World Journal of Applied Chemistry
2025, Vol. 10, No. 3, pp. 71-77
https://doi.org/10.11648/j.wjac.20251003.14

Research Article

Participatory Evaluation and Demonstration of Agricultural Lime with Site Specific NPS Fertilizer on Wheat Production and Amelioration of Soil Acidity at Burka Jiren Watershed

Bati Dube*, Dagne Chimdessa, Gedefa Sori, Dechasa Mengistu, Amanuel Kejela, Mosisa Mezgebu, Suliema Aman, Belay Beyene

Oromia Agricultural Research Institute (IQQO), Bedele Agricultural Research Center (BeARC), Bedele, Ethiopia

Abstract

Soil acidity is among the major soil fertility bottlenecks causing low crop productivity worldwide. The addition of agricultural lime is used to mitigate soil acidity. Therefore, this study was conducted to Participatory evaluation and demonstration of Agricultural Lime with Site specific NPS Fertilizer on wheat production and Amelioration of soil Acidity at Burka jiren community watershed. The experiment was implemented during 2024 crop season in Gechi district at Burka Jiren community watershed. The treatments was consisted two level; T1= Recommendation 100% of P_2O_5 from NPS without Lime application, T2= Recommendation 100% of P_2O_5 from NPS with Recommended Agricultural lime and the recommended N fertilizer rate of 92 kg ha^{-1} was used for each treatment at equal ratio. The collected data was analyzed using T-test and interpreted as mean and standard deviation by SAS software version 9.0. Results indicated that the grain yield of bread wheat was significance ($P<0.05$) influenced between two treatments. The highest grain yield (28.167 qt/ha) was recorded from treatment two which treated by agricultural lime with site specific NPS fertilizer. However the lowest grain yield (11.25 qt/ha) was obtained from NPS fertilizer alone. The application of agricultural lime significantly increased the mean of soil pH from 5.07 to 5.57. Both treatments presented similar levels of organic carbon and total nitrogen. Farmers in the Burka Jiren community watershed should consider integrating agricultural lime with site specific NPS fertilizer to mitigate soil acidity and enhance crop productivity.

Keywords

Agricultural Lime, Bread Wheat, Site Specific NPS Fertilizer, Urea

1. Introduction

Soil acidity is among the major soil fertility bottlenecks causing low crop productivity worldwide [1]. Acidic soils consist of nearly 40-50% of the world's total potential arable land [2]. Besides, about 43% of agricultural land in the Ethiopian highlands is affected by soil acidity [3]. The west, north-west, southwest and south regions of the country that receive high amounts of rainfall and have good potential for agriculture are mainly affected by soil acidity [4]. High concentrations of Al, Mn and Fe, and extreme deficiency of essential plant nutrients such as P, N, S, Ca and Mg are considered to be the main constraints limiting plant growth and sustainable crop yields in acid soils [5]. High contents of Al and Fe cause extreme P

*Corresponding author: duberoba16@gmail.com (Bati Dube)

Received: 15 August 2025; **Accepted:** 28 August 2025; **Published:** 25 September 2025

