Original Research Article||

Response of food barley (*Hordeum vulgare* L.) to split application of lime in acidic Nito-Soil at Gummer District, Southern highland of Ethiopia

Tarekegn Tefera Lele[1]* Paulos Ketema[1], Sasahu Lewot[1] and Jemal Mohamed[1]

[1]*Southern Agricultural Research Institute, Worabe Agricultural Research Center P.O. Box 21, Worabe, Ethiopia*

Abstract

Soil acidity is a barrier to agricultural production in areas with heavy rainfall, leading to reduced crop yields in acid soils. A fixed plot field investigation was conducted to evaluate the influence of split application of recommended lime rate, based on exchangeable acidity, on yield and yield attributes of barley in acidic soils over three cropping seasons (2018, 2019 and 2020). Four level splits of lime (full dose of required applied at onetime, split in to two applied 50% in 1st and 2nd year, 50% in first and third year, split in to three applied 33% in every year) laid in randomized complete block design with three replications. Over years mean of grain yield was not statistically significant ($p < 0.05$) by split application of recommended amount of lime compared to one time application of full dose. The results revealed that the highest yield was recorded in all plots treated with lime while the lowest yield was recorded in the un-limed treatment. The highest yield (5.67 ton ha^{-1}) was recorded from full lime dose plant while lowest yield (2.4 ton ha^{-1}) recorded from control. Resource poor farmers who cannot afford the full dose of lime can split it into two or three applications annually, achieving similar yields to single full dose application. The increased yield of limed treatments might be attributed to rising of soil pH and making supplied nutrients plant-available.

Key words: Barley, lime, soil acidity, yield

Original submission: December 18, 2021; **Revised submission**: January 26, 2022; **Published online**: April 30, 2022

***Corresponding author's address:** Tarekegn Tefera, Email *tarekegntefera50@gmail.com*
Author(s): Paulos Ketema: paulove089@gmail.com; Sasahu Lewot: sasahulewot2008@gmail.com; Jemal Mohamed: *memsmo2008@gmail.com*

INTRODUCTION

Soil acidity is a complex process caused by the excessive concentration of non-soluble and toxic ions in the soil solution, which acts as a barrier to agricultural production in areas where heavy rainfall causes nutrient losses through leaching and soil erosion. Crop yields are frequently reduced by 50% in acid soils and can drop to zero even with the application of the optimum rate of NP fertilizers (Haile and Boke, 2011). Increasing soil acidity trends may lead to reduced yields, stunted plant growth and development, poor nodulation of legumes, and increased incidence of diseases. It can also result in poor water use efficiency due to nutrient deficiencies and imbalances, as well as induced aluminum and manganese toxicity (Kisinyo et al., 2014). Soil acidity and exchangeable Al^{3+} in arable and abandoned lands are attributed to intensive cultivation and continuous use of acid-forming inorganic nitrogen fertilizers (Deressa, 2013). According to Haile, *et al*., (2009), the Guragie district areas are severely affected by soil acidity. The severity of acidity has induced farmers to shift to producing oats, a crop more tolerant to soil acidity than wheat and barley (Deressa, 2013). The poor performance of crops that induced by acidic soils might be due to acidity decreasing plant growth owing to the unavailability of nutrients (P, Ca and Mg) and toxicity of some trace elements (Caires, *et al.*, 2005). Application of lime in the form of $CaCO_3$, CaO, and Ca $(OH)_2$ is becoming an adequate practice to reclaim acid soils. The main effect of liming is the neutralization of exchangeable H^+ and Al^{3+} and increasing the degree of base saturation and pH values. The decrease in exchangeable Al^{3+} and Mn^{2+} and the high reduction in Al activity in the soil solution is believed to be the main reasons for the frequently observed crop yield improvements as a result of liming acid soils (Fageria and Baligar, 2008). Many small-scale farmers of the country depend on acid soil for their day today livelihoods, thereby liming is a vital and commonly used to be enhancement of acid soil productivity. However, lime is not obtained for free and it is not easily available. Large quantities may be required for highly affected areas, and its transportation is also difficult. Therefore, the present study has been initiated to determine the efficiency of split application of lime on yield and yield attributes of barley under rain-fed conditions in acidic soils at Gumer District, Southern Highlands of Ethiopia, over three consecutive main cropping seasons (2018, 2019, and 2020).

