Agriculture, Forestry and Fisheries
2022; 11(3): 100-104
http://www.sciencepublishinggroup.com/j/aff
doi: 10.11648/j.aff.20221103.11
ISSN: 2328-563X (Print); ISSN: 2328-5648 (Online)

Agronomic Performance of Barley as Affected by Biochar and Lime Application on Acid Soil of Hula Hagereselam Sidama, Ethiopia

Ashenafi Nigussie*, Abreham Yacob

Department of Natural Resource Management, Wondo Genet Agri. Research Center, Shashemane, Ethiopia

Email address:
nashenafinew@gmail.com (A. Nigussie)
*Corresponding author

To cite this article:
Ashenafi Nigussie and Abreham Yacob. Agronomic Performance of Barley as Affected by Biochar and Lime Application on Acid Soil of Hula Hagereselam Sidama, Ethiopia. *Agriculture, Forestry and Fisheries*. Vol. 11, No. 3, 2022, pp. 100-104. doi: 10.11648/j.aff.20221103.11

Received: April 25, 2022; **Accepted**: May 25, 2022; **Published**: May 31, 2022

Abstract: Biochar has been shown to improve soil chemical parameters such as pH, electrical conductivity (EC), cation exchangeable capacity (CEC), and exchangeable acidity, and currently, researchers are looking at its liming potential. In view of this, a field experiment was conducted to assess the main and interaction effects of biochar and lime on yield, and yield components of barley as well as selected soil chemical properties, and to determine optimum combination of soil amendment. A randomized complete block design (RCBD) with three replications was used to lay out a factorial combination of three levels of lime (0, 24.3, and 47.9 t ha^{-1}) and four levels of biochar (0, 5, 10, and 15 t ha^{-1}) with twelve treatments combinations. Over the unfertilized plot, the pooled mean analysis revealed that soil amendments had a substantial impact on yield and yield components as well as soil chemical properties. The combined application of 5 t ha^{-1} biochar and 24.3 t ha^{-1} lime t ha^{-1} resulted in the maximum grain yield of barley. The use of 24.3 t ha^{-1} lime and 5 t ha^{-1} biochar could significantly boost barley grain yields. Therefore, for barley production in the study area and acid soil amelioration, combined use of lime and biochar at rates of 24.3 t ha^{-1} and 5 t ha^{-1} could be proposed.

Keywords: Acid Soil, Barley, Biochar, Lime Application

1. Introduction

Land degradation including soil acidity is a great threat to future agricultural production in the country [1]. One of soil chemical degradation challenging the highland soils of the country is soil acidity which can be caused leaching by high rainfall and plant uptake of cations such as calcium (Ca^{2+}) and magnesium (Mg^{2+}) and application of acidifying N fertilizers such as diammonium phosphate (DAP) and Urea. Soil acidity affects productivity of the soil through its effects on nutrient availability and toxicity by some elements like aluminum (Al) and manganese (Mn); most plant nutrient become more limited in supply and a few micronutrients become more soluble and toxic. These problems are particularly acute in humid tropical regions that have been highly weathered [8, 20]. As soils become more acidic, particularly when pH drops below 5.5, it becomes increasingly difficult to produce different crops. High level of acidity can cause reduction of root growth, nutrient availability, affect crop protection activity, reduction and total failure of crops and deterioration of soil physical properties [8]. In general, it affects the biological, chemical and physical properties of soil, which in turn affects the sustainability of crop production.

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops in the world. In Ethiopia, among the cereals, barley is the fifth most important crop next to teff (*Eragrostis tef*), maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L.) and wheat (*Triticum aestivum* L.). It is the staple food grain for Ethiopian highlanders who manage the crop with indigenous technologies and utilize different parts of the plant for preparing various types of traditional food such as Kita, Kolo, Beso, Injera, local beverage called tela and as an important raw material for many industries [16]. The major production of barley still largely depends on the traditional varieties and farming practices, which is also assumed to be one of the constraints accounting for its low yield. In addition, cultivation of barley in marginal areas with low soil fertility, soil acidity in the highlands and diseases and pests contribute to the low yield levels of the crop. Because of this, the current production of Barley in Ethiopia cannot fulfill the demands of the rapidly growing population.

Biochar application helps to increase crop productivity through increasing soil nutrient supply and microbial activity and decreasing nutrient leaching [7]. Biochar helps to improve the supply of essential macro- and micronutrients for plant growth mainly in acidic soils [3]. Moreover, soil amendment with biochar addition, significantly improves soil structure by increasing soil porosity and aeration [5, 14], enhances WHC, and improves nutrient retention in soil micro pores [13]. Biochar strongly influences the composition and abundance of the soil microbial community, depending on its taxa, and the source and production technology of specific biochar, and thus plays a critical role in nutrient cycling [1].

