



Pre-Extension Demonstration and Evaluation of Soil Test Based Lime Application in Reclamation of Acid Soil for Cereal-Legume Productivity in Selected Districts of Western Oromia

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Abstract

The experiment was executed for three years (2016-2018) in three Districts of Western Oromia (Diga, Jimma Geneti, and Horro Districts). Two crops from cereal (maize, wheat) and one from legume (faba bean) were used as test materials throughout the experimental periods on 10m x10m side by side on limed and non-limed plots for all tested crops. The objective of the activity was to demonstrate and evaluate soil test-based lime application with recommended fertilizer for acidic soil reclamation in enhancing cereal-legume productivity of the smallholder farmers. Accordingly, descriptive data analysis indicated that among different parameters measured plant height, biomass yield, pod number for faba bean and total grain yield showed variations. The trial was demonstrated and evaluated by DA's, Woreda experts and by farmers of the FRG's. Eventually, they preferred the lime treated plots from the non-treated for all commodities tested due to greater plant height, deep green coloration and densely populated and vigorous performance/better crop stand for lime treated plots to the non-limed plots before harvested. Some physico-chemical properties of the soil (pH, Ca, Mg, K, Av. P(ppm), %TN, %OC, %OM) were also evaluated in line with crop yield and the other measured parameters. So, it showed that there is progressive change through the experimental period more for treated soil with lime than untreated plots. It is an indicator of soil nutrient availability were increased for crop growth and development as compared to composite soil parameters analyzed before sowing and consequently increased crop yield besides keeping soil health for long term utilization.

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Keywords: Acid Soil, Cereal-Legume, Grain Yield, Lime, Participatory Approach

Introduction

Soil acidity is a serious constraint for crop production in many regions of the world. Especially it is now a serious problem to crop production in most highland area of Ethiopia in general and in southern and western parts in particular. Currently, it is estimated that about 40% of the total arable land of Ethiopia is affected by soil acidity (Abdenna *et al.*, 2007; Taye, 2007) ^[1, 11]. From these 27.7% moderately to weak acids with pH 5.8-6.7 and 13.2% covered by strong to moderate acidic soils with pH less than 5.5 (Schlede, 1989) ^[10]. Acidic soils occupy approximately about 60 % of the land area of the earth. They arise under humid climatic conditions of the earth from carbonaceous less soil forming rocks in all thermal belts of the earth. Soil acidification is partly a consequence of the depletion of calcium and magnesium. This occurs through the leaching of cations of calcium and magnesium by infiltrating water and through uptake by crops. Acidification of soil is intensified by the application of mineral fertilizers, primary nitrates as well as by acid rains and climate change. Acidic soil reaction and the associated negative characteristics reduce the productivity of the soil and quality of crops as well as adversely affecting ecological balance in farm land. Soil acidity affects the growth of the crop because acidic soil contains toxic levels of aluminum, manganese and

characterized by deficiency of essential plant nutrients such as P, Ca, K, Mg, and Mo (Wang *et al.*, 2006)^[13]. At pH below 5, aluminum is soluble in water and becomes the dominant ion in the soil solution. In acid soils, excess aluminum primarily injures the root apex and inhibits root elongation. The poor root growth leads to reduced water and nutrient uptake, and consequently crops grown on acid soils are confronted with poor nutrients and water availability. The net effect of which is reduced growth and yield of crops (Wang *et al.*, 2006)^[13]. Soil acidity is expanding both in scope and magnitude in Ethiopia even though it varies from location to location and severely limiting crop production (Abdenna *et al.*, 2007)^[1]. The strongly acid soils are found in ecologies which receive or have historically received high incidence of rainfall and have warm temperatures much of the year. They are often found in Oxisols, Nitisols, and Ferralsols. Thus, the most strongly acidic soils are found in Western and South Western parts of Ethiopia, the central highlands, the high rainfall areas of North Western part of the country. Nevertheless, moderately acidic soils (pH 5.5- 6.5) are distributed through much of the rest of the country (Taye, 2008)^[12]. In moving from central (West Shoa) to Western Ethiopia (West Wellega), the degree of soil acidification that is measured in terms of acid saturation percentage is increased (ASP>60). In Western and Eastern Wollega Zones, the large proportions exchangeable acidity was due to exchangeable Al while at West Shoa Zone it was due to exchangeable H. The acidity problem in East and West Wellega Zone of Oromia Region is critical (Abdenna *et al.*, 2007)^[1] and deserved immediate intervention to amend the soils for crop production. As a case in point, a site-specific study of soils around Asosa and Wellega revealed that in aggregate, some 67 percent had pH values less than 6 and were very strongly to strongly acidic (Mesfin, 2007)^[7]. In some cereal crop growing areas (barley and wheat) of central and Southern Ethiopia, farmers have shifted to producing oats which is more tolerant to soil acidity than wheat and barley (Desta, 1988)^[3]. Considering this fact, the Federal Government of Ethiopia has identified soil acidity as a key agricultural problem and directed the concerned stakeholders to find integrated and sustainable solution to address the problem (Abdenna *et al.*, 2007)^[1]. Lime application to acidic soils is one of the solutions to address soil acidity problem (Brady and Weil; 2002)^[2]. There are voluminous research findings indicating that liming raises the pH of soil there by making unavailable nutrients in to available form to crops. Accordingly, for the last three years pre-extension demonstration and participatory evaluation of soil test-based lime application in reclamation of acid soil for cereal-legume productivity was conducted on three Districts of Western Oromia.

