Effects of Lime and Phosphorus on Wheat (Triticum aestivum L.), Teff (Eragrostis teff) and Barley (Hordium vulgar L) Yields in the Amhara Highlands

[1*]Birhanu Agumas, [1]Anteneh Abewa, [1]Dereje Abebe, [2*]Kenzemed Kassie, [2]Genet Taye and [2]Gebreyes Gurmu

[1]Adet agricultural Research Center, P.O.Box: 08, Bahir Dar, Ethiopia

[2]Debrebirhan Agricultural Research Center, P.O.Box: 112, Debrebirhan, Ethiopia

[*]First Authors, the coauthors follow the name order in their respective center

Abstract

The success in soil management to maintain soil quality depends on an understanding of how soils respond to agricultural practices over time. $)LHOG H[SHULPHQW ZDV GRQH *in 2011 and 2012 to determine lime and phosphorus rates for higher teff wheat and barley yields. The experiment was arranged in randomized complete block design with three replications. The treatments were factorial combinations of 3 levels of lime (0, 1, 2 t ha^{-1}) at Tarmaber and 4 levels of lime (0, 1, 2 and 3 t ha^{-1}) at Banja, Mecha and Gozamen and 4 levels of P (0, 10, 20, 30 kg ha^{-1}) for all locations. Composite soil samples were collected from 0-20 cm before planting and from all plots at sixty days after planting and at harvest to determine some soil chemical properties. All data were subjected to statistical analysis using SAS software and the mean separation was done using LSD (0.05) whenever the difference between treatments was significant. The result showed that maximum grain yield was obtained from 30 kg P ha^{-1} with 2 t lime ha^{-1} while the lowest was from the control (no input). Therefore, 30 kg P ha^{-1} with 2 t lime ha^{-1} is recommended for the study sites and similar agro ecologies.*

Keywords: Barley, Wheat, Teff, lime, Phosphorus

1*Birhanu Agumas, 1Anteneh Abewa, 1Dereje Abebe, 2*Kenzemed Kassie, 2Genet Taye and 2Gebreyes Gurmu

Introduction

The success in soil management to maintain soil quality depends on an understanding of how soils respond to agricultural practices over time. However, land degradation is one of the challenges facing Ethiopian agriculture. Among the land degradations soil erosion and soil fertility depletion are current problems to boost production in Ethiopia. One of soil chemical degradation challenging the Ethiopian highland soils is soil acidity which can be caused by leaching and plant uptake of basic cations (Ca and Mg), production of organic acids from organic matter decomposition, and application of acidifying N fertilizers (Ammonium/ammonia N sources including products like urea) (Bierman and Carl, 2005).

Acid soils are rampant and occupy about 40.9 percent of the country agricultural fields (Schlede, H., 1989). They extend from south-west to north-west with east-west distribution. They are concentrated mainly in the western part of the country including the lowlands but are limited by the eastern escarpments of the Rift Valley (Mesfine A., 2007). Out of the 40.9 percent total coverage, 27.7 percent are moderate to weakly acidic (pH of 5.5 - 6.7); 13.2 percent are strong to moderately acidic (pH< 5.5) and nearly one-third have aluminum toxicity problem (Schlede, H., 1989). From the soil analysis result by Bahir Dar, Debremarkos and Gonder soil laboratories indicate that south west Ethiopia especially the highlands of Gojam and Gonder are dominated by soil acidity problems (unpublished data). Soil acidity affects productivity of the soil through its effect on nutrient availability and toxicity by some elements like aluminum and manganese; most plant nutrients become more limited in supply, and a few micronutrients become more soluble and toxic. These problems are particularly acute in humid tropical regions that have been highly weathered (Harter, 2002). As soils become more acid, particularly when pH drops below 4.5, it becomes increasingly difficult to produce food crops.