Acidic soil amendments materials used as in practice and identify acid tolerant crops impacts on house hold income level determination of optimum yield production and productivity and validate food security. However, the basis of sustainable agricultural development is good soil quality. Performance evaluation of soil amendments materials, technical assessments thus material used as in practices their impacts on acid soil properties in crop performance, determination of acidic soil properties amendments materials, performance of major crops and identify best acid soil properties amendment materials for crop production.

Several research findings depicted that, amending acid soils with lime is indispensable to overcome soil acidity but should be combined with inorganic or organic inputs in order to get adequate production. Similarly, biochar addition on acidic soils also significantly improves the soil reaction. However, there is scanty information on the effect of lime and biochar application alone or in combination on the yield and yield components of barley in Sidama region, particularly at Hula Hagereselam. Therefore, the present investigation was under taken to examine the effects of biochar, lime and their mixture application on the yield and yield components of barley.

2. Material and Methods

2.1. Description of Soil Sampling Area

A field study was conducted in the Loya pesante association at Hula woreda, in Sidama zone, SNNPR, for two consecutive years (2016/17 and 2017/18) to explore the effects of biochar and lime application alone or in combination on barley yield and yield components. The site is around 350 kilometers south of Addis Ababa and 12 kilometers from Hager Selam town. The site is located at 38°30'47" E and 06°33'30"N, at a height of 2689 meters above sea level. According to Ethiopia's agro-ecological categorization, the location is classified as dega-agroecology, and the area is characterized by a bi-modal rainfall pattern with a lengthy duration. In the area, the average annual temperature (°C) and rainfall (mm) are 12.6-22.5°C and 1401-1600 mm, respectively. The dominant soil type of the woreda is nitiosls with clay loam textural class. These soils have relatively good agricultural potential. The major crops of the area where barley, wheat, oilseeds, and pulses.

2.2. Treatments and Experimental Design

A randomized complete block design (RCBD) with three replications was used to lay out a factorial combination of three levels of lime (0, 24.3, and 47.9 ton/ha) and four levels of biochar (0, 5, 10, and 15 t ha^{-1}) with a total of twelve treatment combinations. At seed rates of 125 kg ha^{-1}, a high producing cultivar designated HB-1307 was employed as a test crop. The plot size for each experimental unit was 2.4*3m =7.20 m^2. Crop management procedures were implemented evenly throughout all experimental units, as recommended.

2.3. Experimental Procedure

Biochar used in this trial was collected from wonji sugar cane factory and applied on weight bases, according to the treatments. Lime Requirement (LR) of the site was determined based on exchangeable acidity (Ex. Ac).

The full dose of lime was applied at once in the first year. Lime was broadcasts uniformly by hand and incorporated into the soil at least a month before planting. Urea and triple super phosphate were used as the sources of N and P, respectively. Application of Urea was applied in split form, while the entire rate of phosphorus was applied once during seed sowing in band row application method. The plots were kept permanent for the duration of the experiments to observe the carry-over effects of the lime.

2.4. Soil and Crop Data Collection

Prior to the application of the treatments, three composite soil sub samples were taken for the analysis of initial soil status. After experimentation, soil samples were collected from each experimental plot. The collected samples were combined, homogenized and prepared representative composite samples per each treatment. The collected soils were air dried at room temperature, ground and sieved through a 2 mm mesh wire for the analysis of Soil pH, EA and available P. Soil pH was determined by using a pH meter in a 1:2.5 soil/water suspension using pH meter, and exchangeable acidity was extracted by 1M KCl [17].

Table 1. *Effects of Biochar and lime application on pH, Exchangeable acidity and Available phosphorus after experimentation.*

pH (H_2O)	Exch. Acidity (Al^{+3} +H^+)	Av. P
5.04	0.904	3.11

Plant height was measured (in cm) from ground level to the base of the spike of ten randomly selected plants per just before physiological maturity and the average was taken for computation. Sun dried; aboveground biomass was measured at physiological maturity of barley from a net plot area of 4.8

m^2. The grain yield was harvested from a net plot area of 4.8 m^2 (2.4 m x 2 m) by excluding the border rows. The harvested grain yield was adjusted to 12.5% moisture level and it was converted into hectare bases. Thousand-seed weight was counted using an electronic seed counter from the bulk of threshed seeds and weighed using a sensitive balance from each plot at harvest and was adjusted to 12.5% moisture content. The harvest index was calculated using the following formula: - as the ratio of grain yield at 12.5% moisture to aboveground dry biomass and multiplied by 100.

$$Harvest\ index\ (\%) = \left(\frac{Grain\ yield}{Biological\ yield}\right) * 100$$

2.5. Statistical Data Analysis

The collected data were subjected to normality test prior to analysis, and then statistical analysis was carried out using the SAS 9.3 software package [16]. Differences among treatments (mean separation) was evaluated with the protected Least Significant Difference (LSD) at $P \le 0.05$ probability level [19].