MATERIALS AND METHODS

Description of the Study Area

A field experiment was carried out consecutive main cropping seasons for three years (2018, 2019, and 2020) under rain fed conditions at Gumer Woreda, Guraghe Zone, Southern Nations Nationalities and Peoples' Regional State of Ethiopia. Experimental site is situated at 7°59'26.2"N and 38°05'28.3"E, and at altitude of 2952 meters above sea level with temperature of min 7.5% and max 20%. The area receives a bimodal rainfall with an annual average rainfall of 1200 mm. Rainfall is distributed between the short rainfall season (March to April) and the main rainy season (June to September). Mixed crop-livestock farming is the dominant economic activity in the rural areas.

Experimental design and treatments

An HB-1307 variety of barley was used in the experimentation and was sown by drilling seed rate of 150 $kg \cdot ha^{-1}$; 20 cm spacing between rows and a plot size of 3mx3m. The experiment was laid out in randomized complete block design (RCBD) with three replications. Six levels of treatments (100% required amount of lime applied one time, 50% applied in 1st and 2nd year, 50% applied in 1st and 3rd year, 33% in every year, 92 Nitrogen 69 phosphorus kg ha-1, and Control). Good quality commercial grade agricultural lime ($CaCO_3$) with 98% neutralizing value and <250 µm in diameter was used. Lime requirement of the soil was calculated based on its exchangeable acidity (Al^{3+} and H^+) adapted from Kamprath, (1984). Lime was broadcasted uniformly and incorporated into the soil a month before planting (Mosissa, et al., 2019). Recommended rate of 92 Nitrogen, 69 phosphorus kg ha-1 were uniformly applied every year for all treatments except control. Urea was used as the source of N and its application was made in two splits: half at sowing and half at tillering stage while the entire rate of phosphorus was applied at sowing in a band. The experimental plots were kept permanent throughout the investigation.

Physicochemical Soil Characteristics

Before beginning experiment, experimental field was characterized for selected soil physical and chemical properties. Soil samples were collected from 0-15 cm depth for initial determination of soil fertility parameters. The soil samples were analyzed for pH, available phosphorus, exchangeable acidity, % Nitrogen, and % Organic carbon.

Table 1. Chemical and physical properties of soil prior to planting.

Descriptors	Levels
pH	4.8
EA	2.69
Ex H	1.6
BD	0.99
% OC	1.1
% TN	0.094
Ava. P (ppm)	1.28
CEC (cmol kg^{-1})	41.2
Textural Class	
Sand (%)	70
Clay (%)	14
Silt ((%))	16
Texture	Sandy loam

Agronomic data Collection

Different agronomic parameters such as plant height, spike length, tillers number was measured in (cm) from five plants sampled randomly from the central rows. Above ground dry biomass yield was weighed and grain yield was taken by threshing the harvested plants adjusted to 10% moisture.

Statistical data analysis

Data collected from the crop were subjected to analysis of variance using SAS version 9.0 software packages and mean separation was done using LSD (Gomez and Gomez, 1984) at 5% probability level.

RESULTS AND DISCUSSION

Physicochemical Properties of the Soil

Over the years, the mean data showed that split application of lime did not significantly affect barley grain yield at this study location ($p < 0.05$). Splitting the lime into three, two, or a full dose did not significantly affect barley grain yield throughout the entire experiment. Split application of lime into consecutive years gave similar grain yield with full rate application of lime. While compared to control, all split and full dose of lime application treatments gave significant yield in the consecutive years whereas the highest yield was recorded from full dose lime application in the first year. However, during the consecutive years, all split treatments resulted in similar grain yields compared to the full dose. The increased yield of barley treated with lime is due to the yearly application of lime, which increases nutrient availability and gradually increase pH and the buffering capacity of the soil, enhancing P release. Result revealed that splitting the required amount of lime into 33% and 50% is possible if to be grown on this soil. This result agrees with with those reported by Negese et al. (2022) and Dawid and Hailu (2017) who reported split application of lime in to 25%, 33%, and 50% was not significantly affected the yield of soybean compared with full dose application of lime. The finding of Anetor and Ezekiel (2007) also showed that lime increases pH and available P. Liming can increase soil pH and alter soil physical, chemical and biological properties. Therefore, resource poor farmers who cannot afford the full dose lime can split in to two, three and apply every year without yield loss significantly compared to one time application of full dose. Lime alone cannot boost crop production. Therefore, for increased production, the recommended amount of fertilization should be incorporated with lime. Induced declining the yield of plants that treated with only inorganic fertilizers might be phosphorus fixation nature of acidic soils.