General Objective (s)

- To demonstrate and evaluate soil test-based lime application with recommended fertilizer for soil acidity reclamation in enhancing cereal-legume productivity of the smallholder farmers of Western Oromia

Specific Objectives

- To demonstrate and popularize acidic soil management practices with lime in acid belt areas of the study areas
- To enhance acid soil productivity for small farming system and other stakeholders consequently to ensure sustainable food security.

Material and Methods

Description of the study area

The experiment was carried out for consecutive three years during 2016, 2017 and 2018 main cropping seasons in purposively selected districts of Diga, Jimma Geneti and Horro. It was conducted on six farmer fields by selecting two farmers from each district considered as a replicate in collaboration with the district of Agricultural and Rural Development office.

Site selection and FRGs Organization

The selection criteria of the districts were based on their crop production potential for wheat, maize and faba bean and the suitability of the environment for that specific commodity. Besides, accessibility for supervision compatibility for the AGP criteria was considered as important parameters for selection. For both Diga and Jimma Geneti districts maize var. BH-661, and faba bean were used as test materials but wheat (buluk var.) and faba bean were used for Horro district. From each district 15-20 farmers were organized in FRGs and participated in all activities starting from land preparation until harvesting and threshing for comparison and knowledge sharing. The experimental area for all commodities (maize, wheat and faba bean) was 10 m x 10 m (100m²) plot size for lime treated and similar area for non-treated plots laid adjacent to each other for evaluation and comparison by FRGs and other stakeholders. Training were also provided for all FRG members regarding the importance of soil reclamation with lime and the proper management and monitoring required for the experiment being demonstrated in order to perform similar management practices at all locations. All commodities were sown keeping respective recommendation and proper agronomic management practices (fertilizer rates and its application methods, spacing between rows and plants, weeding time etc.) Data on pod number, plant height, biomass yield, and grain yield were collected and explained in descriptive statistics. Soil samples were collected after harvest from each plot and soil parameters like pH, Ava. P, %OM, %OC, %TN after harvest showed variations as compared to composite soil samples collected and analyzed before sowing.

Technology evaluation and demonstration methods/techniques

FRGs/FRGEs members and other nearby farmers were encouraged to participate on training and mini-field day programs organized at each demonstration sites. These are techniques used to enhance farmer-to-farmer learning and information exchange mechanisms.

Training of farmers and other stakeholders

Mini-field day was organized in each district (Horro, Jimma Geneti and Diga). Brief explanation on the progress of AGP project was clearly explained before field observations. On field day questioners and comments were entertained. Training/both theoretical and practical/ was provided to the farmers, woreda experts and for DA's on the importance of acidic soil reclamation with lime for sustainable crop production. All participants were invited to give comments with observing all commodities in the fields. The training covered a total of 108 farmers, 9 woreda experts, 21 DA's and 7 subject matter specialists. Among the farmers trained 88 of them were male and 20 are females. Eventually, the farmers, DA's, woreda expertise and researchers participated

on the training clearly observed the difference between lime treated and non-treated plots for all commodities in all the study areas and very much attracted with the performance of those limed plots to non-limed treatments. Finally, the farmers were decided to apply lime to their farm land for soil acidity reclamation and sustainable crop production.