3. Results and Discussion

3.1. Effects of Split Lime Application on pH Exchangeable Acidity and Available Phosphorus

Lime and biochar application had a positive effect on soil reaction, exchangeable acidity, and available phosphorus. Following the application of 24.3 t ha^{-1} lime and 5 t ha^{-1} Biochar, increases in soil pH, Exchangeable acidity, and Available phosphorus were observed, as well as a reduction in soil Exchangeable acidity. Previous research conducted revealed that soil chemical properties significantly improved due to the soil amendment through biochar application [9, 23]. Buni [2] showed that the application of 3.75 t lime ha-1 on Nitisol with a strong P fixation property improved soil pH from 5.03 to 6.72 and considerably reduced exchangeable acidity (EA) in southern Ethiopia. These preliminary findings show that using biochar and lime on one side and mineral fertilizers on the other could boost barley crop productivity in acid soils of the study area.

Table 2. *Effects of soil amendments on selected soil chemical properties.*

TRT	PH	EA	PA
1	5.15	0.22	2.77
2	5.20	0.26	3.99
3	5.15	0.38	5.18
4	5.11	0.22	3.15
5	5.02	0.30	3.99
6	5.27	0.26	3.58
7	5.29	0.23	4.31
8	5.24	0.32	4.35
9	5.01	0.58	3.17
10	5.32	0.17	7.17
11	5.25	0.58	3.17
12	5.18	0.22	3.95

3.2. Effects of Biochar and Lime on Plant Height Spike Length and Number of Tillers

The application of varying levels of biochar results in significant variation in plant height, according to analysis of variance; the highest pooled mean plant height was reported at 5 t ha^{-1}, though statistically comparable to plots treated with 10 and 15 t ha^{-1} (Table 3). Plant height was also affected by lime application; the highest and lowest pooled mean plant heights were found at 24.3 t ha^{-1} lime and control treatments, respectively. However, various levels of biochar, lime, and their interactions resulted in considerable differences in plant height, whereas the other parameters had no effect on spike length or number of tillers.

Table 3. *Means for plant height and spike length of barley as affected by phosphorus fertilizer, lime and their interaction at Hagereselam during 2016/2017 to 2017/2018 cropping seasons.*

Treatments	PH (cm)			SL (cm)			Number of tillers		
	Year 1	Year 2	Pooled mean	Year 1	Year 2	Pooled mean	Year 1	Year 2	Pooled mean
LR (t ha^{-1})									
0	93.66^b	93.60^b	93.63^b	0.66	0.67	0.66	63.80	65.56	64.68
24.3	100.78^a	103.48^a	102.13^a	0.69	0.69	0.69	66.33	64.81	65.57
47.9	99.43^a	101.05^a	100.24^a	0.69	0.69	0.69	64.18	63.93	64.04
LSD@ 0.05	2.77	3.33	2.11	ns	ns	ns	ns	ns	ns
BR (t ha^{-1})									
0	90.13^b	88.25^b	89.19^b	0.64^a	0.67^a	0.66^a	58.66^b	61.77^a	60.22^b
5	101.20^a	103.97^a	102.58^a	0.69^a	0.69^a	0.69^a	66.13^{ab}	65.24^a	65.68^{ab}
10	99.66^a	102.68^a	101.17^a	0.70^a	0.70^a	0.69^a	68.46^a	67.95^a	68.21^a
15	100.84^a	102.60^a	101.72^a	0.68^a	0.69^a	0.68^a	65.82^{ab}	64.11^a	64.96^{ab}
LSD@ 0.05	3.20	3.85	2.44	ns	ns	ns	8.58	ns	5.92
LR*BR*YR	***	***	***	NS	Ns	Ns	Ns	Ns	Ns
CV (%)	3.36	3.98	3.69	8.40	8.55	8.48	13.62	13.65	13.64

