

Review Article

Progress of Soil Acidity Management Research in Ethiopia

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Abstract

This review paper tries to put together soil acidity management research-based evidences generated recently. In the context of agricultural problem soils, acid soils are soils in which acidity dominates the problems related to agricultural land use. Soil acidity problems are increasing in the highland areas of Ethiopia. Application of lime coupled with fertilizer improves the productivity of crops in acid affected soils. In Nedjo condition, lime level 5 t ha⁻¹ with 69 kg ha⁻¹ phosphorus gave best yield (1346.2 kg ha⁻¹) and (1635.5 kg ha⁻¹) of finger millet and teff respectively. Similarly, yield of faba bean was obtained by applications of 16.5 (t ha⁻¹) and 13 (t ha⁻¹) of lime along with 30 kg ha⁻¹ P fertilizer at Bedi and Emdibir respectively. Application of 16.5 t ha⁻¹ lime with 30 P (kg ha⁻¹) gave 212% yield increment over the control that has no lime but 30 P (kg ha⁻¹).

Integrated reclamation approach centering lime-fertilizer and soil nutrients interaction is vital to establish cost effective and sustainable nutrient management of this soil. 50% FYM+50% NP+50% lime treatment gave significant yield and yield component of teff at Nedjo testing site, this result showed that proper knowledge and enhanced use of integrated soil fertility management technologies such as combined use of organic and inorganic fertilizers in the presence of a soil- conditioner lime are vital in improving and sustaining crop production. From an experiment conducted to evaluate the effectiveness of limes produced at different locations in Ethiopia no statistical yield difference was observed, and this implies that both lime produced at Senkele (Oromia region) and Dejen (Amhara region) can successfully answer their regional lime needs. When Senkele lime, Dejen lime and Ca(OH)₂ from Ghion gas factory were compared with Awash calcite and Awash dolomite, these two Awash products were greatly preferred. The reason might be mainly from the material they are processed and as well the technology under which they were crushed.

Keywords: Soil acidity; Nitosol; Lime; pH; Phosphorus; Exchangeable acidity

Introduction

Soil acidity associated to Al toxicities, soil erosion and soil nutrient depletion are the main soil related constraints to agricultural development in parts of developing countries relying on agricultural to feed their growing population [1]. In Ethiopia, huge surface areas of the highlands located at almost all regional states of the country are affected by soil acidity. From current ATA report it was estimated that about 43% of the total arable land in Ethiopia is affected by soil acidity. Soil acidity problem is significant in the north-western, south-western, southern and central regions of the country which receive precipitation high enough to leach down soluble salts and/or basic cations appreciably from the surface layers (root zone) of the soils. Some of the well-known areas severely affected by soil acidity in Ethiopia are Ghimbi, Nedjo, Hossana, Sodo, Chencha, Hagere-Mariam and Awi Zone of the Amahara Regional State [2].

Over use of agricultural by products (crop residue) and continuous crop harvest (without proper fertilization), removal of cations [3] and continues use of acid forming inorganic fertilizers [4] make important contribution to soil acidity development in most highland areas of Ethiopia. Acidity related soil fertility problems are major production constraints reducing the productivity of the major crops grown in the country [5]. The detrimental effect of soil acidity on plant growth and yield is mainly attributed to the deficiency of phosphorus, which is caused by adsorption of P to colloidal fractions [6-8]. Deficiencies of calcium, magnesium, potassium and molybdenum have also been reported to limit crop yield in acid soils [6].

In order to alleviate the soil acidity problem using agricultural lime different research activities have been done with different organizations in different parts of the country. The objectives of this review were to summarize the past lime technology research achievements and recommend future research direction for lime technology.

Materials and Methods

Academic publications were searched through both electronic and hard copy literature sources. A large set of keywords were chosen to identify as many publications as possible. These include soil acidity, nitisol, lime, phosphorus, pH, exchangeable acidity. Moreover, publications in hard copies (research reports, articles in journals, chapter in books, proceedings and thesis) were obtained from different institutions such as Ethiopian Institute of Agricultural Research (EIAR), Regional Agricultural Research Institute (RARIs), NGO's and personal communication. Only publications dealing with a progress of acid soil management research in Ethiopia were selected and arranged together for this review.

