10. Verification of Split Application of Lime on Acid Soils for Food Barley Production at North Shewa Zone highlands

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Abstract

The present study was conducted to investigate the response of food barley to row application of micro-dosing, which involves application of small, affordable quantities of lime during planting. A field experiment was carried out at Tarma ber and Basona warana districts of North Shewa Zone of Amhara Regional state, Ethiopia. A randomized complete block design with three replications was used. The treatments comprised of control (without fertilizer and lime), recommended fertilizer, 12.5, 25, 50, and 75% of the full dose of lime calculated based on exchangeable acidity method. The rate of recommended Nitrogen and Phosphorus fertilizer were 64 N and 46 P_2O_5 $Kgha^{-1}$. Phosphorus fertilizer was applied as a straight fertilizer at planting in the form of NPSB. Half of N was applied at planting and the remaining N was at tiller stage in the form of split application. Lime and fertilizer were applied to the soil by hand after planting using the band application method. The highest grain yield of barely (2.70 tha^{-1}) was recorded under the treatment of 75% lime with recommended fertilizer and followed by 50% lime with recommended fertilizer, while lower grain yield (1.24 tha^{-1}) was recorded under the treatment of control without lime and recommended fertilizer. Generally, application of lime in the form of micro-dosing and in row improved soil pH and significantly reduced exchangeable acidity of the soil after harvesting. As a result, grain yield of barley was improved. Even though, micro-dose application give significantly s grain yield of barley among treatment, which was significantly different from control the yield advantage as compared to with other treatments the lime application of 12.5 is economical.[1]. Therefore, 12.5% of the required lime applied in row could give better economic advantages for resource poor farmers who cannot afford to invest the total amount of required lime to be applied once at a time.

Keywords: food barley, lime, micro-dose application

Introduction

A major challenge to barley production in the highlands of Ethiopia is low soil pH and low fertilizer application which resulted low soil fertility status. Low soil pH reduces availability of several plant nutrients, increases levels of some elements to phytotoxic concentrations (i.e., Al^{3+} toxicity), and influences microbial activity or other soil properties (Brady, 1990; Merino *et al.*, 2010). These poor growth conditions can lead to reductions in root development which consequently causes slow vegetative growth and low total biomass per unit area. Application of lime is no doubt the best alternative to alleviate topsoil acidic problem and provide suitable conditions for adequate crop development. In Kenyan highlands application of 25-50% from actual lime requirement (3.09 tha^{-1}) application increased grain by 14-31% (Dillion and Hardkar, 1993) and 5-17% maize yield (Kisinyo and Palapala, 2015). Even though application of 46-69 $Kgha^{-1}$ P_2O_5 and 1-2 tha^{-1} of lime for barley at highland of North Shewa of Tarma ber district gave maximum yield increment (120-128%) as compared to plots without lime and phosphors fertilizer (Agumas *et al.*, 2016) to recommended and promote the above amount is challenged due to its bulkiness and unaffordable by small holder farmers.

A lot of efforts were done to improve the productivity of acid soils of Ethiopian highlands. Among those developed technologies, 25% of the actual lime amount determined using exchangeable acidity method (EAx1.5) applied in row during planting was economical and applicable to farmers (Agumas *et al*., 2021. Evaluation and verification of this technology has paramount importance. As a result, this research was done with the objective of evaluating and verifying the comparative advantage of micro-dose lime application compared to full dose synthetic fertilizer without lime and its effect on food yield barley.

Materials and Methods

Description of the Study Areas: The experiment was carried out at high land areas of north Shewa of Tamara Ber and Basona Warana districts for two consecutive seasons (2017/18-2018/19). Geographically, the experimental sites were located at a range of 09^0 9’ to 10^0 03’N and 40^0 02’ to 380 9’E in Tarma Ber and 09^0 36’ to 09^0 48’N and 39^0 39’ to 39^0 50’E in Basona Warana with a mean altitude of 2678-2935m and 2650-2868m m.a.s.l respectively. The long term climate data of the study areas characterized the area as a unimodal rainfall pattern and receive an average annual rainfall of 984 and 928 mm at Tarma Ber and Basona Warana districts respectively with a dominant soil type of Cambisols.

The experimental design was randomized with 3 replications and within each season three sites. The land was divided in to three blocks. Each block also was divided in to six plots with a size of 3.6 x 3.2m. Recommended rate of 64 N and P_2O_5 Kgha^{-1} fertilizers for barley was applied using urea and NPS sources respectively**.** Half of N was applied at planting and the remaining N was at tillering stage in the form of split application. Full dose of $P_2 O_5$ was applied at planting only. The control group comprises those who did not apply lime or the recommended fertilizer. At planting, each treatment received the entire recommended amount of fertilizer to the specific site. When planting, the band application method was used to apply lime and fertilizer, which were then manually mixed into the soil. HB1307 variety of food barley with a seed rate of 137.5 Kgha^{-1} was used as the test crop. The seed was drilled in rows and the space between rows was 20cm apart. From total rows 10 middle rows was harvested for yield measurement during harvesting.