3.3. Effects of Lime and Bio Char on Above Ground Biomass, Grain Yield and 1000 Seed Weight

The results of a pooled mean study revealed that differing levels of biochar and lime, but not their interaction, had a significant (p 0.01) impact on aboveground biomass. These results show that varied levels of lime had no effect on the effects of different levels of biochar. The application of biochar and lime at rates of 24.3 and 5 t ha^{-1}, respectively, resulted in superior above ground biomass of 7.61 t ha^{-1} and 7.78 t ha^{-1}. Similarly, the application of varying levels of lime and biochar had a substantial impact on barley grain yield. The application of biochar and lime at rates of 24.3 and 5 t ha^{-1}, respectively, yielded the highest gain yields of 2.78 t ha^{-1} and 2.92 t ha^{-1}. The application of organic fertilizers such as crop residues, manures, compost and biochar to acid soils have been effective in reducing phytotoxic levels of Al resulting in yield increases [1, 18]. In all harvesting seasons, and pooled mean of TSWT did not show significant variation among different levels of lime and biochar. Therefore, sustainable barley production on acid soils in the highlands of Ethiopia should entail combined applications of both lime and biochar soil amendments materials has been used the best way barley production and productivity for sustainable development in hagera selam woreda condition.

Table 4. *Means for above ground biomass, grain yield and 1000 seed weight of barley as affected by lime, bio char and their interaction at Hagere selam during 2016/2017 to 2017/2018 cropping seasons.*

TRT	AGBM (t ha^{-1})			GY (t ha^{-1})			TSWT (gm)		
	Year 1	Year 2	Pooled mean	Year 1	Year 2	Pooled mean	Year 1	Year 2	Pooled mean
LR (t ha^{-1})									
0	4.50^{b}	8.72^{b}	6.61^{b}	1.78^{b}	2.91^{b}	2.35^{b}	32.42^{a}	36.84^{a}	34.63^{a}
24.3	5.73^{a}	9.56^{ab}	7.87^{a}	1.91^{b}	3.66^{a}	2.78^{a}	29.49^{a}	32.02^{b}	30.75^{b}
47.9	5.67^{a}	10.08^{a}	7.61^{a}	2.12^{a}	3.63^{a}	2.78^{a}	31.96^{a}	34.06^{ab}	33.01^{ab}
LSD@ 0.05	0.65	0.90	0.54	0.19	0.43	0.23		4.74	2.98
BR (t ha^{-1})									
0	4.26^{c}	8.48^{c}	6.37^{b}	1.61^{b}	2.80^{c}	2.21^{b}	26.99^{c}	30.90^{b}	28.95^{c}
5	5.37^{b}	10.18^{a}	7.78^{a}	2.24^{a}	3.61^{ab}	2.92^{a}	32.90^{ab}	35.25^{ab}	34.07^{ab}
10	5.7^{b}	9.98^{ab}	7.67^{a}	1.71^{b}	3.92^{a}	2.82^{a}	35.22^{a}	37.96^{a}	36.59^{a}
15	6.20^{a}	9.07^{bc}	7.63^{a}	2.18^{a}	3.27b^{c}	2.73^{a}	30.03^{a}	33.11^{ab}	31.57^{bc}
LSD@ 0.05	0.75	1.04	0.62	0.23	0.50	0.27	4.46	5.47	3.44
LR*BR*YR	*	Ns	**	***	**	***	Ns	Ns	Ns
CV	14.66	11.41	12.74	12.21	15.27	15.10	14.66	16.14	15.65

4. Conclusions

Soil acidity affects the growth of crops because acidic soil contains toxic levels of aluminum and manganese and characterized by deficiency of essential plant nutrients such as P, N, K, Ca, Mg, and Mo. According to the findings of this study, the experimental soil responded positively and considerably to the applied lime and biochar. Overall, the results demonstrated that the combined application of lime and biochar soil amendments resulted in considerable improvements in above ground biomass and grain yield. Barley grain yields could be increased significantly by using 24.3 t ha^{-1} lime and 5 t ha^{-1} biochar. Therefore, integrated use of lime and biochar with rate of 24.3 t ha^{-1} and 5 t ha^{-1} should be recommended for barley production in the study area and ameliorating acid soil.

References

[1] Agegnehu, G. Yirga, C. and Erkossa, T., 2019. EIAR Addis Ababa, Ethiopia. Soil Acidity Management, Ethiopian Institute of Agricultural Research, 2019.

[2] Buni, A., 2014. Effects of Liming Acidic Soils on Improving Soil Properties and Yield of Haricot Bean. J. Environ. Anal. Toxicol. 5, 1-4.