Results and Discussion

Phosphorus status of the reddish-brown soils of Ethiopian highlands

The reddish-brown soils of the Ethiopian highlands are highly deficient in phosphorus. For instance, soil analytical results have indicated that most of the soils in the Walmera area are low in pH and deficient in available P (Table 1).

Field	pH 1:1	P (ppm)	N (%)	OC (%)	Meq/	100 g s	soil		
	(1120)				Na	к	Ca	Mg	CEC
Rep I	4.2	5.5	0.19	1.56	0.11	1.66	2.76	2.31	23.44
Rep II	4.3	5	o.16	1.48	0.14	1.25	2.73	2.36	28.98
Rep III	4.4	5	0.17	1.52	0.07	1.28	2.75	2.2	27.94
Rep IV	4.4	4.2	0.1	1.52	0.08	1.14	2.74	1.48	26.04
Mean	4.3	4.95	0.17	1.52	0.1	1.33	2.74	2.09	26.6

Table 1: Initial soil chemical properties of the experimental field of Holeta Agricultural Research Centre, 2001-2003. P determined by Olsen method; CEC=Cation-exchange capacity; OC=Organic carbon. Source: Getachew Agegnehu and Taye Bekele [9].

Thus, the amount of available P in the soil is, by and large, insufficient to meet the requirements of barley production. Soil analytical results were found to be suboptimal for the production of crops. Similar to Marschner finding, soils with pH values less than 5.5 are deficient in Ca and/or Mg, and also P [10]. As presented in Table 1, the soil pH, available P and exchangeable cations were found to be far below the optimum.

Management of acid soils with lime application

Due to increasing scope and magnitude of soil acidity problem in Ethiopia, reclamation program focusing on liming has been under taken in seriously affected part of the country. Some of the achievements obtained are presented as follows.

Lime t/ha	N P ₂ O ₅ (k	g/ha)	Mean Yield (t/ha)	
	0-0	35-35	70-70	
0	5.4	4.95	4.22	4.86
3	3.95	6.14	5.49	5.19
Mean	4.67	5.55	4.85	

Table 2: Effect of lime on the grain yield (t/ha) of maize at Nedjo.Source: Holeta Agricultural Research Center (HARC) [11].

As indicated in Tables 2 and 3, increased rate of lime application from 0-3 t/ha resulted in increased yield of Maize when applied with 35-35 N P_2O_5 (kg/ha) and Barely yield also increased with increasing lime (0-1.5 t/ha) and P application (0-30 P_2O_5 kg/ha). This clearly indicated that, application of lime coupled with fertilizer improve the productivity of crops in acid affected soils. This might be related with poor fertility of acid soils prevalent in high rainfall areas where leaching of nutrients is expected to be high.

Lime t/ba	P (kg/ha)							
Line una	0	10	20	30				
0	1256	2059	2397	3060	2393			
0.5	2132	2501	3447	3833	2978			
1	2498	3184	4362	4675	3680			
1.5	2536	3995	4697	5117	4086			
2	2498	3769	4846	4976	4022			
Mean	2184	3102	3950	4332				

Table 3: Effect of Lime and P application on grain yield (kg/ha) ofBarley at Bedi. Source: Holeta Agricultural Research Center (HARC)[11].

An experiment was conducted at Nedjo testing site to evaluate the interaction effects of different lime rates and phosphorus levels on yield of teff and finger millet. The lime level which gave best yield of finger millet was 5 t ha^{-1} with 69 kg ha^{-1} of phosphorus (1346.2 kg ha^{-1}) (Table 4).

**	P1 (0 kg ha ⁻¹)	P2 (23 kg ha ⁻¹)	P3 (46 kg ha ⁻¹)	P4 (69 kg ha⁻¹)
0 lime (control)	459.6 L	494.6 KL	826.1 G	699.3 HI
0.5 (5 t ha ⁻¹)	459.3 L	931.4 EF	1230.6 B	1346.2 A
1 (10 t ha ⁻¹)	507.1 KL	790.9 GH	861.4 FG	982.0 DE
1.5 (15 t ha⁻¹)	580.1 JK	647.5 IJ	881.8 FG	797.2 G
2 (20 t ha ⁻¹)	673.0 IJ	1046.0 CD	1269.7 AB	1111.7 C
cv				6.98
LSD				68.95

Table 4: Influence of lime and Phosphorus on Finger millet grain yield (kg ha⁻¹), Nedjo 2013. Source: HARC Progress Report [12].