fixation, which decreases the availability and use efficiency of soil P by the crops [6]. Phosphorus can be strongly adsorbed on the soil surfaces by forming chemical bonds with oxides and hydroxides of Fe and Al in acidic soils. Besides, Al toxicity primarily causes stunting of the primary root, inhibition of cell elongation and lateral root formation [7]. Poor root growth impaired nutrients and water uptake, making plants more susceptible to drought stress [8]. Bread wheat (Triticum aestivum L.) is one of the most important cereal crops playing a vital role in the country's economy, food security, and consumption. In Ethiopia, wheat covers an estimated area of 1.7 million ha with total annual grain production of 4.6 million tons by 4 million smallholder farmers. In terms of area of production, wheat ranks fourth after tef (Eragrostis tef [Zucc.] Trotter), maize (Zea mays L.) and Sorghum (Sorghum bicolor L.) and third in total grain production after tef and maize in Ethiopia [3]. However, the productivity of wheat is still low with a national average yield of 3 t ha^{-1} stations, i.e., 5 t ha^{-1} compared to yields obtained from the research [9]. Soil nutrient deficiency associated with severe soil acidity [10] and low nutrient inputs application are among the primary drivers of low wheat yields in the highlands of Ethiopia [11]. According to [12] research done on Maize at Omo Nada district stated that NPS and NPSB alone did not affect the yield but their combined application with lime significant affect maize yield. This increased yield might in part due to increased pH and reduced exchangeable aluminum and in part might be due to improved nutrients recovery as a result of lime application. Similarly liming has been considered an effective method to mitigate soil acidity, increase soil pH, nutrient availability, and crop yields [13]. Previous studies revealed that lime application significantly decreased exchangeable and soluble aluminum levels and increased soil pH, available soil nutrients such as P, N, exchangeable Ca and Mg [2]. Furthermore, lime application enhances microbial activities, organic matter mineralization, availability and uptake of nutrients [14]. Liming with optimal rate also substantially improves soil structure by binding the soil particles into more stable aggregates [15]. However, the practice of liming by smallholder farmers is inadequate in the study area due to its limited to supply. Thus, developing feasible mechanisms that can minimize the lime amount for resource-poor farmers is necessary. Information about the optimum lime rate to be applied is so far lacking. Therefore these study objectives initiated to demonstrate effect of NPS on calibrated soil test-based crop response with and without lime application on Bread wheat production and amelioration of soil acidity by lime application and to collect farmer's perception the use of lime application to ameliorate soil acidity and wheat production.

2. Materials and Methods

2.1. Descriptions of the Study Area

The watershed is situated in the Gechi district of Buno Bedele zone, southwestern Ethiopia (Figure 1). The specific place of the watershed is Bido Jiren Kebeles, and so the local communities named the watershed Burka Jiren Community Watershed. The watershed lies between 8°12'50.4" or 8°14'52.8 N latitudes and between 36°25'27.48" or 36°26'52.8" E longitudes. Burka Jiren Community Watershed is about 15 km from Gechi town in Gechi district and about 35 km from Bedele town in Buno Bedele zone. The watershed covers about 535.13 hectares, and 148 smallholder households benefit from the watershed. According to the Google Earth Pro software, the length of the Burka Jiren Community Watershed is about 6 kilometers from the watershed in-late to the outlet. Based on slope gradient, Burka Jiren Community Watershed is characterized mostly by slop, gently slop, and strongly slop. The dominant soil type of the watershed is nitosols, and the common crops produced by the communities are tef and wheat.

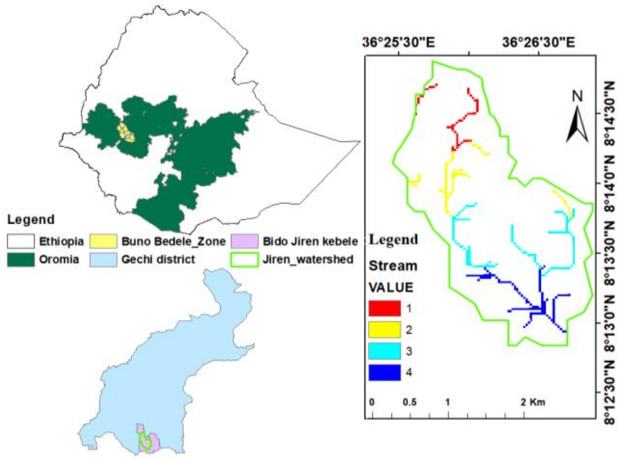

Figure 1. Map of Burka Jiren Community Watershed.

2.2. Sites, Farmer's Selection and Technology Promotion Events

The activity was conducted in purposively three selected farmers from the watershed based on wheat production potential, initial available phosphorus level of soil and their accessibility for determine the amount of P_2O_5 from NPS was determined. One FREG having 15 members (male and female) was established in each upper, middle and lower parts of the watershed. After, stablished of FREG three host farmers were selected among the FREG members and the activity were implemented on their farm land. The farmers Selection was done with collaboration of district experts and development agents. After the establishment of FREGs Mini-field day and training was provided for development agents, subject matter specialists (SMS) and FREG members on the use of lime application with and without chemical fertilizers, wheat production, management and its dissemination methods.