Aluminum and manganese become more soluble (i.e. more of the solid form of these elements will dissolve in water when the soil is acid) and toxic to plants, most plant nutrients become more limited in supply, and a few micronutrients become more soluble and toxic. The ideal soil pH for most crops is slightly acidic to neutral (pH in water 6-7). Favorable soil pH in water for wheat production is 5.5 -7.0 below this pH ranges especially below 5.1- 5.5 wheat production is severely affected due to toxicity of aluminum and unavailability of macronutrients. The critical aluminum level extracted by $CaCl_2$ solution for wheat production is 0.4-0.8 ppm in which aluminum toxicity will affect wheat production (Fenton and Helyar, 2007). High levels of soil acidity (low soil pH) can cause reduction of root growth, nutrient availability, affect crop protecting activity (The Pennsylvania State University, 1995), reduction and total failure of crop yields and deterioration of soil physical properties. In general it affects the biological, chemical and physical properties of soil, which in turn affect the sustainability of crop production in both managed and natural ecosystem.

Reclamation and maintenance of soil acidity is very important soil management practices for crop production. Lime is the major means of ameliorating soil acidity (Anetor and Ezekiel, 2007) because it has very strong acid neutralizing capacity, which can effectively remove existing acid. Liming increases the uptake of nutrients, stimulate biological activity and reduce toxicity of heavy metals. Liming raises the soil pH and causes the aluminum and manganese to go from the soil solution back into solid (non-toxic) chemical forms. Regular applications of lime are required on many soils to maintain soil pH in the desired range, because soil acidification is an ongoing process (Bierman and Carl, 2005). Limestone is the most commonly used material to increase soil pH. However, for most efficient crop production on acid soils, application of both lime and fertilizer are required. Since lime make minerals more available to plants, in addition to the liming, applying fertilizer to correct nutrient constraints caused by acidity is necessary.

Lime and fertilizer management practices are primary important for proper management of acid soils. Some research attempts were made at Arekain Boloso Sore Wereda of Wolaita Zone of the Southern Nations Nationalities and People Regional States (Abay A. 2011), and a green house experiment was conducted by Chimdi and his associates at Guto-Gida District (East Wollega Zone) of Oromia Regional State (Chimeda et al. 2012), the latter reported that incubation of soil with applied lime rate at 10 t ha^{-1} showed considerable drop of the acid saturation percentage and reduced soil acidity thereby increasing soils pH and available P in soils in three land uses. In addition to the aforementioned studies in Ethiopia, Currently there are different research activities going on to determine the liming factor and the interaction of lime and phosphorous fertilizer by the federal and regional research institutes. However, there is scanty information available about the response of lime and fertilizer and the rates of these inputs for bread wheat, food barley and teff production in the Amhara highlands. Hence, this experiment was conducted to determine the lime and phosphorus rates to reclaim acid soils and improve its productivity.

Materials and methods

Description of the study area

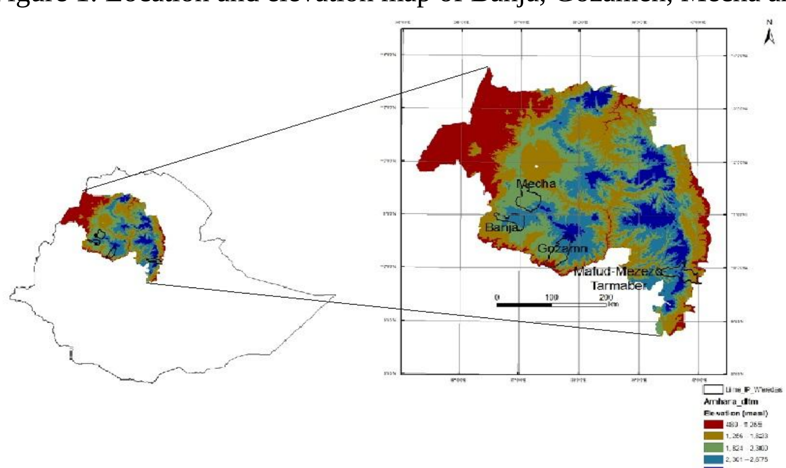
The study was conducted at Banja which is located in Awi Zone, Gozamen at East Gojam Zone, Mafud-Mezezo-Tarmeber at North Shewa Zone and Mecha at West Gojam Zone of the Amahara Regional State which are known for high soil acidity (Figure 1). The test crops were bread wheat for Banja and Gozamen Woredas, Teff for Mecha Woreda and Barley for Mafud-Mezezo-Tarmaber Woreda.

Table1. Physiographic characteristics of the Woredas.