**	P1 (0 lime)	P2 (23 kg ha ⁻¹)	P3 (46 kg ha ⁻¹)	P4 (69 kg ha⁻¹)
0 lime (control)	192 ^ĸ	1142.9 ^{DEF}	1169.8 ^{DE}	1328.6 ^C
0.5 (5 t ha ⁻¹)	268.9 ^J	1136.3 ^{EFG}	1348.8 ^C	1635.5 ^A
1 (10 t ha ⁻¹)	485.1 ¹	1205.6 ^D	1365.8 ^{BC}	1426.6 ^B
1.5 (15 t ha ⁻¹)	484.5 ¹	1144.8 ^{DE}	1155.4 ^{DE}	1176.9 ^{DE}
2 (20 t ha ⁻¹)	500.6 ¹	964.1 ^H	1177.3 ^{DE}	1107.8 ^{FG}
cv				11.7
LSD				104.3

Table 5: Influence of lime and Phosphorus on teff grain yield (kg ha⁻¹),Nedjo 2013. Source: HARC Progress Report [12].

Similarly, the best yield of teff was obtained by 5 t ha^{-1} with 69 kg ha^{-1} of phosphorus (1635.5 kg ha^{-1}) (Table 5). Both teff and finger millet grown on extremely acidic soils (Nedjo site) were more responsive to inorganic fertilizer phosphorus rate than lime levels. This might be because of temporary saturation of phosphorus fixation around the plant root zone.

Research work has been done on integrated soil fertility management (i.e., organic fertilizer sources combined with inorganic fertilizers) under limed/unlimed condition on teff yield at Nedjo testing site. The experiment was conducted for two consecutive years without changing plots that received the organic fertilizer sources farmyard manure (FYM) and compost only in the first year but received the inorganic fertilizers (TSP and Urea) every year.

S No	Treatment	Cropping Season		Over Year Means	
		2013	2014	2015	
1	Control (no amendment)	43.4	87.9	0	43.8
2	Recommended NP	66.8	193.1	0	86.6
3	100% FYM	1367.6	547.1	155	689.9
4	100% compost	1163	381.9	127.6	557.5
5	50% FYM+50% NP	806.2	890.4	657.1	784.6
6	50% comp+50% NP	771.7	833.2	489.9	698.3
7	100% FYM+100% lime	1258.8	747	488.1	831.3
8	100% Compost +100% lime	1075.5	529.2	650	751.6
9	NP+100% lime	415.3	740.2	427.3	527.6
10	50% FYM + 50% NP +50% lime	1053.4	1191.6	907.5	1050.8
11	50% compost+50% NP+50% lime	911.4	1011.3	730.7	884.5
12	Rock phosphate as a treatment combination	407.1	462.1	197.9	355.7
	Mean	778.4	634.6	402.6	605.2
	CV	203.5	269.8	49.2	405.8
	LSD	15.4	25.1	16.3	39.6

Table 6: Over year aggregate effect of organic fertilizer sources on teff grain yield (kg ha⁻¹) on acidic soil at Nedjo (2014-2015). Source: HARC Progress Report [12].

Result obtained from over years aggregate (Table 6) clearly showed that superior grain yield, biomass weight and plant height were recorded with treatment 50% FYM+50% NP+50% lime.

The second-best result was obtained with treatment 50% compost +50% NP+50% lime. Similar result was obtained by Chilimba et al. [13] evaluated the response of maize grain yield to applied compost

and farmyard manure in combination with inorganic fertilizer materials.

Both organic fertilizer sources (FYM and Compost) combined with equal amount of NP inorganic fertilizers in the absence of a soil conditioner lime gave statistically similar teff grain yield, biomass and plant height. This might be probably happened due to

The obtained results clearly assured that proper knowledge and enhanced use of integrated soil fertility management technologies such as combined use of organic and inorganic fertilizers in the presence of lime are vital in improving and sustaining crop production.

