

Research Article

Evaluation of Micro-dosing Lime Application on Selected Soil Chemical Properties and Barley Crop Performance at Gedeo Zone, Southern Ethiopia

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Abstract

Liming acidic soil on smallholder farms is one of the major challenges to enhance crop yields in Ethiopian highlands. To address the problem associated with the high cost of liming, a precision technique referred to as lime micro-dosing, which involves application in small and affordable quantities of lime was evaluated on acid soil of the central highlands of Ethiopia from 2019/20 to 2020/21. The objective was to evaluate the effects of lime micro-dosing on selected soil physicochemical properties and yield and yield components of barley on farmers' field in suko and sika districts. The treatments consisted of 5 lime rates of (T1) 0%, (T2) 6.25%, (T3) 12.5%, (T4) 25%, and (T5) 33.3% of the recommended lime rate. The experiment was laid out in randomized complete block design (RCBD) with 3 replications. The result showed that application of lime significantly ($P < 0.01$) affected selected soil chemical properties and yield and yield components of barley. Soil pH was significantly increased from 5.0 to 5.8 and available P from 9.0 to 14.53 mg kg⁻¹. Exchangeable acidity decreased from 1.5 to 0.90 Cmol(+) kg⁻¹ due to lime application. Significant higher grain yield of barley was obtained from application of 25 and 33.3 % of recommended lime. Grain yield was increased by 100.5 and 110.2 % through application of 25 and 33.3 % of the LR of soils. Thus, application of 25 and 33.3 % of the LRs acid soils on spot at planting was found to be agronomically efficient and economically viable management option for barley production in the central highlands of Ethiopia.

Keywords

Biomass Yield, Exchangeable Acidity, Lime, Grain Yield, Soil pH

1. Introduction

Barley (*Hordeum vulgare* L.) is the major grain crop cultivated in Ethiopia's highlands, where soil acidity poses a significant concern. Barley production occupies approximately 0.95 million hectares, with a national average productivity of 2.5 t/ha⁻¹ [7]. While the Ethiopian highlands have enormous potential for barley production, this potential is severely restricted in many areas due to soil degradation, particularly

soil acidity.

In Ethiopia, where agriculture plays a vital role, an alarming 40% of arable land grapples with soil acidity or aluminum toxicity [23]. Moreover, approximately 43% of the cultivated land in the humid and sub-humid highlands of Ethiopia is affected by this issue [1]. The prevalence of acidic soil conditions in specific regions, particularly in the northern

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and western areas, can be attributed to elevated rainfall and steep terrain [9].

The acidic nature of these soils results in deficiencies in crucial cations such as calcium, potassium, and magnesium [2]. Consequently, this leads to reduced nutrient absorption by crop plants [12], constraints on root elongation [14, 17], and reduced crop biomass and yield, ultimately stunting crop growth and limiting plant productivity [4, 19]. Low pH has been identified as a factor contributing to yield losses exceeding 50% across various crop species [12].

Liming is the most commonly used and reasonably long-term method for mitigating soil acidity, and its effectiveness has been well established. However, significant quantities of lime need to be applied to alleviate soil acidity problems and optimize soil conditions for crop growth in the plough layer. The high cost of liming associated with these recommendations often prevents small-scale farmers from adopting the technology. Most lime recommendations in Ethiopia have been based on field experiments utilizing the broadcast application strategy. Applying large volumes of lime significantly impacts the chemical characteristics of acidic soils, particularly in raising soil pH to near neutrality, with effects that can last for three or more years. However, the high cost of liming acid soils to bring the soil pH to near neutrality has been negatively affecting adoption of the technology by small scale farmers. To alleviate the problem associated with adoption of the technology, a number of research activities have been conducted on micro dose and split application methods [21, 18] found that yields from applications of small doses using row application method or splitting over 2 or 3 years can give similar results compared to the high dose applications applied once using broadcast method.

Micro-dosing technology was developed and promoted by ICRISAT and partner institutions over a decade ago to enhance fertilizer use in the semi-arid tropics [5, 15, 27]. This technology was created in response to decreased crop yields in the semi-arid regions of Sub-Saharan Africa, attributed to various factors such as declining soil fertility due to monocropping, inadequate fertilizer application, unfavorable weather patterns, and the misconception that inorganic fertilizers burn crops.

Micro-dosing mitigates environmental harm by providing essential nutrients in affordable amounts, particularly for degraded or weak soils [27]. However, its disadvantages include the necessity for frequent application throughout the

planting season. Additionally, according to [8], liming acidic soil 40 to 60 days prior to planting facilitates proper lime decomposition and chemical reactions, thereby extending the effectiveness of liming.