In each seasons three farmers were selected based on their willingness and acid soil properties and exchangeable acidity which were determined at Debre Birhan Agricultural Center Soil laboratory (Table 2). Based on the result of exchangeable acidity, the actual requirement of lime was calculated using equation 1for each site. Different rates of lime were calculated based 12.5, 25, 50, and 75% from each site actual requirement of lime (Equation 2).

$$\mathrm{LR}\ (\mathrm{kg\ ha}-1) = \left[\frac{\mathrm{EA\,x\,SD\,X}10^{4}\,m^{2}\times\mathrm{BD\,x}1000}{2000}\right]\times 1.5 \ldots \text{ Equation (1)}$$

$$\text{Lime application in rows (kg/ha)} = \left[\frac{\text{Equation 1}}{100}\right]\text{x Y\%} \ldots\ldots \text{Equation (2)}$$

Where, **LR**=lime requirement in Kgha^{-1}

EA= Exchangeable Acidity **SD**=Soil Depth in cm

BD=Bulk density in Kg m^{-3} **Y%**=rate of Lime (0 12.5, 50 and 75%)

Soil Sampling and Analysis: Prior to planting and following harvesting, a diagonal pattern of composite soil samples were taken from the experimental plots at a depth of 0–20 cm. The sub-samples were combined into a composite soil sample after uniform slices and soil volumes were obtained in each sub-sample through the vertical insertion of an auger. Following air drying and grinding with a pestle and mortar, soil samples were then allowed to pass through a 2 mm sieve. Standard laboratory techniques were then used to analyze the soil samples for the chosen chemical properties, primarily soil pH, exchangeable acidity, and available Phosphorus. Potentiometric measurement of the pH of the soil was done in a 1:2.5 (w/v) soil to water supernatant suspension using a pH meter equipped with a combined glass electrode (Van Reeuwijk, 1992). In order to ascertain exchangeable acidity, the base titration method—described by (Rowell, 1994) which entails saturating the soil sample with a 1 M KCl solution and titrating with sodium hydroxide was used. Utilizing the Bray II method (Bray and Kurtz, 1945), the amount of available soil Phosphorus was extracted and measured colorimetric ally using a spectrophotometer set to 882 nm.

Statistical Analysis: All agronomic and soil data were analyzed using SAS software version 9.3 (SAS, 2002). Treatment means were separated using the least significant difference (LSD) at a statistical significance level of $P \leq 0.05$. Partial budget analysis was carried out using the CIMMYT (1988) technique based on local market prices.

Results and Discussion

The total lime requirements of the sampled sites were ranged from 0.46 to 2.71 tha^{-1}. These values were calculated from the analyzed value of exchangeable acidity (0.43-2.01 $CmolKg^{-1}$). According to Tekalign (1991) the pH of soils was ranged from strongly (5.01) to moderately (5.4) acidic value (Table 1). Soil sample analysis prior to planting revealed that soil exchangeable acidity and available Phosphorus levels ranged from 0.43 to 2.01 $CmolKg^{-1}$ and 5.54 to 7.11 ppm, respectively (Tekalign, 1991).

Table 1. Laboratory analysis result of selected soil chemical properties and calculated amount of lime for each site during 2017/18 and 2018/19 at Basona warana and Tarma Ber districts

Year	Districts	Site	pH (1:2.5)	Av.P (ppm)	Exch. Acidity ($CmolKg^{-1}$)	calculated lime (tha^{-1})
2017	Basona	Faji	5.30	6.86	0.53	0.72
		Angolela	5.01	5.58	2.01	2.71
	Tarma ber	Wiyenber	5.40	5.54	0.43	0.46
2018	Basona	Angolela	5.30	7.11	1.14	1.54
	Tarma ber	Wiyenber1	5.25	7.06	1.97	2.66
		wiyenber2	5.30	6.89	0.75	1.01

Soil sample analysis after barley harvest showed that soil pH value was significantly increased due to lime application as compared to control regardless of the lime amount. The higher soil pH was obtained when soil is limed while the lowest soil pH was observed at control (Table 2). These changes of soil pH might be attributed to the neutralizing effect of lime in acid soil due to application of lime at increasing rates (Tisdale *et al.,* 1997). Caires *et al.,* (2005) and Nekesa (2007) also reported that the application of lime decreased exchangeable acidity and increased the available P of acidic soils. In contrary, the highest exchangeable acidity was observed from control and recommended NP treatments (Table 2). The increase in pH and reduction of exchangeable acidity is related with the existence of basic cations such as Ca^{2+} and Mg^{2+})) and anions CO_3^{-2} in liming material which can able to exchange H^+ from exchange sites to form $H_2O + CO_2$. Cations occupy the space left behind by H^+ on the exchange leading to the rise in pH (Fageria *et al*., 2007).