Lime (t ha ⁻¹)		P (kg ha⁻¹)						
	0	0 10 20 30						
0	1338.5	2071.2	2332.8	2355.8	2024.6			
0.5 (0.55 t ha ⁻¹)	2275.6	2817.4	3242.2	3310	2911.3			
1 (1.1 t ha ⁻¹)	2804.2	3886.2	4081.9	4330.6	3775.7			
1.5 (1.65 t ha ⁻¹)	3119.9	3769.9	4924.2	5007.4	4205.4			
2 (2.2 t ha ⁻¹)	3466.3	4489.7	4647.7	4997.6	4400.3			
Mean	3251.1	4258.6	4807.2	5000.4				

Table 7: The interaction effect of Lime and P on seed yield of Faba bean in (kg ha⁻¹) during 2009/10 cropping season at Bedi. Source: HARC Progress Report [12].

To observe the interaction effect of lime and P on seed yield of faba bean an experiment was conducted at Bedi and Emdibir. The results of these experiments are presented in tables below. The highest significant ($P \le 0.05$) yield of faba bean was obtained by applications of 1.65 (t ha⁻¹) and 13 (t ha⁻¹) of lime along with 30 kg ha⁻¹ P fertilizer at Bedi and Emdibir respectively. Application of 1.65 t ha⁻¹ lime with 30 P (kg ha⁻¹) gave 212% yield increment over the control that has no lime but 30 P (kg ha⁻¹) (Tables 7 and 8).

Lime (t ha ⁻¹)	P (kg ha⁻¹)	P (kg ha ⁻¹)				
	0	10	20	30		
0.5 (3.25 t ha ⁻¹)	64.8	93	92.2	105.1	89	
1 (6.5 t ha ⁻¹)	190	193.4	256	324.1	240.9	
1.5 (9.75 t ha ⁻¹)	236.6	260.7	374.5	383.5	313.8	
2 (13 t ha-1)	241.8	318.5	381.3	420.1	340.4	
Mean	202.86	228.8	306.1	311.5		

Table 8: The interaction effect of Lime and P on seed yield of Faba bean in (kg ha⁻¹) during 2009/10 cropping season at Emdibir. Source: HARC Progress Report [12].

To discern the effects of liming on root nodulation and grain yield of soyabean an experiment was conducted at Bako area, western Ethiopia. The finding from the experiment with regard to growth and yield attributes revealed that liming acid soil in soybean production had significantly influenced

Page 3 of 8

Trt No	Lime Rate in (t ha ⁻¹)	Nodule Number/Plant	Nodule Volume (in ml)/Plant	Nodule Dry wt. (mg)/Plant
1	0	65d	2.16	563.33d
2	1.56	85c	3.76	633.33cd
3	2.34	97b	4.3	713.33b
4	3.13	113a	4.43	963.33a
5	3.91	84c	2.93	650bc
6	4.69	93bc	3.26	653.33bc
	LSD (0.05)	11.185	NS	79.693

Table 9: Nodulation of soybean as influenced by liming, BakoAgricultural Research Center, western Ethiopia [16].

the number and dry weight of nodule, the plant height, the above ground biomass and grain yield (Tables 9 and 10).

The nodule number and nodule dry weight increased linearly with increase of liming rate until it reached the recommended level [16]. The optimum value of nodule number and weight obtained is 113 and 963.3 mg /plant which were improved remarkably by 73.84% and 71.04% respectively due to liming (Table 9).

Trt No	Lime Rate in (t ha ⁻¹)	SC/Plot	Plant Height (cm)	Biomass Weight in (t ha ⁻¹)	Grain Yield Weight in (t ha ⁻¹)	н
1	0	540	45.93c	6.46c	3.92c	0.43
2	1.56	604	50.93b	7.3b	4.38ab	0.45
3	2.34	617	55.26b	7.66ab	4.36ab	0.42
4	3.13	564	60.23a	7.46b	4.2bc	0.4
5	3.91	593	51.66b	8.27a	4.69a	0.43
6	4.69	605	53.5b	7.3b	4.14bc	0.4
	LSD (0.05)	NS	4.36	0.74	0.41	NS

Page 4 of 8

Table 10: Yield and Yield Related Traits as influenced by Liming, Bako Agricultural Research Center, Western Ethiopia [16]. Sc=Stand count, HI=Harvest Index. Means within a column followed by the same letter(s) or with no letter are not significantly different, NS=Non-significant at p>0.05.

