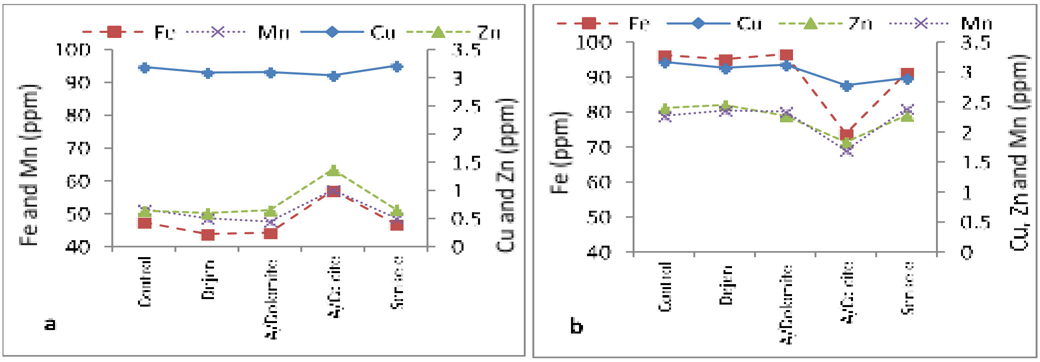

Figure 6. Influence of lime application on Micronutrient content of the soils HARC (a) and Robgebeya (b) sites.

The effect of all lime materials on acidic soil properties such as pH, exchangeable acidity and exchangeable aluminium, available phosphorus, total nitrogen and organic carbon, calcium, magnesium, potassium and CEC and micronutrients never showed variation. This might be because, all lime sources had nearly comparable values of percent $CaCO_3$, CCE, fineness and RNV.

Effect of Lime Materials on Yield and Yield Components of Food Barely and Faba Bean

In the first year (2014) the experiment was conducted only at Robgebeya on farmers' field, and all agronomic parameters (plant height, spike length, spikelet per spike, biomass, grain yield, hector litre weight and thousand seed weight never showed significant difference among lime materials, but Awash calcite gave better grain yield (87.7%) over the control (Table 3). In the third year (2016), at Robgebeya a comparable grain yield was recorded among lime materials, but Awash dolomite and Dejen lime gave comparatively better grain yield (64%) and (63.5%) respectively; than the control treatment (Table 3).

The over year combined analysis (2014 and 2016) of an experiment conducted at Robgebeya showed no significant ($P \leq 0.05$) yield difference among lime materials, except when compared with the control treatment that has no lime (Table 3).

Table 3. Mean yield of food barley as affected by different lime materials at Robgebeya

Treatment	*2014*		*2016*		*Combined*	
	Biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Biomass (kg ha^{-1})	Grain yield (kg ha^{-1})
Control	12133 ^{b}	3453.6 ^{b}	5897.4 ^{b}	2227.1 ^{b}	9015.2 ^{b}	2840.3 ^{b}
Dejen lime	17000 ^{a}	6245.4 ^{a}	8389.0 ^{a}	3642.5 ^{a}	12694.5 ^{a}	4943.9 ^{a}
Awash dolomite	16633 ^{a}	6279.0 ^{a}	8537.0 ^{a}	3653.6 ^{a}	12585 ^{a}	4966.3 ^{a}
Awash calcite	17067 ^{a}	6483.6 ^{a}	8019.0 ^{ab}	3582.5 ^{a}	12543 ^{a}	5033 ^{a}
Senkele	17433 ^{a}	6126.3 ^{a}	7796.0 ^{ab}	3420.1 ^{a}	12614.5 ^{a}	4773.2 ^{a}
Mean	**16053.3**	**5717.6**	**7727.6**	**3305.1**	**11890.5**	**4511.3**
CV (%)	**7.8**	**7.2**	**15.7**	**15. 8**	**11.7**	**11.5**

In 2015, at Robgebeya faba bean was sown to maintain the crop rotation pattern; and from the result some parameters (seeds/pod, biomass, grain yield, hectolitre weight and thousand seed weight) showed no significant ($P\leq0.05$) difference among lime materials, but Awash dolomite gave a slightly better stand count at harvest (34%), grain yield (246%) and biomass (143%) than the control treatment (Table 4).