The objective of this study was to evaluate the short-term effects of lime micro dosing on selected soil physicochemical properties and the performance of barley in the acidic soils of the Gedeo Zone Sika, and Suqo District of Ethiopia. However, there is no solidified information on the applicability of this method in this region. This study aims to benefit resource-poor farmers who cannot afford to apply the full recommended dose of lime on their soils.

2. Materials and Methods

2.1. Description of Study Sites

A field experiment was conducted over two consecutive cropping seasons (2019/20 and 2020/21) in Sika, and Suqo, Ethiopia, specifically in two Districts: Suqo (N 06°39'16", E 38°33'28", altitude 2893 m.a.s.l.) and Sika (N 06°13'16", E 38°13'25", altitude 2840 m.a.s.l.). The study took place on a total of five farmers' fields located in the Suqo and Sika districts of the South National Nationality Peoples Regional State in the southern part of the Ethiopian highlands. The soils in the study area are predominantly Nitisols, which are all acidic with a pH of less than 5.5. The agroecology is characterized as cool to humid, with a unimodal precipitation pattern where the main rainy season extends from June to September.

Experimental Design and Procedure

The experiment was conducted on selected areas of representative strong acidic soil affected areas with barely crop grown in the area. The treatment includes five level of liming factor and the experiment was arranged systematically and laid out in randomized complete block design. The control represents practice where farmers do not apply lime. All the treatments were received full recommended site-specific blended fertilizer uniformly at planting. Quick lime (Cao) was applied in row and fertilizer (NPS) was applied in band application method at planting, application of urea was in two splits. The amount of quick lime that was applied based on exchangeable acidity (EA) was calculated as follows:

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

Where LR = Lime requirement based on exchangeable acidity and EA = Exchangeable acidity

Table 1. Treatments and their description.

Treatment	CaCO ₃ kg ha ⁻¹ Treatments		
	Sika	Suko	Mean
Control	0	0	0
6.25% Recommended Lime	50.00	80.00	90.00
12.5% Recommended Lime	55.00	160.00	135.00
25% Recommended Lime	60.00	320.00	220.00
33.3% Recommended Lime	63.00	430.00	278.00

2.2. Soil Sampling and Analysis

Prior to planting, composite soil samples were taken in a diagonal manner from the experimental plots at a depth of 15 cm. Following harvest, plot-level samples were taken from the surface soil layer at random. Vertically inserting an auger produced uniform slices and volumes of soil for each sub-sample, which were then combined to generate a composite soil sample. The soil samples were then air-dried, ground with a pestle and mortar, passed through a 2-mm sieve, and analyzed for selected physicochemical properties such as soil pH, exchangeable acidity, available phosphorus, available potassium, cation exchange capacity (CEC), and exchangeable bases using standard laboratory procedures.

Soil pH was determined using potentiometric methods at a 1:2.5 soil-to-water ratio [28], total nitrogen was analyzed using the Kjeldahl digestion, distillation, and titration method [3], and available phosphorus was measured using the Bray II method. Exchangeable acidity was extracted with unbuffered 1M KCl, and exchangeable cations (Ca, Mg, K, and Na) were determined after extracting the soil samples with 1N ammonium acetate solution.

Table 2. Status of selected initial soil physical & chemical properties of Suqo and Sika sites.

Parameters	Sika	Suqo	Rating	Reference
Soil pH (1:2.5)	5.2	5.1	Strong acidic	Tekalign [25]
Exchangeable acidity (Cmol ₍₊₎ kg ⁻¹ soil)	1.2	1.5	--	--
P (mg kg ⁻¹)	10.62	9.01	Low	Landon [20]
K (Cmol ₍₊₎ kg ⁻¹ soil)	1.13	1.25	High	FAO [11]

Exchangeable potassium (K) ranged from 1.2 to 1.31 Cmol (+) kg⁻¹ soil, indicating sufficient K availability across all sites. Available phosphorus (P) ranged from 9.0 to 14.53 mg kg⁻¹, classified as medium [20]. The total nitrogen (N) content was categorized as low at most experimental sites, except for Sika, where it reached 0.31% [20]. Calcium

2.3. Agronomic Data Collection and Analysis

The yield data for each crop were collected from 10 randomly selected plants, and the average values were used for computation. Grain and biomass yield data were obtained from the middle ten to twelve rows and converted to kilograms per hectare for statistical analysis. The collected data were analyzed using analysis of variance (ANOVA) in SAS 9.3 software, [22]. Significant differences were further analyzed by comparing means using the least significant difference (LSD) method. A partial budget analysis was conducted based on CIMMYT [6], with prices set according to local market rates.

3. Results and Discussion

3.1. Soil Physicochemical Properties Initial Soil

Chemical properties

Different levels of micro-dosing lime application significantly affected the recorded yield and yield components of barley, while some parameters were not significantly impacted. According to the study results, the application of 25% of the recommended lime showed better yield and yield components in Suko kebele.