Lime (t be-1)	Varieties	Gununo			Dolla				
		Pod No	Seed No	Pod Length	Seed Yield	Pod No	Seed No	Pod Length	Seed Yield
0	Omo-95	8.8	5.42	8.35	826.32	8.85	5.62	8.72	875.17
	Hawassa Dume	9.25	5.17	8.47	930.2	8.62	5.22	8.72	972.96
0.4	Omo-95	8.77	5.02	8.17	1079.4	7.77	4.91	8.52	1122.58
0.4	Hawassa Dume	9.35	5.17	8.47	1282.49	8.67	5.22	8.4	1416.99
CV		27.7	17.14	9.5	34.27	22.7	11.9	0.79	46
LSD		1.43	0.44	0.57	201	1.65	0.65	3.11	200

Table 11: Mean value of lime on yield and yield components performance of haricot bean varieties at Gununo and Dolla in 2012-2013 [17].

To evaluate the response of haricot bean varieties to liming on acid soils a field experiments were conducted at the two locations on acidic soil (Dolla and Gununo) in Wolaita Zone, Southern Ethiopia. Hawasadume and Omo-95 haricot bean varieties were treated by 0 and 0.4 t ha⁻¹ of lime. There was a significant increase on growth parameters of the two varieties as rates of lime increased both at Dolla and Gununo sites.

Maximum values of plant height, leaves and branches number were recorded at application rates at both location with liming in year 1 and 2. Similarly, the highest grain yield and yield components were obtained at 20 kg P ha⁻¹ with lime (0.4 t ha⁻¹) on both varieties at two locations (Table 11). An experiment was also carried out on acid soils of Jima and Ilubabore zones of south-western Ethiopia to know the effect of split application of lime on the basis of maize-soybean rotation system in two sets.

Treatments of split lime applications were control, full dose of recommended lime applied at one time during the cropping season,

Treatments	2009	2010	2011	2012	2013	Over Year Mean
Control	1656b	2524b	4259	2762c	1910	2622c
25% every year	1730b	3370ab	4464	3671ab	1792	3005bc
33% every year	1756b	3412ab	4677	4221a	2180	3249ab
50% every year	2176ab	3640ab	4936	3491ab	2256	3300ab
Full dose	2798a	4163a	5101	3192bc	2149	3481a
LSD _{0.05}	780	1441	ns	784	ns	466
CV (%)	20.48	22.36	14.83	12.01	35.88	11.09

Table 12: Effect of Split Application of Lime on Maize Yield (kg ha⁻¹) at Doyo in 2009-2013 growing seasons [18]. Means with in a column with the same letter(s) are not significantly different at 0.05 probability level. ns=Not significantly different at 0.05 probability level.

two splits in which 50% of the dose applied in the first year and the rest 50% in the second year, three splits in which 33% of the dose applied in the first year, 33% in the second year and the rest 33% in the third year and four splits in which 25% of the dose applied in the first year, 25% in the second year, 25% in the third year and the rest 25% in the fourth year.

Recommended rate of N, 46 kg ha⁻¹ and 92 kg ha⁻¹ were uniformly applied for soybean and maize, respectively. However, 20 P kg ha⁻¹ was uniformly applied for all treatments and for both test crops. Over years mean showed that split application of the required amount of lime into two or three parts, then applying in two or three consecutive years respectively gave nearly equal yield with that of full recommended rate lime application in the first year for maize at Doyo (Jima) [18]. Result of this experiment revealed that splitting into 33% and 50% is possible if maize to be grown on this soil (Table 12).

Treatments	2009	2010	2011	2012	2013	Over Year Mean
Control	1259	1185	1219b	1705	2416	1557b
25% every year	1454	1541	1978a	1977	2441	1878a
33% every year	1674	1662	2270a	1739	2441	1957a
50% every year	1848	1694	2275a	1880	2108	1961a
Full dose	1944	1780	2286a	1850	2408	2054a
LSD _{0.05}	ns	ns	638	ns	ns	294
CV (%)	22.86	20.77	16.91	8.92	7.91	11.62

Table 13: Effect of split application of lime on soybean seed yield (kg ha⁻¹) at Doyo in 2009-2013 growing seasons [18]. Means with in a column with the same letter(s) are not significantly different at 0.05 probability level. ns=Not significantly different at 0.05 probability level.