Table 1: Stakeholders training participated across three demonstration districts

Participants	Districts			Remark
	Horro	Jimma Geneti	Diga	Total
Experts	3	3	3	9
DA's	7	7	7	21
Farmers	38	40	30	108
Researchers	-	-	-	7
Total	48	50	40	145

Source: Own data, 2018

Data collection (data type and method of data collection)

Both qualitative and quantitative data were collected using appropriate data collection methods FGD, direct field observation and recorded measurements. Agronomic and grain yield data were collected. Total number of farmers participated on extension events such as training, field visit and mini-field days were recorded by gender composition. Feedback assessments on farmers' preference to the demonstrated fields (likes and dislikes) and farmers' perception towards the performance of the technologies were also identified.

Data analysis

The data was analyzed using descriptive statistics such as mean of yields, yield components and soil parameters from the three years data recorded. It was interpreted by words and clearly by figure.1 for yield and table.1 for soil parameters respectively. Ranking techniques given by farmers, DA's, and expertise participated during mini-field day observation. Leaf color, crop stand/performance and plant height were considered as important parameters for selection criteria observed by participants. Percentage of yield advantage of lime treated over non-treated plots also considered.

Results and Discussions

Generally, for all tested commodities the results of the study revealed that variations/progressive changes were observed for measured parameters like (plant height, biomass yield, and pod number for faba bean and total grain yield) between lime treated and non-treated plots.

Agronomic and yield performance

A. For maize

The highest plant height was observed in maize var. (BH-661) 267.63 cm, 277.52 cm for limed plots but the lowest 262.22 cm, 256.88 cm were observed for non-limed plots at Diga and Jimma Geneti Districts, respectively. The highest average biomass yields 100.22qtha⁻¹, 120.58qtha⁻¹ were recorded for limed plots but the lowest average biomass 60.40qtha⁻¹, and 70.43qtha⁻¹ were obtained for non-limed plots in Diga and Jimma Geneti Districts, respectively.

Finally, the highest mean grain yield 44qtha⁻¹ and 56qtha⁻¹ were obtained having a yield advantage of 24.29% and 70% for Diga and Jimma Geneti Districts, respectively to the non-limed plots but the lowest mean yield recorded were 35.40qtha⁻¹ and 32.80qtha⁻¹ for similar Districts on non-limed plots. From this it is possible to conclude that parameters measured for all commodities, lime treated plots have greater as compared to the non-limed plots. The results of the study demonstrated that there was a significant increase in yield and yield components of maize due to the application of recommended nitrogen and mineral P fertilizer with liming acidic soil over the control. Since maize is a huge feeder of nutrients, application of recommended dose of mineral P and N fertilizer together with lime has paramount importance in reclaiming soil acidity and enhancing soil fertility, and improving maize yield and yield components. From this study, it is possible to deduce that integrated application of mineral fertilizers with lime amended the acidic soils and improved its fertility which in turn increased crop yield and yield components. Hence, application of lime based on the degree of soil acidity and mineral fertilizers is very crucial and could be recommended for reclaiming soil acidity and improve nutrients for maize as it enhanced grain yield and yield components of maize plant in strongly acidic soils. This result is in agreement with Okalebo *et al.* (2009)^[8] who stated that combined application of lime with nitrogen and phosphorus significantly increased maize yield in Kenya.

B. Faba Bean

The highest plant height for faba bean was 150.40 cm, 97.55 cm, 117cm were obtained from lime treated plots but the lowest value 128cm, 76.6cm, and 88.90cm were obtained from non-treated plots in Diga, Horro, and Jimma Geneti Districts, respectively. As the plant heights of faba bean increases the number of pods setting ability also increases consequently it has a positive effect on final yield. This result is in line with (Mesfin *et al.*, 2014) that stats growth parameters, yield and yield components were significantly increased with increasing rates of liming for Haricot Bean. The highest biomass yield obtained were 20.16qtha⁻¹, 20.1qtha⁻¹, 12.70qtha⁻¹ for lime treated plots but the lowest was 10.3qtha⁻¹, 10.13qtha⁻¹, 9.4qtha⁻¹ for Diga, Horro and J. Geneti Districts, respectively. The highest yields obtained were 11.6qtha⁻¹, 16.5qtha⁻¹, 6.2qtha⁻¹ but the lowest yield was 7qtha⁻¹, 3qtha⁻¹, and 4.1qtha⁻¹ for Diga, Horro and Jimma geneti Districts for limed and non-limed plots, respectively. Even though there is significant difference exists between lime treated and non-treated plots of faba bean but the following problems were observed:

- Non-uniformity of the crop over locations due to disease (Checoletspot)
- Lack of released resistant/tolerant varieties of faba bean to diseases
- Complexity and unidentified soil related problems, and
- Less attention of the farming communities for the crop management relative to the other crops in the study area

Due to those mentioned problems difficulties encountered regarding this crop production and clearly to identify the

difference between lime treated and non-treated plots to give recommendations like that of maize and wheat trials. So, it requires further investigation to have conclusive results.