The initial soil properties of Suko and Sika are presented in Table 2. The soil texture is clayey, with a strongly acidic reaction, ranging from pH 5.0 to pH 5.8, [25]. This level of acidity suggests the potential for aluminum (Al) toxicity and a deficiency of certain essential plant nutrients, particularly cations. All sites in the Suko and Sika districts were characterized by high exchangeable acidity, indicating a significant risk of Al toxicity. Exchangeable acidity decreased from 1.5 to 0.90 Cmol (+) kg⁻¹ soil.

(Ca), magnesium (Mg), and sodium (Na) contents were classified as low to medium, while the cation exchange capacity (CEC) was considered moderate [11, 16]. (Table 2).

3.2. Effect of Lime Micro Dosing on Soil Physicochemical Properties

Chemical properties

The results of the lime micro-dosing effect on selected soil physicochemical properties after harvesting are presented in [Tables 1 and 2](#). Lime micro-dosing had a significant effect ($P < 0.01$) on several soil chemical properties, including soil pH, exchangeable acidity, and available phosphorus ([Table 2](#)).

Table 3. Effect of lime micro dose application on soil pH, Exch acidity and available P 2020/21.

TRT	pH 1:2.5	EA (cmolc/kg)	Aval. P
Control	5.00 ^c	1.30 ^a	9.10 ^b
6.25% of LR	5.20 ^{bc}	1.10 ^b	10.40 ^b
12.50% of LR	5.40 ^b	0.97 ^c	10.75 ^b
25% of LR	5.80 ^a	0.91 ^c	14.36 ^a
33.3% of LR	5.80 ^a	0.90 ^c	14.53 ^a

TRT	pH 1:2.5	EA (cmolc/kg)	Aval. P
Mean	5.40	1.05	11.80
LSD (0.05)	0.22	0.11	2.01
CV (%)	3.10	8.60	12.90

3.3. Effect of Micro Dosing of Lime on Grain and Biomass Yields

The effect of micro-dosing lime was also significant ($P \leq 0.01$) on the mean biomass yield (AGB) of food barley ([Table 4](#)). The highest AGB was obtained from applications of 25%, and 33.3%, of lime rate, while the lowest AGB was recorded from the control plot that received no lime. The mean dry AGBs were 10300 kg/ha, and 10800 kg/ha, for the 25%, and 33.3%, lime rate, respectively, while the control yielded only 7100 kg/ha. These findings align with previous studies, where AGB was significantly affected by liming, [26, 21]. Similarly, [13] reported that lime and phosphorus fertilizer application significantly increased the yield of food barley.

Table 4. The mean yield of barley as affected by different levels of lime rate in the area.

TRT	pH (cm)		SL (cm)		AGB (ton/ha)		GY (ton/ha)	
	2020	2021	2020	2021	2020	2021	2020	2021
Control	85.1 ^c	107.1 ^c	5.95 ^a	6.2	6.48 ^c	7.1	2.00 ^b	2.3 ^b
6.25%RL	90.7 ^b	107.2 ^{ab}	6.15 ^a	6.5	7.85 ^b	9.9	2.42 ^{ab}	2.75 ^a
12.5% RL	92.3 ^{ab}	106.9 ^c	6.07 ^a	6.3	8.07 ^{ab}	10.3	2.48 ^{ab}	2.89 ^a
25.0% RL	94.4 ^a	108.4 ^a	6.13 ^a	6.4	8.95 ^a	10.8	2.9 ^a	3.06 ^a
33.3% RL	90.7 ^b	108.3 ^{ab}	6.41 ^a	6.6	8.78 ^{ab}	11.2	2.8 ^a	3.22 ^a
CV%	1.97	0.53	4.76	3.87	6.72	13.58	11.56	7.38
LSD (0.05)	3.37	1.076	0.55	ns	1.01	Ns	0.55	0.38

4. Conclusion and Recommendations

Micro-dosing of agricultural Lime is significantly increased grain yields suggesting that the technology has the potential to improve Food barley production on acid soils of Suqo and Sika districts. The economic analysis indicated that micro dosing application at 25%, and 33.3% of the LR is an efficient and economically affordable method for small scale farmers. Thus, the following recommendation can be drawn from the results of the study: small scale farmers can use micro dosing application of lime at a rate

of 25%, and 33.3% of the LR of acid soils using row application method during planting time to improve the yields of Food barley. However, further work is required on the residual effect of micro dosing on soil properties and yields of crops.

Abbreviations

AGB	Above Ground Biomass
GY	Grain Yield
CMMIT	Collaborative Management and Mitigation Information Tool

ICRISAT International Crop Research Institute for
Semi-arid Tropics
MARR Minimum Acceptance Rate of Return

Author Contributions

Abreham Yacob is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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