Split application and full rate application gave almost similar soybean yield at the testing site (Table 13). However, resource poor farmers who cannot afford the price of full dose lime can split in to two, three or four and apply every year without significant yield loss for both crops compared to one-time application of full dose.

Treatments	2009	2010	2011	2012	2013	Over years Mean
Control	5226c	4654b	6804	5868d	5993	5709b
25% every year	5851bc	5082ab	7115	6975b	5643	6133ab
33% every year	6579ab	5337ab	7127	7875a	5755	6535a
50% every year	7157ab	5812ab	7914	6678bc	5794	6671a
Full dose	7439a	5864a	8069	6204c	5616	6638a
LSD _{0.05}	1337	1202	ns	485	ns	725
CV (%)	11.01	11.94	9.96	3.85	12.96	8.60

Table 14: Effect of split application of lime on maize grain yield (kg ha⁻¹) at Hurumu in 2009-2013 growing seasons [18]. Means with in a column with the same letter(s) are not significantly different at 0.05 probability level. ns=Not significantly different at 0.05 probability level.

Similar to Doyo soil, Hurumu's soil was also responsive to split lime application. Splitting into two or three gave similar maize and soybean yield with full recommended lime rate application at once (Tables 14 and 15). Depending on the availability of lime and affordability of maize and soybean growers, it is possible to use either of the above frequencies.

Another study was conducted at Megele-33 kebele, Assosa area of north western Ethiopia from 2012-2015 on the basis of cereal food legume/oil crops rotation system in two sets.

Treatments	2009	2010	2011	2012	2013	Over year Mean
Control	1382b	1530	1344b	1436b	2077	1554b
25% every year	1421b	1539	1953a	1766ab	2390	1814ab
33% every year	1674ab	1631	2024a	1858a	217 0	1871a
50% every year	1848ab	1709	2004a	1752ab	2327	1867ab
Full dose	1944a	1734	2050a	1727ab	2188	1929a
LSD _{0.05}	497	ns	470	384	ns	218
CV (%)	15.97	10.06	13.33	11.86	10.17	8.98

Table 15: Effect of Split Application of Lime on Soybean Seed Yield (kg ha⁻¹) at Hurumu in 2009-2013 Growing seasons [18]. Means with in a column with the same letter(s) are not significantly different at 0.05 probability level. ns=Not significantly different at 0.05 probability level.

Treatment	PLHT (cm)	Gy kg/ha
Control	91.1	573.5
Full dose of lime	99.1	2378.7
50% lime each year	121.3	3143.3
33% lime each year	105.4	2315
25% lime each year	110.1	2402.3
CV	29.7	78.4
LSD	NS	1618.8

 Table 16: Effect of Split Application of Lime on Soybean seed Yield (kg ha⁻¹) at Asosa.

As clearly seen from (Table 16) treatment with 50% lime in split application gave the highest mean grain yield (3143.3 kg/ha) of sorghum [19].

To evaluate different agricultural lime materials produced in Ethiopia for their agronomic effectiveness on acid soils an experiment was conducted at Holeta agricultural research centre for three years. The agricultural lime materials were brought from Senkele (Oromia), Dejen (Amhara) and both Awash Dolomite and Awash calcite from Awash 7 kilo.

Statistically no yield difference was observed among different agricultural limes produced in Ethiopia, and this implies that both limes produced at Senkele (Oromia) and Dejen (Amhara) can successfully answer their regional lime needs. When Senkele lime, Dejen lime and $Ca(OH)_2$ a byproduct from Ghion gas factory were

Page 5 of 8

Page 6 of 8

compared with Awash calcite and Awash dolomite, these two Awash products were greatly preferred (Tables 17 and 18). The reason might

be mainly from the material they were processed and as well the technology under which they were crushed.