Wheat

The highest plant height 96.73cm and the lowest 92.43cm were obtained for limed and non-limed plots, respectively in Horro District. The highest biomass yield recorded was

94qtha⁻¹ and the lowest is 65qtha⁻¹ for limed and non-limed plots, respectively in Horro District. The highest mean grain yield was 32.5qtha⁻¹ and the lowest is 27qtha⁻¹ for lime treated and non-treated plots, respectively in the same District. Labetowicz *et al.* (2004)^[5] and Fageria and Baligar (2001)^[4] reported that liming is the most common soil management practice and effective for reducing soil acidity related problems and it may be beneficial as plant nutrients.

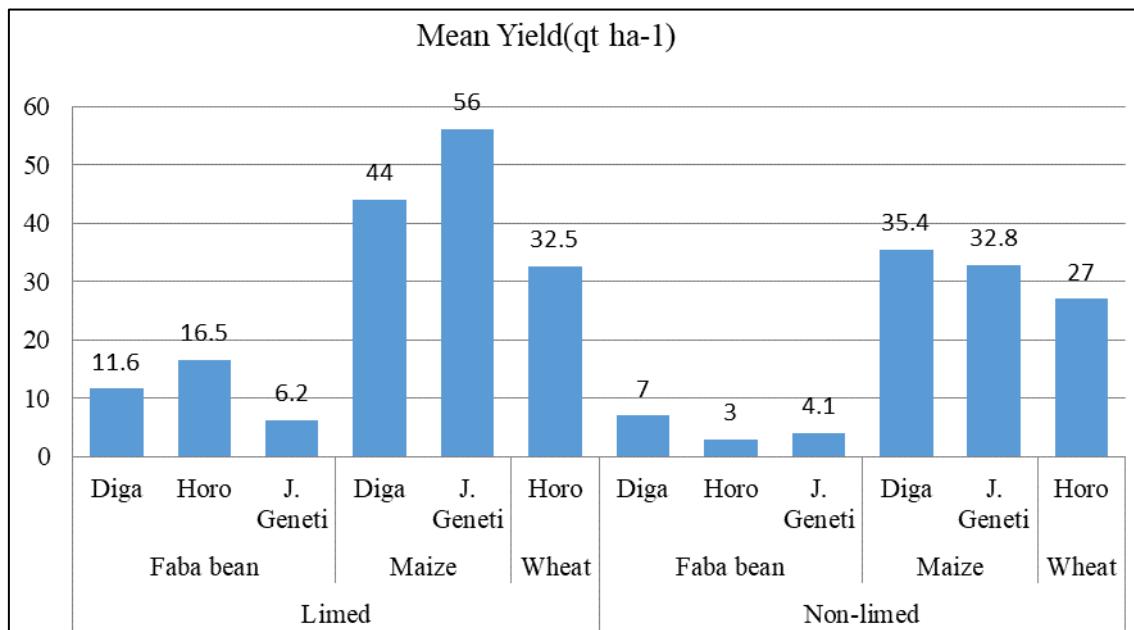


Fig 1: Over all mean yield data obtained for three years from over locations qtha⁻¹(2016-2018)

Soil data

Table 2: Over all summaries of three years some soil parameters (2016-2018)

Location	Horro				
	Crop type	Pre-sowing	Post harvest	Post harvest	Descriptions
Teated plot	F.Bean			Wheat	Source: Tekalign (1991)
Paraeters					
pH(1: 1.25 H2O)	4.84	5.47	5.55	Moderately Acidic	
Av.P(ppm)		-	-		
% OC		3.76	3.41		
% OM		6.47	5.88		
% TN		0.33	2.29		
Non-treated plot					
pH(1: 1.25 H2O)	4.84	5.37	5.42	Moderately Acidic	
Av.P(ppm)		-	-		
% OC		3.60	2.97		
% OM		6.22	5.12		
% TN		0.31	0.25		

Key: pH- power of hydrogen, Av.P(ppm) Available Phosphorus, %OC(Organic Carbon), % OM(Organic Matter), %TN(Total Nitrogen)