Table 4. Mean yield of faba bean as affected by different lime materials at Robgebeya, 2015

Treatment	PLHT (cm)	PPP	Spp	No stands	BM (kg ha^{-1})	GY (kg ha^{-1})	HLW (%)	TSW (g)
Control	72.7^{b}	5.3	1.5^{b}	217.7^{c}	1456.0^{b}	622.1^{b}	68.9^{b}	539.8^{b}
Dejen lime	100.1^{a}	10.5^{a}	2.7^{a}	286.6^{ab}	3410.0^{a}	2013.4^{a}	79.1^{a}	680.0^{a}
A/ dolomite	96.6^{a}	10.5^{a}	2.7^{a}	291.0^{a}	3538.3^{a}	2154.9^{a}	78.7^{a}	657.5^{a}
A/ calcite	96.0^{a}	11.1^{a}	2.8^{a}	242.7^{bc}	3226.7^{a}	2010.2^{a}	78.7^{a}	667.5^{a}
Senkele lime	94.8^{a}	8.6^{a}	2.1^{ab}	260.3^{abc}	2933.3^{a}	1809.9^{a}	79.0^{a}	660.7^{a}
Mean	92.0	9.2	2.4	259.7	2912.8	1703.8	78.8	641.1
CV (%)	4.4	17.3	1.8	9.7	23.8	23.1	0.6	3.7

PLHT = plant height, PPP = pods per plant, SPP = Seeds per pod, BM = biomass, GY = grain yield, HLW = hectolitre weight, TSW = thousand seed weight

In the second year (2015) the experiment was conducted on additional location at HARC research field. At this site, no significant ($P\leq0.05$) grain yield difference was observed among different lime materials, but Senkele lime gave better grain yield (17.6%) than the control treatment (Table 5).

In the third year (2016), at Holeta research station no significant ($P\leq0.05$) grain yield difference was observed among different lime materials, but Awash dolomite and Awash calcite gave comparatively better grain yield (14.9%) and (10%) respectively, over the control (Table 5.

Combined analysis results of an experiment conducted at HARC research station showed no significant yield difference among lime materials, except when compared with the control treatment that has no lime. Senkele lime gave better grain yield (12.9%) than the control treatment (Table 5). The second-best grain yield was recorded by Awash dolomite and Awash calcite (11.4%) and (10.5%) respectively, over the control (Table 5).

Table 5. Mean yield of food barley as affected by different lime materials at Robgebeya

Treatment	***2015***		***2016***		***Combined***	
	Biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	Biomass (kg ha^{-1})	Grain yield (kg ha^{-1})
Control	12808.7 a	4121.2 b	3913.0 b	3916.6c	8360.7 b	4018.9 b
Dejen lime	13425.9 a	4552.9 ab	10426.0 a	4142.6 bc	11925.9 a	4347.8 a
Awash dolomite	13592.6 a	4455.0 ab	10685.0 a	4500.1a	12138.9 a	4477.6 a
Awash calcite	13426.0 a	4580.7 ab	10698.0 a	4304.8 ab	12062.1a	4442.8 a
Senkele	13314.8 a	4847.7 a	10539.0 a	4223.8 b	11926.8 a	4535.8 a
Mean	13313.6	4511.5	9252.1	4217.6	11282.9	4364.5
CV(%)	4.6	6.9	25.6	3.1	14.9	5.8

The probable reasons why yield difference was not significant among different lime materials might be due to nearly comparable mineralogical makeup of the lime materials, which is useful indication to use any of the lime materials by crop growers.

Conclusion

The results of the study showed that lime materials produced in Ethiopia at different locations (Dejen/Amhara and Senkele/Oromia, Awash calcite and dolomite) have nearly equal percentage of $CaCO_3$, hence neutralizes soil acidity nearly at equal capacity. All lime materials improved soil pH, exchangeable acidity and Al ion concentration in the soil solution at different levels. Similarly, at both experimental sites P fixed by Al/Fe oxides was released by calcite and dolomite. Simultaneously, some lime materials increased some exchangeable bases such as Ca and Mg availability in acidic soils. The lime materials improve the productivity of the soil to increase the agronomic performance of barley and faba bean in comparably. Therefore, these lime materials can suitably serve the regional as well as national lime demand to ameliorate soil acidity in the country. Thus, the resource poor farmers dwelling in western, northwestern and central highlands who cannot afford to transport the two Awash limes from eastern part of the country can make use of Senkele and Dejen lime to amend their soil acidity.

Acknowledgements

The authors are grateful to Ethiopian Institute of Agricultural Research for financial support and provision of facilities, acid soil research team for implementation of the experiment and data collection. We are also thankful to Holeta soil and plant tissue laboratory staff for their indispensable contribution in soil sample analysis.

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