Treatment	PLHT (cm)	Spkin (cm)	Spkpsp	BM (kg ha⁻¹)	GY (kg ha⁻¹)	HLW (%)	TSW (g)
1	114.39	6.25	49.4	17911.1	6146.7	61.5	41.87
2	114.83	6.3	49.4	18788.9	6524.7	63.5	42.27
3	115.11	6.39	50.27	18611.1	6879.2	62.1	41.64
4	113.22	6.58	51.4	18266.7	6975.3	61.1	42.02
5	113.78	6.14	49.67	18233.3	6577.4	62.1	41.78
Mean	114.27	6.33	50.03	18362.22	6620.66	62.08	41.92
CV (%)	3.15	5.55	11.54	10.44	12.62	4.39	4.73
LSD (0.05)	NS	NS	NS	NS	797.26	NS	NS

Table 17: Effects of different agricultural limes on yield and yield components of barley, combined analysis (Year I)-2014. Trt.1=control, 2=Dejen lime, 3=Awash Dolomite, 4=Awash Calcite, 5=Senkele lime, $6=Ca(OH)_2$, PLHT=plant height, Spkln=Spike length, Spkpsp=No of Spikelet per Spike, BM=Biomass (kg ha⁻¹), GY=Grain yield (kg ha⁻¹), HLW=hectolitre weight, TSW=Thousand seed weight. Source: HARC Progress Report [12].

Treatment	PLHT (cm)	Spkin (cm)	Spkpsp	BM (kg ha ⁻¹)	GY (kg ha⁻¹)	HLW (%)	TSW (g)
1	90.13	6.33	45.80	7389.0	3261.0	61.33	47.60
2	88.30	6.87	52.13	8389.0	3642.5	61.03	47.00
3	88.93	6.60	50.33	8537.0	3653.6	62.13	47.73
4	89.73	7.00 A	49.53	8019.0	3582.5	61.87	47.53
5	86.33	6.20	49.20	7796.0	3420.1	61.83	47.07
Mean	88.69	6.60	49.40	8025.92	3511.94	61.64	47.39
CV (%)	3.33	6.40	5.70	15.81	15.92	1.69	2.09
LSD (0.05)	NS	0.79	5.30	NS	NS	NS	NS

Table 18: Effects of different agricultural limes on yield & yield components of barley, Rob Gebeya (Kifile)-2016. Trt. 1=control, 2=Dejen lime,3=Awash Dolomite, 4=Awash Calcite, 5=Senkele lime, 6=Ca(OH)₂, PLHT=plant height, Spkln=Spike length, Spkpsp=No of Spikelet per Spike,BM=Biomass (kg ha⁻¹), GY=Grain yield (kg ha⁻¹), HLW=hectoliter weight, TSW=Thousand seed weight. Source: HARC Progress Report [12].

The Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia (CASCAPE) project conducted research in selected woreda's in the Southern and Amhara regions with the aim of reclaiming acid soils for crop production. In both regions different treatments with varying quantities of lime per hectare were tested.

In the South region six treatments were used.

- 900 kg ha⁻¹ lime.
- 900 kg ha⁻¹ lime plus the recommended fertilizer rate.
- 1800 kg ha⁻¹ lime.
- 1800 kg ha⁻¹ lime plus the recommended fertilizer rate.
- Application of recommended fertilizer (100 kg DAP and Urea per ha) only.
- Control (no treatment).

Where as in CASCAPE Amhara

(i) 1925 kg ha⁻¹ lime; (ii) 2050 kg ha⁻¹ lime and (iii) Control (no lime application) were used.

All three treatment plots followed the recommended fertilizer dosage. Barley was the experimental crop used.

The highest grain yield of 1367 kg ha⁻¹ was obtained with application of 1800 kg lime and recommended fertilizer (Table 19). These yield levels were significantly higher than the control (554.0 kg ha⁻¹).

Barley grain yield in Dera and Jabi Tehnan wored Amhara region showed significant differences between lime treated plots and nontreated plots. Lime rates based on the buffer method (1925 kg ha⁻¹ on average of four sites) and the exchangeable acidity method (2050 kg ha⁻¹ on average of four sites) gave grain yields of 3648 and 3643 kg ha⁻¹ of barley, respectively and the difference were not significant (Table 20).

rage / 010	Page	7	of	8	
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Treatments	Mean grain yield across replications (kg ha ⁻¹)
Control	554.00
RFR	778.00
900 kg ha ⁻¹ lime+0 Fertilizer	891.50
900 kg ha ⁻¹ lime+RFR	1283.50
1800 kg ha ⁻¹ lime+0 Fertilizer	924.75
1800 kg ha ⁻¹ lime+RFR	1367.67

Table 19: Mean grain yield of barley across different liming treatments in Bule woreda, Southern Ethiopia [20]. RFR: recommended fertilizer rate (100 kg DAP and 100 kg Urea).