2.3. Materials and Research Design

The gross plot size of 100 m^2 (10 m x 10 m) was allotted for each two treatments: Recommended Phosphorus fertilizer (P_2O_5) from Soil test based was applied in all treatment equal amounts. Phosphorus rate was calculated and was applied according to the formula, P (kg ha-1) = (Pc - Po)*Pf, where Pc= Phosphorus critical level, Po = initial soil phosphorus in the soil and Pf= phosphorus requirement factor. The treatments was consisted two level; T1= Recommendation 100% of P_2O_5 from NPS without Lime application, T2= Recommendation 100% of P_2O_5 from NPS with Recommended Agricultural lime and the recommended N fertilizer rate of 92 kg ha-1 was used for each treatment at equal ratio. (at sowing and at knee time) and Kingbird bread wheat variety was used as a test crop with a seed rate of 150 kg ha-1 and row spacing of 20 cm. Full recommended dose of P_2O_5 fertilizer was applied as per the treatment and ¼ N was applied at sowing. Whereas, ¾ N was top-dressed at 30 days after planting and recommended Agri. Lime was applied one month before sowing to buffer soil acidity.

2.4. Soil Sampling and Analysis

Before planting, composite soil samples were randomly collected per farmer's field up-to 0-20 cm soil depth using an auger to determine the amount of lime recommended for the experimental field. The collected samples were ground and air-dried to pass 2 mm sieves, prepared, and analyzed for soil pH, and exchangeable acidity. The pH of the soils was measured potentiometrically and in water suspension of 1:2.5 (soil: water ratio) [16], whereas the exchangeable acidity was determined by saturating the samples with potassium chloride solution with sodium hydroxide titration [17].

2.5. Data to Be Collected

Grain yield, Farmers' perception towards the growth performance of bread wheat due to application of agricultural lime with chemical fertilizers and alone chemical fertilizers and Soil PH due to application of agricultural Lime. And total number of farmers participated in training was collected.

2.6. Data Analysis

The collected data was analyzed using T-test and interpreted as mean and standard deviation. Partial budget analysis was done to identify economically feasible recommended agricultural lime with inorganic fertilizer rate and fertilizer alone.

3. Results and Discussions

3.1. Soil Chemical Properties Before Planting of Experimental Field

The soil PH (H_2O) of the study sites were strongly to moderately acidic the value ranged from 4.80 to 5.39 according to the rating indicated by [18]. Thus the pH of the experimental soil was needed to amend by Lime ($CaCO_3$) in order to buffer the soil PH to become productive for plant growth. The available phosphorus contents of the soil were very low which ranged from 0.74 to 0.92 ppm this results agreed with [18] indicated that the available Phosphorus which put under less than 5 ppm was very low. The results of organic carbon indicated medium with value ranged from 4.23 to 5.85% this obtained results linked with [18]. The gain results of Total Nitrogen of the study sites before planting was medium with value ranged 0.36 to 0.5% it is also, agreed with [18] and Cation Exchange capacity of the soil ranged from 14.7 to 16.0 cmol (+)/kg soil, results shows medium level.

Table 1. *Soil Chemical properties of experimental sites before planting.*

Soil properties	Site 1	Site 2	Site 3	Mean
PH (H_2O)	4.8	5.39	5.01	5.07
Exchangeable acidity (meq/100gm soil)	2.32	0.12	1.32	1.25
Available P (ppm)	0.74	0.92	0.62	0.76
Organic carbon (%)	4.23	5.85	4.03	4.70
Total nitrogen (%)	0.36	0.5	0.35	0.40
CEC (cmol (+)/Kg soil)	14.7	16	14	14.90

The soil chemical properties of experimental sites after harvesting wheat, comparing two treatments:

The application of agricultural lime significantly increased the mean of soil pH from 5.07 to 5.57, (Tables 1 & 2) demonstrating its effectiveness in reducing soil acidity. Organic Carbon and Nitrogen: Both treatments presented similar levels of organic carbon and total nitrogen, telling that lime application did not negatively influence these soil health indicators. The combined use of NPS fertilizer and agricultural lime improved soil pH (reducing acidity) without compromising organic carbon or nitrogen content, supporting better wheat production in acidic soils. These results linked with [19] who stated that application of lime rates significantly affected soil chemical properties.