Parameter	Woredas			
	Banja	Gozamen	Mecha	Mafud-Mezezo-Tarmaber
Soil Type	Acrisols	Nitosols	Nitosols	Cambisols
Altitude	2700	2920	Na	2580
Mean Annual Rain fall	1295	1320	Na	984
Min Temp	4.1	8.3	Na	6.8
Max Temp	28.6	24.8	Na	23.6

Na = data not available

Figure 1: Location and elevation map of Banja, Gozamen, Mecha and Mafud-Mezezo-Tarmaber weredas.



Experimental Set up

Bread wheat atBanja and Gozamen, and teff at Mecha

The experiment was done for two consecutive years (2011 and 2012) RQ IDUPHUV¶ ILHOGV. Four rates of lime (0, 1, 2 and 3 t lime ha^{-1}) were combined with four rates of phosphorous (0, 10, 20 and 30 kg P ha^{-1}) factorially arranged in a randomized complete block design (RCBD) with three replications.

Barley at Mafud-Mezezo-Tarmaber

The experiment was conducted at four location for two consecutive years with three rates of lime (0, 1 and 2 t ha^{-1}) combined with four rates of phosphorous fertilizer (0, 10, 20 and 30 kg P ha^{-1}) factorially arranged in randomized complete block design (RCBD) with three replications. For all locations urea and DAP were used as the sources of N and P respectively, whereas calcic limestone was used as the source of lime. The lime was incorporated in to the soil one month before sowing. Nitrogen was applied in split; half at planting and half at tillering. The whole doses of DAP was applied during planting. Bread wheat and Barley were drilled in row with spacing of 20 cm while Teff was broadcasted in a well prepared seed bed. The seed rate for wheat, Barley and teff were 150, 175 and 30 kg ha^{-1} respectively.

Soil sampling and analysis

Soil samples were collected from 0-20 cm i.e. one composite sample from the experimental site before planting and from each plot sixty days after planting and at harvest to determine different soil chemical properties. Samples were air dried, grinded, and passed through a 2 mm sieve and prepared for laboratory analysis. Soil pH was measured by using 1M KCl solution in the supernatant suspension of soil to solution ratio of 1:2.5 mixtures by using pH meter. The total exchangeable acidity was measured according to McLean (1965) while cation exchange capacity (CEC) was determined by the 1M ammonium acetate (pH 7) method according to the percolation tube procedure (Van Reeuwijk, 1993).

Data Analysis

The soil data collected were subjected to mean comparison using descriptive statistics and yield parameter for analysis of variance using statistical analysis software (SAS, 2002). Whenever treatment effects were significant, mean comparison were made using least significant difference at 0.05 % probability level.

Resultsand Discussions

At Banja Woreda, the soil type was Acrisols with pH (H_2O) ranging from 4.64-5.08, While at Gozamen and Mecha Woredas, the soil type was Nitisols with pH(H_2O) ranging from 4.3-4.77 in and 4.3-5.3 respectively. Similarly, the soil type at Mafud-Mezezo-Tarmaber was Cambisols with pH (H_2O) ranging from 4.6-5.41. The acidity level of the soils of the study sites were categorized as moderately to strongly acidic (Tekalign, 1991). The combined analysis of variance over years at all locations indicated that application of lime and phosphorus fertilizer had contributed to the improvement of the yield of the test crops compared to the recommended fertilizer rate without lime and the control.

Bread wheat

At Gozamen

There was an interaction effect between lime and phosphorous fertilizer on dry biomass and grain yield. The analysis of variance revealed that there was significant difference S ” in all the parameters between years. Therefore, it is better to analyze the individual years independently. The statistical analysis in 2011 revealed that there was significant difference among lime and P fertilizer combinations. Maximum grain and biomass yields were recorded by applying 30 kg P ha^{-1} with 2 t lime ha^{-1} while the lowest grain yield was recorded by the control (no input) (Table 1). However there was no statistically significant difference among 10/2, 10/3, 20/3, 30/1, 30/2 and 30/3 P/lime (kg/t) rates in grain yield (Table 1).

Table 2: Effects of lime and P on the grain (a) and biomass (b) yields of bread wheat at Gozamen in 2011.