[3] Chan, K. and Xu, Z., 2009. Biochar: Nutrient Properties and Their Enhancement. In: Lehmann, J. and Joseph, S., Eds., Biochar for Environmental Management: Science and Technology, Earthscan, London, UK, 67-84.

[4] Getaneh S. and Kidanemariam, W., 2021. Soil acidity and its managements: a review, International Journal of Advanced Research in Biological Sciences, vol. 8, no. 3, pp. 70–79.

[5] Glaser B, Lehmann J, Zech W., 2002 Ameliorating physical and chemical proper-ties of highly weathered soils in the tropics with charcoal— a review. Biology and Fertility of Soils 35, 219–230.

[6] Goulding, 2016. Soil acidification and the importance of liming agricultural soils with particular reference to the United Kingdom. Soil Use and Management, vol. 32, no. 3, pp. 390–399.

[7] Graber, ER, TsechanskyL, GerstlZ, Lew B., 2012. High surface area biochar negatively affects herbicide efficacy. Plant and Soil 353, 95 –106.

[8] Harter RD. 2002. Acid soils of the Tropics University of New Hampshire. The Pennsylvania state university.

[9] Hong C., Su Y., Lu S. G. Phosphorus availability changes in acidic soils amended with biochar, fly ash, and lime determined by diffusive gradients in thin films (DGT) technique. Environ. Sci. Pollut. Res., 25, 30547, 2018.

[10] Kidanemariam A, Gebrekidan H, Mamo T, Tesfaye K. Wheat crop response to liming materials and N and P fertilizers in acidic soils of Tsegede highlands, northern Ethiopia. Agric For Fish. 2013; 2 (3): 126–35.

[11] LA, Harpole WF (2013) Biochar and its effects on plant productivity and nutrient cycling: a meta-analysis. Global Change Biology–Bioenergy 5, 202–214.

[12] Laekemariam F. and Kibret, K., 2020. Explaining soil fertility heterogeneity in smallholder farms of southern Ethiopia. Applied and Environmental Soil Science.

[13] Lehmann J, Joseph S., 2015. Biochar for environmental management: an introduction. In: Lehmann J, Joseph S (eds) Biochar for environmental management: science, technology and implementation. Taylor and Francis, London, pp 1–13.

[14] Lehmann, J., Da Silva, J. P. Jr., Steiner, C., Nehls, T., Zech, W. & Claser, B. 2003. Nutrient availability and leaching in an archeological Anthrosols and Ferralsols of the Central Amazon basin: fertilizer, manure and charcoal amendments. Plant Soil 249, 343–57.

[15] Mamo, T. and Haque I., 1991. Phosphorus status of some Ethiopian soils. II, Forms and distribution of inorganic phosphates and their relation to available phosphorus. Trop. Agric., 68: 2-8.

[16] SAS (Statistical Analysis System) 2004. SAS/STAT Software Syntax, Version 9.0. SAS Institute, Cary, NC. USA. 751pp.

[17] Sertsu, S., and T. Bekele. 2000. (Eds) Procedures for soil and plant analysis. National Soil Research Center, EARO, Technical Paper No. 74, Addis Ababa, Ethiopia. P 110.

[18] Sharma, P. K., Verma, T., and Gupta, J., 1990. Ameliorating effects of phosphorus, lime and animal manure on wheat yield and root cation exchange capacity in degraded Alfisols of North-West Himalayas. Fertilizer Res. 23, 7-13.

[19] Steel, R. G. D. and Torrie, J. H. 1980. Principles and Procedures of Statistics: a Biometrical Approach. 2nd Edition. McGraw-Hill. New York. Pp. 631.

[20] Takele, C. Iticha, B. and Sori, G., 2018. Index,” =e Anabasis of Cyrus, vol. 18, no. 5, pp. 275–281.

[21] Tessema G, Mekuria A, Enyew A. Assessment of Soil Acidity in Different Land Use Types; The Case of Ankesha Woreda, Awi Zone northwest Ethiopia; A Thesis Submitted to School of Graduate Studies of Addis Ababa University in the Partial Fulfillment of the Requirements for Degree of Master of Science in Environmental Science. 2008.

[22] Van Schoonhoven T, Voysest H (1991) Common bean: Research for Crop Improvement, CIAT, Cali, Colombia.

[23] Zhao B., Xu R., Ma F., Li Y., Wang L. Effects of biochars derived from chicken manure and rape straw on speciation and phytoavailability of Cd to maize in artificially contaminated loess soil. J. Environ. Manage, 184, 569, 2016.