Table 2. Soil Chemical properties of experimental sites after harvesting.

Treatments	Mean of soil PH	Mean of organic carbon	Mean of total nitrogen
NPS fertilizer alone	4.77	2.89	0.25
NPS fertilizer with Agricultural lime	5.57	3.04	0.26

3.2. Participatory Mini-Field Visit Based Training for Participants

Participatory min-field visit based training was given to participants on the concept and principles of FREG, the role and accountability of the FREG members in management of the trial, application of Site specific NPS Fertilizer on wheat production and Amelioration of soil Acidity and importance of Agricultural Lime makes difference yield performance, improving soil reaction (PH) and at the end of the training; participants visit the trial field as all FREG members practice on their own field and whereas others share the experience. A total of 23 participants among which 15 farmers (13 male and 2 female), 2 DAs (2 male and 0 female) and 6 other concerned stakeholders (5 male and 1 female) were participated on field visit based training.

Table 3. Stakeholders participated on field visit based training events.

Watershed	Participant	Male	Female	Total
Burka Jiren Community	Farmers	13	2	15
	DAs	2	0	2
	Other stakeholders	5	1	6
Total		20	3	23

3.3. Effects of Site Specific NPS-fertilizer with Agricultural Lime and NPS-fertilizer Alone on Wheat Grain Yield

The obtained results revealed that indicates statistical significance ($p < 0.05$). This means the difference in yields between the two treatments is very unlikely due to random chance, confirming that adding agricultural lime to NPS fertilizer significantly improves wheat grain yield. The lowest grain yield gained from T1 which by NPS fertilizer alone (11.25 qt/ha), with a high standard deviation of 3.75, indicating significant variability in yield under this treatment. Whereas, the highest grain yield was recorded from treatment T2 which treated by NPS with Agricultural lime (28.167 qt/ha), The mean grain yield increased substantially to 28.167 qt/ha, with a lower standard deviation of 2.81, suggesting more consistent and higher yields compared to using NPS fertilizer alone. Depending on these results agricultural lime plays a critical role in ameliorating soil acidity, which enhances the effectiveness of NPS fertilizer, leading to higher and more stable wheat yields. The obtained results agreed with [20] who stated that the highest grain yield was obtained from combined use of Agricultural lime and NPSB blended fertilizer than the control (no lime only NPSB) fertilizers.

Table 4. The Effect of site specific NPS and Agricultural Lime on bread wheat grain yield (qtha^{-1}).

Treatments	Mean of	Standard Deviation
NPS fertilizer alone	11.25	3.75
NPS fertilizer with Agricultural lime	28.167	2.81
P-value	0.003	

3.4. Farmer's Preference of Wheat Production

Farmers selected T2 which treated by site specific NPS with agricultural lime rather than alone NPS fertilizer depending on the result obtained.

Table 5. Reason for preference of result obtained on wheat grain yield.

Treatments	Rank	Reason of farmers preference
NPS fertilizer alone	2nd	Poor performance of head, short length, deep brown color, and short head
NPS fertilizer with Agricultural lime	1st	Very good performance than T1, full head, attractive green color, longer than T1 and long head

3.5. Economic Partial Budget Analysis

The partial budget analysis of the treatments was done considering all variable costs and all benefits (grain yield). The analysis of marginal rate of return (MRR) revealed that the rate of return per unit cost of production was highest for application of site specific NPS fertilizer plus RN from Urea with Recommended agricultural lime (% MRR =372). This showed that it would yield gave 3.72 Ethiopian Birr for every Birr invested. Thus, applications of site specific NPS fertilizer plus RN from Urea with recommended agricultural lime ha^{-1} of is economically beneficial as compared to the NPS fertilizer plus recommended N from urea alone treatments, because the highest net benefit (NB) and marginal rate of return (MRR) was above the minimum level (100%).