(a)

	Grain Yield kg ha^{-1} Lime t ha^{-1}			
P kg ha^{-1}	0	1	2	3
0	314.48^{i}	439.50^{hi}	540.51^{gh}	804.37^{de}
10	628.42^{fg}	730.06^{ef}	1067.87^{abc}	1120.26^{ab}
20	762.25^{ef}	930.56^{cd}	1030.53^{bc}	1133.42^{ab}
30	829.36^{de}	1114.01^{ab}	1202.33^{a}	1196.09^{a}
CV	9.97			

(b)

	Biomass t ha^{-1} Lime t ha^{-1}			
	0	1	2	3
0	1.01^{g}	1.20^{fg}	2.03^{bcde}	1.50^{efg}
10	1.43^{efg}	2.00^{cde}	2.50^{abcd}	1.93^{cdef}
20	2.37^{abcd}	2.40^{abcd}	2.80^{ab}	2.53^{abc}
30	1.73^{defg}	2.67^{abc}	2.93^{a}	2.50^{abcd}
CV	22.61			

The 2012 analysis of variance showed that there was significant difference among the treatments in all the variables considered in 2012 (Table 2). Similar to 2011, the maximum dry biomass and grain yields were obtained from 30 kg P ha^{-1} with 2 t lime ha^{-1} followed by 30 kg P ha^{-1} with 3 t lime ha^{-1} and 20 kg P ha^{-1} (Table 3). The lowest grain and biomass yields were obtained from the control. The yield advantage of using 30 kg P ha^{-1} fertilizer with 2 t lime ha^{-1} was 282.32% (887.85 kg ha^{-1}) in 2011 and 363.19 % (917.59 kg ha^{-1}) in 2012 compared to the control while the yield advantage over the recommended fertilizer alone was 44.97% (372.97 kg ha^{-1}) in 2011 and 111.09 % (615.86 kg ha^{-1}) in 2012 (Table 2 and 3).

Table 3: Effects of lime and P on grain (a) biomass (b) yields on bread wheat at Gozamen in 2012.

(a)

	Grain Yield kg ha^{-1} Lime t ha^{-1}			
P kg ha^{-1}	0	1	2	3
0	252.65^{g}	327.87^{fg}	511.52^{de}	396.39^{ef}
10	350.85^{fg}	743.45^{c}	701.13^{c}	957.52^{b}
20	384.87^{fg}	714.96^{c}	813.26^{c}	962.66^{b}
30	554.38^{d}	808.76^{c}	1170.24^{a}	1020.16^{b}
CV	12.83			

(b)

	Biomass t ha^{-1} Lime t ha^{-1}			
P kg ha^{-1}	0	1	2	3
0	0.37^{hi}	0.33^{i}	0.60^{fgh}	0.60^{fgh}
10	0.40^{hi}	0.53^{fghi}	0.87^{cde}	1.93^{cdef}
20	0.47^{ghi}	0.77^{def}	1.00^{bcd}	1.13^{b}
30	0.67^{efg}	1.20^{ab}	1.43^{a}	1.13^{b}
CV	19.90			

The pH improvement and decrement in exchangeable acidity and aluminum by applying 3 t ha^{-1} in moderately acidic soil was high in 2011 and very low in 2012 as the initial soil acidity was very severe. As shown Table 4, the experiment was conducted on different farms with different soil acidity extent, which is reflected through the improvement on soil pH, exchangeable acidity and Aluminum contents. The improvement in soil chemical properties was less in 2012 which indicates the extent of soil acidity is sever and 3t lime ha^{-1} was not enough to increase the pH above 5.5 and reduce the exchangeable acidity below 0.8 Cmolegm^{-1}. The pH above 5.5 and exchangeable acidity below 0.8 Cmolegm^{-1}are favorable for bread wheat production.