Table 2. After treatment application or residual effects of lime on soil physicochemical properties

Treatments	pH	Ex. Acidity	Ava. P	%N	%OM
T1: Control	4.8	2.8	4.36	0.26	5.9
T2:92N 69P	4.75	2.85	4.4	0.27	6.0
T3: Full dose lime	5.4	1.6	5.5	0.29	5.8
T4: 50% (1st and 2nd year)	5.3	1.5	5.8	0.28	5.95
T5: 33% every year	5.35	1.3	6.1	0.26	6.1
T6: 50% (1st and 3rd year)	5.3	1.2	5.9	0.3	6.16

By the splitting application of lime above ground bio mass was not statistically affected ($p<0.05$) compared with full dose lime application in study area whereas limed treatments gave statistically highest biomass as compared to un-limed. Application of splitting lime i nto 33% and 50% and full dose treatments increased dry matter of barley. The increased biomass may be due to lime application release essential nutrients whi ch are un-available in acid soil and make it plant-avai lable nutrients. This finding agreement Dawid and H ailu (2017) who revealed that splitting application of lime was not statistically affected ($p<0.05$) yield and yield attributes of soy bean compared with full dose lime application.

Plant Height

Plant height was not significantly ($p < 0.05$) affected by the treatments during experimentation by splitting lime. But highest plant height was recorded from all limed plants whereas lowest plant height (cm) was recorded from un-limed treatment. The increased plant height of barley could be lime application attributed to rising of soils pH there by resulting vigor growth.

Tiler number and spike length

Tiller number and Spike Length also was not significantly ($p < 0.05$) affected by the split application of lime whereas significant difference was recorded from between limed and un-limed plants. The highest tillers and spike length was scored from all lime treatments. Similarly, Dawid and Hailu (2017) confirmed that application of splitting lime into 33% and 50% is and full dose treatments was not significantly ($p < 0.05$) increased growth parameters of soybean. While lime application was significantly ($p < 0.05$) affected growth parameters compared to un-limed due to applied lime ameliorate acid soil fertility status.

Table 3. Split application effect of lime affected yield and yield parameters of barley in 2018

Treatments	Plant height(cm)	Tiller Number	Spike Length (cm)	Biomass ton ha^{-1}	Grain yield ton ha^{-1}
T1: Control	76b	2.7c	4.6c	5.0c	1.66d
T2: 92N 69P kg/ha	115a	3.9b	5.6bc	8.6b	3.85c
T3: Full dose lime	123a	5.5a	7.2a	14.073a	6.28a
T4: 50% (1st and 2nd year)	112a	4.5b	6.8a	13.11a	5.72ab
T5: 33% every year	110a	3.9b	6.7a	12.77a	5.093b
T6: 50% (1st and 3rd year)	106a	4.6b	7.2a	12.223a	5.613ab
Mean	107	4.2	6.38	10.96	4.7
LSD (0.05)	17	0.83	1.36	3.23	0.75
CV (%)	9.18	10.77	11.72	16.23	8.85

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level.

Table 4. Split application effect of lime on yield and yield parameters of barley in 2019

Treatments	Plant height(cm)	Tiller Number	Spike Length (cm)	Biomass ton ha^{-1}	Grain yield ton ha^{-1}
T1: Control	90b	3.6b	2c	10.24c	2.72c
T2: 92N 69P kg/ha	100ab	5.4a	3.9b	15.49b	5.0b
T3: Full dose lime	110ab	5.6a	5.4a	19.16a	6.57a
T4: 50% (1st and 2nd year)	120a	5.2a	4.4ab	18.13ab	6.24a
T5: 33% every year	110ab	5.2a	4.4ab	19.20a	6.57a
T6: 50% (1st and 3rd year)	100a	5.4a	4.5ab	17.64ab	6.42a
Mean	105	5.1	4.14	16.64	5.49
LSD (0.05)	24	1.12	1.2	2.82	0.82
CV (%)	12.3	12.1	16	9.33	8.7

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level.

Table 5. Split application effect of lime on yield and yield parameters of barley in 2020

Treatments	Plant height(cm)	Tiller Number	Spike Length (cm)	Biomass ton ha^{-1}	Grain yield ton ha^{-1}
T1: Control	81b	3.1b	4.1b	7.48c	2.58c
T2: 92N 69P kg/ha	112a	5.2ab	5.5a	13.25b	3.85b
T3: Full dose lime	118a	5.6a	5.9a	16.17a	5.33a
T4: 50% (1st and 2nd year)	114a	5.8a	5.8a	16.03a	4.84a
T5: 33% every year	114a	6.4a	5.3a	16.14a	4.96a
T6: 50% (1st and 3rd year)	106a	6.3a	5.5a	15.92a	5.33a
Mean	107	5.4	5.3	14.06	4.44
LSD (0.05)	19	2.29	1.14	2.1	0.9
CV (%)	10.1	23	11.7	8.3	11.1

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level.