Location	J.Geneti				
Parameters	Crop type	pre-sowing	Post harvest	Post harvest	Discription
Teated plot	F.Bean		Maize		Source: Tekalign (1991)
pH(1: 1.25 H2O)	4.59	5.26	5.28	Strongly Acidic	
Av.P(ppm)		-	-		
% OC		4.19	2.34		
% OM		7.23	4.03		
% TN		0.36	0.20		
Non-treated plot					
pH(1: 1.25 H2O)	4.59	5.15	5.17	Strongly Acidic	
Av.P(ppm)		-	-		
% OC		2.44	2.15		
% OM		4.20	3.70		
% TN		0.21	0.18		

Key: pH- power of hydrogen, Av.P(ppm) Available Phosphorus, %OC(Organic Carbon), % OM(Organic Matter), %TN(Total Nitrogen)

Location	Diga				
Parameters	Crop type	pre-sowing	Post harvest	Post harvest	Descriptions
Treated plot	F. Bean		Maize		Source: Tekalign (1991)
pH(1: 1.25 H ₂ O)		4.58	5.28	5.32	Moderately Acidic
Av.P(ppm)			-	-	
% OC			3.56	3.10	
% OM			6.13	4.70	
% TN			0.31	0.23	
Non-treated plot					
pH(1: 1.25 H ₂ O)		4.58	5.19	5.19	Strongly Acidic
Av.P(ppm)			-	-	
% OC			2.92	2.76	
% OM			5.04	4.28	
% TN			0.25	0.21	

Key: pH- power of hydrogen, Av.P(ppm) Available Phosphorus, %OC(Organic Carbon), % OM(Organic Matter), %TN(Total Nitrogen)

From over all mean of soil parameters measured for consecutive three years it is possible to conclude that there is progressive change through the experimental period more for lime-treated plots than non-treated. This is an indicator of the availability of most soil nutrients for measured parameters were increased and available for crop growth and development consequently increased crop yield (biomass and grain yield). In line with this result, Fageria and Baligar (2008)^[4] in their review on the effects of ameliorating soil acidity come to the conclusion that liming improved the use efficiency of a number of elements by upland rice genotypes. Liming reduces Al^{3+} and H^+ ions as it reacts with water leading to the production of OH^- ions, which react with Al^{3+} and H^+ in the acid soil to form $Al(OH)_3$ and H_2O . The precipitation of Al^{3+} and H^+ by lime causes the pH to increase, enhances microbial activity and nutrient availability (Onwonga et al., 2008)^[9]. Practically, it was observed that crop yield numerically declines gradually from the year of lime application more on the third year. It indicates that the soil requires additional liming after the third year of lime application for renewal.

Farmers' opinion/perception

Based on establish farmers' selection criteria that include leaf color, vigorous performance/crop stand, yield (biomass and grain). in all the three Districts (Horro, Jimma Geneti and Diga) farmers preferred those plots having deep green color of the leaf, crop stand/uniform performance, and the highest mean yield of the lime treated plots to non-treated.

Table 3: Overall total and mean score ranks and farmers' perception (selection criteria) for demonstration and participatory evaluation of lime treated and non-treated plots for cereal legume productivity

Districts	J. Geneti		Horro		Diga		Over all Rank	
	Total score	Mean Rank	Total score	Mean Rank	Total score	Mean Rank		
Lime treated plots	30	4.5 1st	20	4 1st	26	4.74 1st	1st	1st
Non-treated plots	30	3.5 2nd	20	3.5 2nd	26	3.75 2nd	2nd	2nd

Conclusion and Recommendations

In general, there is a possibility of harvesting an average yield for all tested commodities bread wheat buluk var.(32.5qtha⁻¹), faba bean16.5qtha⁻¹ and maize (BH-661) 56qtha⁻¹ from acidic soil with liming if the farmers and other end users exercises lime application in acidic environment together with crop rotation with legumes. In all parameters measured

(plant height, pod number/plant for faba bean, biomass yield, and mean grain yield) lime treated value were higher than non-treated plots. In the case of faba bean even though significant differences were observed between lime treated and non-treated plots for all measured parameters (Fig 1: above), it is difficult to give conclusive recommendations in both cases (lime treated and non-treated plots) since diseases and unidentified soil complexity related problems were observed and considered as obstacles for faba bean production at all the study sites. So, chemical screening, provision of resistant/tolerant varieties for producers, and investigation of soil complexity related problems need further investigations together with lime applications. All the soil parameters measured and analyzed during the study period also showed progressive change as compared to composite soil samples collected and analyzed in the first year before sowing. Eventually, further pre-scaling up for bread wheat and maize varieties were recommended to produce reasonable crop yield with liming soil acidity, to keep the soil health, and to feed the alarming rate of the country's population.

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