Table 4: Effect of lime on selected soil chemical properties at Gozamen

	2011				2012				
lime rate t/ha	pH (H2O)	EX.AL (cmol kg^{-1})	EX.H (cmol kg^{-1})	EX. Ac (cmol kg^{-1})	pH	Ex.Al (cmol kg^{-1})	Ex.H (cmol kg^{-1})	Ex.acidity (cmol kg^{-1})	CEC
0	5.07	1.37	0.50	1.87	4.46	2.48	1.01	3.50	18.82
1	5.12	1.01	0.50	1.51	4.48	1.54	0.63	2.17	17.17
2	5.31	0.83	0.48	1.31	4.50	0.82	0.53	1.34	17.67
3	5.38	0.47	0.53	1.00	4.58	0.63	0.42	1.04	18.50

At Banja

Similarly, at Banja Woreda, there was significant difference among the treatments (Table 5). The two years combined analysis result showed that the highest fresh and dry biomass as well as grain yield was recorded by using 20 kg P ha^{-1} and 3 t lime ha^{-1} followed by 10 kg P ha^{-1} and 3 t lime ha^{-1} (Table 5). This shows that at Banja, using lime is a good option to reclaim acidic soils and make it productive. As compared to the control plot, applying 20 kg P ha^{-1} and 3 t lime ha^{-1} gave an advantage of 84.8 % in grain yield.

Table 5: Response of bread wheat to lime and P combined over years at Banja.

Rates		Dry biomass (t ha^{-1})	Grain yield (kg ha^{-1})
Lime (t ha^{-1})	0	6.26^{b}	1874.9^{b}
	1	6.79^{ab}	2108.7^{ab}
	2	6.55^{ab}	2151.0^{ab}
	3	7.0^{a}	2483.1^{a}
	CV	19.51	35.37
P kg/ha	0	5.51^{c}	1699.5^{b}
	10	6.72^{b}	2316.6^{a}
	20	7.36^{a}	2461.8^{a}
	30	7.03^{ab}	2140.0^{ab}
	CV	19.51	35.37

Table 6: Effect of lime on selected soil chemical properties at Banja in 2012.

Lime rate t ha^{-1}	Soil sample after 90 days of lime application				Soil sample at harvest days of lime application			
	pH (H_2O)	EX.acidity (cmol kg^{-1})	EX.H (cmol kg^{-1})	EX. Al (cmol kg^{-1})	pH	Ex.Acidity (cmol kg^{-1})	Ex.H (cmol kg^{-1})	Ex. Al (cmol kg^{-1})
0	4.98	1.60	1.13	0.48	5.37	0.93	0.55	0.38
1	5.00	1.44	1.01	0.44	5.44	0.48	0.12	0.36
2	5.04	1.46	1.01	0.46	5.59	0.26	0	0.26
3	5.09	1.10	0.70	0.40	5.86	0.10	0	0.10

On the contrary, greenhouse experiment conducted by Chimdi *et.al.* (2012), to observe the response of barley on lime rate and particle size revealed that maximum yield was recorded by applying 10 t lime ha^{-1}. Since the area is severely affected by soil acidity, application of fertilizer without soil amendments might lead to phosphorous fixation and phosphorous nutrient may not be available to plants. From the result, it can be shown that addition of more phosphorous fertilizer in acidic soils like Gozamen wereda might not increase yield and yield components. Therefore amendment of soil acidity using lime is very crucial to boost yield.

Similarly, application of lime alone without fertilizer did not make any difference on yield and yield components at Gozamen wereda. So, integration of lime and chemical fertilizer is by paramount important to enhance crop production and productivity. This result was in conformity with Abaye A. (2011) who reported that application of lime alone did not influence maize production at Areka and application of lime with fertilizer generally increased maize production. The researcher added that he received maximum maize grain yield by applying 69 kg ha^{-1} N, 20 kg ha^{-1} P and 1.8 t lime ha^{-1} at the aforementioned location. Inconformity with our study, the research conducted at Nigeria on acidic soils also indicated that application of lime in combination with P was very important to increase the fruit production of Okra (Oluwatoyinbo *et al.*, 2005). Anetor and Akinrinde, (2006) approved that combined application of lime and P positively highly affected Soybean yield in Nigeria.

Teff at Mecha

The combined analysis of variance showed that there was a significant interaction effect of lime and phosphorus rates on teff yield at Mecha (Table 7). The maximum grain yield was obtained from 3 t lime ha^{-1} with 20 kg P ha^{-1} with 118.8% yield advantage over the control (Table 7). This result indicated that application of 3 t lime ha^{-1} with 20 kg P ha^{-1} has doubled the productivity of teff. This can approve the vertical yield increment for land is scarce due to population pressure and can ultimately increases the GDP of the country.