Treatments	Lime Rate (kg)	Mean Grain Yield (kg ha ⁻¹)	Mean Biomass Yield (kg ha⁻¹)	Grain Yield Advantage Over the Control (kg ha ⁻¹)
Control	0	2432 ^b	6385 ^a	
Buffer Method	1925	3648 ^a	9151 ^a	50%
Exchangeable- Acidity Method	2050	3643 ^a	10058 ^a	50%
Mean	3241	8531		
CV	16.2	24		

Table 20: Grain yield of barley across liming treatments following buffer and exchangeable acidity in Amhara region [20]. As the trial in CASCAPE Amhara were conducted at two districts, Dera and Jabi: the data on the table combined over the two woredas.

Comparison of soil pH level changes before planting and after harvest at CASCAPE south showed that after harvest the pH levels consistently increased from 4.68 in the control (T_1) to 5.33 (T_5) due to the treatment with 1800 kg ha⁻¹ lime plus no fertilizer. For the control, pH after harvest showed a reduction by 0.03 compared to the pH level before planting, which might be associated with the macronutrient mining of test crops from the native soil [21-25].

Conclusion

Soil acidity problems are increasing in the highland areas of Ethiopia. Different experiments confirmed that and suggested that lime is essential but must be complimented with balanced plant nutrients in order to get adequate crop yield in acid prone areas. In Nedjo condition, lime level 5 t ha⁻¹ with 69 kg ha⁻¹ phosphorus gave best yield (1346.2 kg ha⁻¹) and (1635.5 kg ha⁻¹) of finger millet and teff respectively. Similarly, yield of faba bean was obtained by applications of 1.65 (t ha⁻¹) and 13(t ha⁻¹) of lime along with 30 kg ha⁻¹ P fertilizer at Bedi and Emdibir respectively.

Around Bako area liming significantly influenced the number and dry weight of nodule, plant height, above ground biomass and grain yield of soybean. The study of lime and phosphorus application on haricot bean varieties at Dolla and Gununo in Wolaita Zone, Southern Ethiopia showed that the highest grain yield and yield components were obtained at 20 kg P ha⁻¹ with lime (0.4 t ha⁻¹) at two locations.

Split application of lime on acid soils of Jima and Ilubabore zones of south-western Ethiopia has showed that splitting into two or three parts gave nearly equal maize yield with full recommended lime rate application at once. Similarly, from an experiment conducted at Megele-33 kebele, Assosa area of north western Ethiopia splitting full dose of lime into two parts gave the highest mean grain yield of sorghum without significant yield loss.

From research work done on integrated soil fertility management (i.e., organic fertilizer sources combined with inorganic fertilizers) under limed/unlimed condition on teff yield at Nedjo testing site, two years data and the over years aggregate clearly showed that superior grain yield, biomass weight and plant height were recorded with treatment 50% FYM+50% NP+50% lime.

Similarly, an experiment was conducted at Holeta station and onfarm to evaluate different agricultural lime materials produced in Ethiopia for their agronomic effectiveness on acid soils. Statistically no yield difference was observed among different agricultural limes produced in Ethiopia, and this implies that both limes produced at Senkele (Oromia) and Dejen (Amhara) can successfully answer their regional lime needs. When Senkele lime, Dejen lime and $Ca(OH)_2$ from Ghion gas factory were compared with Awash calcite and Awash dolomite, these two Awash products were greatly preferred. The reason might be mainly from the material they were processed and as well the technology under which they were crushed.

Soil acidity limits crop production in many tropical soils. Lime and inorganic phosphate fertilizers are used to remedy these problems. However, due to increasing costs and unavailability when needed, their use among our farmers in our country is not widespread. Thus, the government should give an attention to the supply of lime where it is prudently needed.

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Page 8 of 8