Table 2. Soil chemical properties as influenced by lime application

Treatments	2017/18			2018/19		
	pH (1:2.5)	Av.P (ppm)	Exch. Acidity ($CmolKg^{-1}$)	pH (1:2.5)	Av.P (ppm)	Exch. Acidity ($CmolKg^{-1}$)
Control (0)	5.48^{c}	7.02^{b}	0.72^{ab}	5.37^{b}	6.41^{b}	0.92^{a}
64/46 N/P_2O_5 (RF)	5.47^{c}	6.30^{b}	0.84^{a}	5.40^{b}	6.91^{ab}	0.69^{a}
12.5% Lime + RF	5.55^{bc}	7.39^{b}	0.75^{ab}	5.57^{a}	7.24^{ab}	0.43^{b}
25.0% Lime + RF	5.58^{ab}	7.80^{ab}	0.71^{ab}	5.64^{a}	7.63^{ab}	0.42^{b}
50.0% Lime + RF	5.55^{bc}	7.79^{ab}	0.60^{bc}	5.73^{a}	7.80^{a}	0.41^{b}
75.0% Lime + RF	5.66^{a}	9.39^{a}	0.41^{c}	5.58^{a}	7.78^{a}	0.36^{b}
CV (%)	2.43	22.51	32.80	2.98	19.06	46.23
LSD (0.05)	0.09	1.63	0.21	0.08	1.32	0.25

The application of lime in micro-doses has been found to have a positive effect on improving the grain yield of food barley. Research has shown that the yield of food barley can be significantly improved by row applications of lime. The advantage in yield of barley by using 12.5% to 75% of the full dose of lime ranged from 10.2% to 25.0% on acidic soils. Even though, it was observed that the grain yield was consistently increased above the 50% lime application rate (see Fig 1). In the Kenyan highlands, it was found that applying 25% to 50% of the actual lime requirement (3.09 tons per hectare) increased grain yield by 14% to 31% for barley and by 5% to 17% for maize (Dillion and Hardkar, 1993; Kisinyo *et al.*, 2015). Furthermore, in the acid soils of Ethiopia's central highlands, Dereje *et al.*, (2022) demonstrated the efficiency of applying lime in small doses at a rate of 25% of the recommended rate based on exchangeable acidity at planting time to improve soil pH and Phosphorus availability and enhance fababean yield.

Figure 1. Grain yield increased with split application of lime on acidic soils (value in white shaded bar indicates the contribution of lime only and value in black shaded indicated that contribution of both inorganic fertilizer and lime application)

The application of lime in the form of micro-dosing has been shown to have a significant impact on grain yield as compared to control and recommended fertilizer treatments only (Table 3). The highest mean grain yield of 2.70 tha^{-1} was achieved with treatment combinations of 75% lime with recommended fertilizer, followed by 50% of the full dose lime, which was not significantly different each other. Moreover, the findings reveal that the grain yield from the 75% dose of lime was statistically comparable to treatments involving 12.5% and 25% doses of lime applied (Table 3). This implies that even low levels of lime application can lead to significant increases in grain yield. The effect of micro-dose application of lime on straw yield followed a similar trend as that of grain yield, indicating its potential benefits for overall crop productivity.

In general, Calcium-containing lime materials can improve nutrient availability, particularly Phosphorus, by lowering Phosphorus fixation (Mesfin, 1998; Rahman *et al*., 2002). Lime treatment increased soil nutrient availability, resulting in better crop yields and yield components. The study discovered that increasing the lime application rate had a clear association with grain yield in barley production, which increased correspondingly.

Table 3. Effect of row application of lime on food barley grain and straw yield of barley at Basona warana and Tarma ber districts 2017/18-2018/19.