Table 7: Effect of lime and P on teff grain yield combined over years at Mecha

Phosphorous	Lime (t ha^{-1})				
fertilizer (kg ha^{-1})	0	1	2	3	Mean
0	625.8^{e}	640.0^{e}	606.7^{e}	827.5^{cde}	675
10	845.8^{cde}	779.2^{de}	710.8^{de}	863.7^{cde}	799.88
20	947.5^{bcd}	808.0^{de}	1174.2^{ab}	1327.5^{a}	1064.3
30	1288.7^{a}	1124.2^{abc}	1286.0^{a}	1226.3^{ab}	1213.07
Mean	926.95	837.85	830.57	1061.25	938.06
CV	27.93				

Table 8: Effect of lime on soil chemical properties at Mecha in 2011 at 45 days of planting.

lime rate t/ha	pH (H2O)	Ex.Al(Cmole kg^{-1})	Ex.H(Cmole kg^{-1})	Ex.Acidity (Cmole kg^{-1})
0	4.90	0.21	0.34	0.54
1	4.91	0.12	0.34	0.47
2	5.01	0.06	0.28	0.35
3	5.06	0. 057	0.24	0.30

Barley at Mafud-Mezezo-Tarmaber

The pH-H_2O of composite soil sample ranged from 4.6 to 5.41 (Table 9) which is in the range of highly acidic to moderately acidic soils (Tekalign, 1991).

Table 9. Initial chemical properties of soil from Mafud-Mezezo-Tarmaber

Parameters	2010/11				2011/12			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
pH-H_2O (1:2.5)	5.20	4.90	5.32	5.41	5.00	5.30	4.60	4.80
Exch. acidity (Cmole kg^{-1})	2.11	2.23	0.83	1.61	2.56	1.05	1.20	1.15

The main effect of lime and P were significant on barley biomass and grain yield. The highest grain yield (1926.28 kg ha^{-1}) was recorded from the highest level of lime and P while the lowest (844.92 kg ha^{-1}) was obtained from the control plot (Table 10). Even though lime has ameliorative effect on acid soil, initially this experiment was designed to observe one year effect of lime and P with half recommended fertilizer rate. But, this may not be representative because of the nature of the experiment that the effect of lime cannot be explained within a year. The second year result showed that application of 1 and 2 t lime ha^{-1} with 30 kg P ha^{-1} gave the highest barley grain yield while application of 2 t lime ha^{-1} alone gave the second highest and non significant biomass yield compared to the application of 2 t lime ha^{-1} with 30 kg P ha^{-1} (Table 11 and 12).

Table 10: Effect of lime and P on grain yield (kg ha^{-1}) of barley combined years at Mezezo.

	P (kg ha^{-1})			
Lime (t ha^{-1})	0	10	20	30
0	844.92^{h}	1209.33^{f}	1376.73^{e}	1654.24^{c}
1	953.58^{g}	1322.98^{e}	1673.65^{c}	1852.88^{ab}
2	1204.03^{f}	1495.46^{d}	1783.07^{b}	1926.28^{a}
CV (%)	11.97			
LSD (0.05)	98.27			

Table 11: Effect of lime and P on barley dry biomass yield (kg ha^{-1}) combined years at Mezezo.

	P (kg ha^{-1})			
Lime (t ha^{-1})	0	10	20	30
0	2100.8^{g}	2332.6^{g}		

As the level of lime increased, the pH increased. The highest pH (6.03) was recorded at the highest level of lime (Table 12).

Table 12: Effect of lime on soil pH after 45 days of lime application at Mezezo.

	P (kg ha^{-1})			
Lime (t ha^{-1})	0	10	20	30
0	5.36	5.41	5.29	5.35
1	5.90	5.81	5.81	5.82
2	6.03	6.00	5.97	5.86

Conclusion and Recommendation

The soils of Banja, Gozamen and Mecha are severely affected by soil acidity, application of fertilizer without soil amendments might lead to phosphorous fixation and phosphorous nutrient may not be available to plants. In addition, application of lime without fertilizer application will not improve crop yield except soil pH and exchangeable acidity in severely acidic Nitisols and Acrisols. On the contrary on soils like Cambisols with less acidity, application of lime may decrease P fixation and improve barley yield even without the application of P fertilizer. Of-course, it is advisable to use soil test P requirement of barley to decide to use lime alone or with P. The pH improvement, decrement in exchangeable acidity and aluminum at Banja, Gozamen and Mecha experimental sites were higher by applying 3 t lime ha^{-1}; however the amendment in these soil properties is minimum in strongly acidic soils and maximum in moderately acidic soil.