Table 6. *Partial budget analysis for the site specific NPS and Agricultural Lime on bread wheat grain yield.*

Variables	Treatments	
	Bread Wheat with lime application	Bread Wheat without lime application
Yield obtained (qt ha^{-1})	28.167	11.25
Sale price (ETB/qt)	8,000	8,000
Total Revenue (Price * Qt)	225,336	90,000
Variable Costs/ha in ETB.		
Land preparation	4,000	4,000
Seed purchase	6,500	6,500
Fertilizers purchase	7,838	7,838
Cost of lime	600	0
Cost of labor for weeding	3,200	3,200
Cost of labor for lime application	1,200	0
Cost of Labor for harvesting	3,300	3,300
Cost of Labor for threshing	4,000	4,000
Total Variable Costs	30,638	28,838
Cost of Land ETB/ha	30,000	30,000
Total cost (TVC + TF C)	60,638	58,838
Gross Margin (GM)=TR-TVC	194,698	61162
Net Profit=TR-TC or GM-TFC	164,698	31,162
Benefit-cost ratio=Total Revenue/Total Cost	3.72	1.53

4. Conclusions and Recommendations

The results indicated that farmers in acidic soils should consider combining NPS fertilizer with agricultural lime to maximize productivity.

In generally, the data strongly support the use of agricultural lime alongside NPS fertilizer to boost wheat production in acidic soil conditions. The combined use of NPS fertilizer and agricultural lime improved soil pH (reducing acidity) without compromising organic carbon or nitrogen content, supporting better wheat production in acidic soils. This aligns with the study's goal of demonstrating sustainable soil management practices. Farmers in the Burka Jiren community watershed should consider integrating agricultural lime with site specific NPS fertilizer to mitigate soil acidity and enhance crop productivity.

Abbreviations

FREG	Farmers Research Extension Group
SMS	Subject Matter Specialists
Das	Development Agents
NB	Net Benefit
MRR	Marginal Rate of Return
ETB	Ethiopian Birr
Qt	Quinlat
TVC	Total Variable Costs

TFC	Total Farmers Land Cost
GM	Gross Margin
TR	Total Revenue

Acknowledgments

The authors would like to thanks Climate Action through Land scape Management (CALM P4R) for their funding of this research with collaboration Oromia Agricultural Research Institute and Bedele Agricultural Research Center for providing all the necessary facilities required respectively. Additional laboratory analysis team of Bedele Agricultural Research Center for their support and unreserved effort to provide reliable samples analysis data on time.

Author Contributions

Bati Dube: Conceptualization, Formal Analysis, Software, Validation, Writing – original draft

Dagne Chimdessa: Formal Analysis, Investigation, Project administration, Resources, Supervision

Gedefa Sori: Funding acquisition, Investigation, Project administration, Supervision

Dechasa Mengistu: Data curation, Formal Analysis, Investigation, Methodology, Software

Amanuel Kejela: Data curation, Formal Analysis, Resources, Software, Validation, Visualization

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] A. Getachew, et al., (2021). Extent and management of acid soils for sustainable crop production system in the tropical agroecosystems: a review, Acta Agric. Scand. Sect. B Soil Plant Sci. 1-18.

[2] L. Kochian, O. Hoekenga, M. Pineros, how do crop plants tolerate acid soils? Mechanisms of aluminium tolerance and phosphorous efficiency, Annu. Rev. Plant Biol. 55 (2004) 459-493.

[3] CSA, Agricultural Sample Survey Report on Area of Production of Major Crops Volume I, in: The Federal Democratic Republic of Ethiopia Central Statistical Agency. CSA Bulletin No 584, Addis Ababa., 2016.