Table 6. Combined Mean of barley affected by split application of lime on yield and yield parameters of barley

Treatments	Plant height(cm)	Tiller Number	Spike Length (cm)	Biomass ton ha^{-1}	Grain yield ton ha^{-1}
T1: Control	82c	3.1b	3.6d	7.57c	2.32c
T2: 92N 69P kg/ha	110ab	4.9a	4.9c	12.45b	4.23b
T3: Full dose lime	117a	5.6a	6.2a	16.47a	5.98a
T4: 50% (1st and 2nd year)	116ab	5.2a	5.7ab	15.75a	5.60a
T5: 33% every year	112ab	5.2a	5.5bc	16.04a	5.54a
T6: 50% (1st and 3rd year)	106b	5.4a	5.7ab	15.26a	5.79a
Mean	107	4.9	5.3	13.92	4.91
LSD (0.05)	10	0.95	0.66	1.41	0.69
CV (%)	10	20	13.18	10.68	14.9

Means with in a column with the same letter(s) are not significantly different at 0.05 probability level.

CONCLUSIONS

Application of lime over the years, at the rate determined by exchangeable acidity, combined with mineral NPS fertilizer, improves grain yields. Without significant yield loss, splitting lime into 33% and 50% and applying it over three and two consecutive years, respectively, resulted in similar yields to the full rate of lime applied once in the first year. Therefore, resource poor farmers who cannot afford full dose lime could split up to one-third and can cultivate crops under acid soil at study area and as well as similar agro-ecologies. These preliminary results recommend the use of lime split in combination with mineral fertilizers to increase barley yields. Furthermore, research needs to be conducted to investigate the residual effect of split and full-dose applications of lime on the physico-chemical properties of acidic soil.

CONFLICTS OF INTEREST

Authors declare that there are no conflicts of interest regarding the publication of this paper.

ACKNOWLEDGEMENTS

I would like to thanks Southern Agricultural Research Institute for funding costs for experiment and Worabe Agricultural Research Center Natural Research Directorate case teams for their contributions.

REFERENCES

Anetor, Mercy Omogbohu and Ezekiel Akinkunmi Akinrinde(2007). Lime effectiveness of some fertilizers in a tropical acid alfiso. University of Ibadan, Ibadan, Nigeria.

Caires, E.F., Alleoni, L.R., Cambri, M.A. and Barth, G., 2005. Surface application of lime for crop grain production under a no-till system. Agronomy Journal, 97(3): 791-798.

Dawid, J. and Hailu, G., 2017. Application of lime for acid soil amelioration and better soybean performance in southwestern Ethiopia. J. Biol. Agri. and Healthcare, 7(5): 95-100.

Deressa, A., 2013. Evaluation of soil acidity in agricultural soils of smallholder farmers in South Western Ethiopia. Science, Technology and Arts Research Journal, 2(2): 01-06.

Fageria, N.K. and Baligar, V.C., 2008. Ameliorating soil acidity of tropical Oxisols by liming for sustainable crop production. Advances in agronomy, 99: 345-399.

Haile, W. and Boke, S., 2011. On-Farm verification of lime and NPK fertilizers effects on the tuber yield of Irish potato (Solanum tuberosum) on some acidic soils of Southern Ethiopia. Journal of Drylands, 4: 283-288

Haile, W., Boke, S. and Box, P., 2009. Mitigation of soil acidity and fertility decline challenges for sustainable livelihood improvement: research findings from southern region of Ethiopia and its policy implications. Awassa Agricultural Research Institute.

Gomez K. A. and Gomez A. A., 1984. Statistical procedures for agricultural research. John Wiley & Sons.

Kamprath, E.J., 1984. Crop response to lime on soils in the tropics. Soil acidity and liming, 12: 349-368.

Kisinyo, P.O., Othieno, C.O., Gudu, S.O., Okalebo, J.R., Opala, P.A., Ng'Etich, W.K., Nyambati, R.O., Ouma, E.O., Agalo, J.J., Kebeney, S.J. and Too, E.J., 2014. Immediate and residual effects of lime and phosphorus fertilizer on soil acidity and maize production in western Kenya. *Experimental agriculture*, *50*(1), pp.128-143).

Mosisa, F., Balemi, T. and Keneni, G., 2019. Effect of lime rates and incubation periods on the amelioration of acidic nitisols of Bedi area in Ethiopia. *Journal of Agricultural Science and Soil Sciences*, *7*(7), pp.087-093.

Negese, W., Mosisa, T. and Mulugeta, G., 2022. Split Application of Lime for Acid Soil Amelioration and Better Maize Yield at Yubdo Districts West Wollega Zone, Oromia, Ethiopia. population, 77.