From the results, it can be concluded that addition of more phosphorous fertilizer in acidic soils did not increase crop yield. Therefore, amendment of soil acidity using lime is very crucial to boost yield. Applying 30 kg P ha^{-1} fertilizer with 2 t lime ha^{-1} for bread wheat at Banja and Gozamen gave a consistent grain yield and hence recommended for these Woredas. At Mecha, the result indicated that 30 kg P ha^{-1} can be applied solely for teff production as well as lower rates of lime application with phosphorus fertilizers can be applied for improving teff productivity. At Mafud-Mezezo-Tarmaber, for barley productivity, application 30 kg P ha^{-1} with 2 t lime ha^{-1} can give better grain yield.

Acknowledgement

Many thanks to the Amhara Agricultural Research Institute (ARARI) for the financial support for the research project. We also appreciate all staff members of Adet and Debre Berhan ARC who have been participating in the realization of this experiment and offered unforgettable support.

References

Ayalew Abay. 2011. The Influence of Applying Lime and NPK Fertilizers on Yield of Maize and Soil Properties on Acid Soil of Areka, Southern Region of Ethiopia. Innovative Systems Design and Engineering ISSN 2222-1727 (Paper) ISSN 2222-2871 (Online) Vol 2, No 7.

Anetor M.O. and Ezekiel A.A. 2007. Lime effectiveness of some fertilizers in a tropical acid alfisol. University of Ibadan, Ibadan, Nigeria.

Bierman, P.M. and Carl J. R. 2005. Nutrient Cycling and Maintaining Soil Fertility in Fruit and Vegetable &URS 6\VWHPV´ 7KH FROOHJH RI $JULFXOWXUH DQG (QYLUR University of Minnesota, Extension service.

Chimedi Abdena, Heluf Gebrekidan, Kibebew Kibret and Abi Tadesse. 2012. Effects of Liming on Acidity Related Chemical Properties of Soils of Different Land Use Systems in Western Oromia, Ethiopia: World J. Agric. Sci. 8(6):560-567. ISSN 1817- 3047

Fenton, G. and Helyar K. R. (2007). Soil acidification. In: 'Soils: Their Properties and Management'. (Eds. P. E. V. Charman and B. W. Murphy) pp. 224-237. (Oxford University Press, Melbourne.

Harter, R.D. 2002. Acid Soils of the Tropics. University of New Hampshire.The Pennsylvania State 8QLYHUVLW\ ³6RLO $FLGLW\ DQG $JOLPH´

McLean, E. O. 1965. Aluminum. In methods of soil analysis, part-II (C.A. Black, ed.) Chemical and microbiological properties of soils. American Society of Agronomy. Inc. Madison, Wisconsin, USA. pp.978-998.

Mesifin Abebe. 2007. Nature and management of acid soils in Ethiopia pp.5-19.

Oluwatoyinbo, F. I., Akande, M.O. and Adediran J.A. 2005. Response of Okra (Abelmoschus esculentus) to Lime and Phosphorus Fertilization in an Acid Soil. World Journal of Agricultural Sciences, 2005, 1(2): pp 178-183.

S.A.S. (Statistical Analysis System) 2002. Guide for personal computers. 6th edition. S.A.S. Institute Inc., Cary, NC, USA

Schlede, H., 1989. Distribution of acid soils and liming materials inEthiopia.Ethiopian Institute of Geological Surveys, Ministry of Minesand Energy. Addis Ababa, Ethiopia.

Tekalegn, T. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Workind Document No. 13. International Livestock Research Center for Afria, Addis Ababa.

Van Reeuwijk. L.P. 1993. Procedures for soil analysis 4th edition. Technical paper 9, ISRIC, Wageningen.