[4] A. Ermias, H. Shimelis, M. Laing, M. Fentahun, Soil acidity under multiple land-uses: assessment of perceived causes and indicators, and nutrient dynamics in small-holders' mixed-farming system of northwest Ethiopia, Acta Agric. Scand. Sect. B Soil Plant Sci. 67 (2) (2017) 134-147.

[5] E. Eyasu, Soils of the Ethiopian Highlands: Geomorphology and Properties, CASCAPE Project, ALTERA, Wageningen University and Research Centre (Wageningen UR), The Netherlands, 2016.

[6] J. A. Omenda, K. F. Ngetich, M. N. Kiboi, M. W. Mucheru-muna, D. N. Mugendi, Phosphorus availability and exchangeable aluminum response to phosphate rock and organic inputs in the Central Highlands of Kenya, Heliyon 7 (November 2020) (2021), e06371.

[7] D. Castagnara, J. A. L. Dranski, F ́abio Steiner, Tiago Zoz, Artur Soares Pinto Dranski, Effects of Aluminum on Plant Growth and Nutrient Uptake in Young Physic Nut Plants, October, 2012.

[8] W. van Lierop, Soil pH and lime requirement determination, Soil Test. Plant Anal. (3) (1990) 73-126.

[9] H. Molla, M. Gashaw, H. Wassie, 2018. Response of bread wheat to integrated application of vermicompost and NPK fertilizers, Afr. J. Agric. Res. 13 (1) 14-20.

[10] G. Sori, B. Iticha, C. Takele, Spatial prediction of soil acidity and nutrients for site - specific soil management in Bedele district, Southwestern Ethiopia, Agric. Food Secur. 10 (59) (2021) 1-15.

[11] B. Workneh, E. Karltun, L. Mulugeta, T. Motuma, Long-term addition of compost and NP fertilizer increases crop yield and improves soil quality in experiments on smallholder farms, Agric. Ecosyst. Environ. 195 (2014) 193-201.

[12] Alemayehu Abdeta. Effect of Blended Fertilizer and Lime Application Rates on Grain Yield and Yield Component of Maize (Zea mays L.) in Omo Nada District, Jimma Zone South-western, Ethiopia. American Journal of Bioscience and Bioengineering. 2021, 9(4), 98-103. https://doi.org/10.11648/j.bio.20210904.11

[13] T. Geremew, B. Bobe, W. Lemma, Comparison of lime requirement determination methods to amend acidic Nitisols in central highlands of Ethiopia, Ethiop. J. Agric. Sci 30 (1) (2020) 35-48.

[14] S. Vishwanath, Sarvendra Kumar, S. K. S. Tapan Jyoti Purakayastha, S. P. Prasad Datta, K. G. Rosin, Prabhakar Mahapatra, Yadav, Impact of forty-seven years of long-term fertilization and liming on soil health, yield of soybean and wheat in an acidic Alfisol, Arch. Agron Soil Sci. (2020) 1-16.

[15] T. Gizachew, A. Etana, L. Juhl, H. Kirchmann, Liming with CaCO3 or CaO affects aggregate stability and dissolved reactive phosphorus in a heavy clay subsoil, Soil Tillage Res. 214 (July) (2021), 105162.

[16] Van Reeuwijk, L. P. 1995. Procedures for soil analysis. (No Title).

[17] MCLEAN, E. 1965. Aluminum. Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties, 9, 978-998.

[18] Food and Agricultural Organization of the United Nation. Rome, 2006 series No. 37.

[19] Workineh Ejigua, Yihenew G. Selassieb, Eyasu Eliasc, Eyayu Mollab, 2023. Effect of lime rates and method of application on soil properties of acidic Luvisols and wheat (Triticum aestivum, L.) yields in northwest Ethiopia.

[20] MULUKEN ALEMUa, MEKONNEN ASRATb* AND YIRSAW HUNEGAWb, 2022. Effects of lime and blended fertilizer rate on yield and yield components of bread wheat (Triticum Aestivum L.) in Basoliben District, Northwestern Ethiopia.