Treatment	Grain yield(tha^{-1})						Grain yield (tha^{-1})	Straw yield (tha^{-1})
	2017/18			2018/19				
	Sit1	Site2	Site3	Sit1	Site2	Site3		
Lime (tha^{-1})	0.72	2.71	0.46	1.54	1.01	2.66		
Control (0)	1.72^{d}	0.08^{e}	2.17^{d}	0.86^{b}	2.14^{b}	0.46^{d}	1.24^{c}	2.28^{c}
64/46 N/P_2O_5 (RF)	2.70^{c}	0.42^{d}	3.20^{c}	2.36^{a}	2.86^{a}	1.40^{c}	2.16^{b}	3.33^{b}
12.5% Lime + RF	2.91^{bc}	0.80^{bc}	3.82^{ab}	2.33^{a}	3.11^{a}	1.76^{bc}	2.38^{ab}	3.61^{ab}
25.0% Lime + RF	3.42^{a}	0.58^{cd}	3.86^{ab}	2.39^{a}	2.57^{a}	1.88^{ab}	2.45^{ab}	3.51^{ab}
50.0% Lime + RF	3.30^{ab}	0.94^{ab}	4.18^{a}	2.00^{ab}	2.81^{a}	1.95^{ab}	2.53^{a}	3.63^{ab}
75.0% Lime + RF	2.93^{abc}	1.05^{a}	3.68^{b}	3.24^{a}	3.03^{a}	2.23^{a}	2.70^{a}	3.99^{a}
CV (%)	9.55	17.62	16.66	12.79	11.48	14.11	23.24	22.78
LSD (0.05)	0.51	0.25	0.43	0.39	0.55	0.43	0.35	0.51

Mean values within column followed by the same letter are not significantly different P>0.05)

Economic Analysis: As shown in table 4, total variable costs, which are responsible for yield increase in each treatment, were listed. The economic analysis revealed that application of 12. 25% of recommended lime gave marginal rate return values above 100% which is acceptable. The treatments were dominated by application of 12.5 of micro-dose lime application and full application of recommended lime. The net benefit and the MRR were 18152.8 ETBha^{-1} and 407.99%, from the application of 12.25% of recommended lime application per hectare. The control plot showed the lowest net benefit of 11143.6 ETB ha^{-1} (Table 4). As a result, among all treatments, micro dose application is the most cost-effective. The results are consistent with other studies (Twomlow *et al*., 2010; Afework and Yenesew, 2018), who indicated that micro dosing is one technology that can be affordable to farmers and assures that poor farmers get the best returns from this strategy since they cannot spend the largest dose of lime to reclaim the almost all of soil (Akibode S, Maredia M, 2011). Most treatments' returns improved as crop yield increased due to a minimal rise in production costs when compared to the achieved net returns with an acceptable

MRR. An increase in output will always improve profit as long as the marginal rate of return is more than the 100% (CIMMYT, 1988).

Table 4. Dominance and marginal analysis of barley grain yield.

Tr	GY* (Kgha^{-1})	ADGY (Kgha^{-1})	GB (ETBha^{-1})	TVC (ETBha^{-1})	NB (ETBha^{-1})	MRR%
control	1238.2	1114	11143.6	0.0	11143.6	_
RF	2155.8	1940	19402.4	2843.3	16559.1	190.46
12.5%+RF	2376.3	2139	21386.7	3233.9	18152.8	407.99
25%+RF	2451.1	2206	22059.7	3793.3	18266.4	20.31
50%+RF	2529.2	2276	22762.9	4743.3	18019.6	-25.98
75%+RF	2695.2	2426	24256.6	5693.3	18563.3	57.23

**GY=Grain yield, ADGY=Adjustable yield@10%, GB=Gross Benefit, TVC=- Total Variable Cost, NB=Net Benefit, MRR=Marginal Rate of Return (1 Kg of lime with transport costs=2.5 ETB and 1 Kg of Barley costs=10 ETB)*

Conclusion and Recommendation

The economic analysis of lime application in agriculture indicated that applying 12.25% of the recommended lime per hectare produced a marginal rate of return (MRR) greater than 100%, which is regarded acceptable. This suggests that investing in lime at this rate resulted in a strong return on investment. The net benefit of this application was estimated to be 18152.8 ETBha^{-1}, with a MRR of 407.99%. In comparison, the control plot resulted in the lowest net benefit of 11143.6 ETBha^{-1}. The study also discovered that of all treatments, micro-dose lime application was the most cost-effective. The total variable costs associated with a yield increase in each treatment were demonstrated, and it was revealed that most treatments' returns improved as crop output grew, minor increase in production costs. This resulted in an increase in net returns at an acceptable MRR. Finally, the economic analysis of lime application in agriculture revealed that applying 12.25% of the recommended lime per hectare yielded a significant net benefit and a positive marginal rate of return. Furthermore, of all the treatments studied, micro-dose lime application was shown to be the most cost-effective.

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