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Time of Lime Application on Food Barely Yield in Acid Soil in Gumer Woreda, Guraghe Zone Ethiopia

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Abstract

Soil acidity is the main bottleneck to crop production, causing reduced yields in highlands areas with heavy rainfall. Lime application is the most common method of restoring soil acidity and can increase soil pH, improve nutrient availability for plants, and alter physical, chemical, and biological properties of soils. However, the lime application time varies greatly along the boundary and deviates from the time recommended by different researchers. The experiment was initiated to determine the appropriate timing of recommended lime application as a function of exchangeable acidity (Al^{3+} and H^{+}) on yield and yield attributes of barley on acidic soils during three main growing seasons. The experiment consisted of six treatments (incorporated lime 15, 30, 45, 60, 75 and 90 days before planting) and was arranged in a three-replicate randomized complete block design. The result over the years showed that barley yield and yield parameters were influenced in a statistically significant ($P < 0.05$) by the timing of lime application. The highest yield (5065 kg ha^{-1}) was obtained from lime incorporation 30 days before sowing, while the lowest yield (4050 kg ha^{-1}) was recorded from 15 days before sowing. The current experiment suggests that a reasonable lime reaction time is required to effectively neutralize the exchangeable acid. Therefore, practice application of lime beginning from 30 days and above earlier than planting to enhance the productivity of barley in study area and comparable agro-ecologies.

Keywords

Barley, Exchangeable acidity, Lime, Reaction time, Soil properties, Yield

Introduction

Soil acidity is the main bottleneck of crop production as it leads to reduced yields in highlands areas that receive heavy rainfall, leading to nutrient loss through leaching and soil erosion. Soil acidity is a complex process resulting from the excessive concentration of insoluble and toxic ions in the soil solution. On acidic soils, crop yields often halve and drop dramatically to zero even with a balanced application of NP fertilizer [1]. Soil acidity affects soil productivity through its effect on nutrient availability and the toxicity of some elements such as aluminum (Al) and manganese (Mn). The supply of most plant nutrients becomes more limited and some micronutrients become more soluble and toxic. These problems are particularly acute in the humid tropical regions, which are heavily stressed [2]. High acidity can result in reduced root growth, reduced nutrient availability, impaired crop protection activity, [3] yield reduction and total crop failure, and deterioration in soil physical properties, development poor legume node formation, increased disease incidence and poor water use efficiency due to nutrient deficiencies and imbalances and/or aluminum and manganese induced toxicity [4]. Soil acidity and exchangeable Al^{3+} on arable and fallow land are attributed to intensive agriculture and the continuous use of acid-forming inorganic nitrogen fertilizers [5]. According to [1], the areas of the Guragie District are severely affected by soil acidification. The severity of acidity caused by farmers has shifted to the production of oats, a crop that is more tolerant of soil acidity than wheat and barley [5]. The low crop yield caused by acidic soils could be due to acidity reducing plant growth due to lack of availability of nutrients (P, Ca and Mg) and toxicity of some trace elements [6]. Lime application in the form of $CaCO_3$, CaO and $Ca(OH)_2$ is becoming a good practice to remediate acidic soils. The main effect of liming is neutralization of exchangeable H^{+} and Al^{3+} and increase of base saturation level and soil pH. The decrease in the exchangeable Al^{3+} and Mn^{2+} and the strong reduction in

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Al activity in the soil solution are considered to be the main reason for the frequently observed improvements in crop yields as a result of soil liming [7]. Many small farmers in the country depend on acidic soil for their current livelihood. Therefore, liming is vital and often used to improve the productivity of acidic soils. It can increase soil pH and alter soil physical, chemical, and biological properties [8]. Lime application is the most common method for restoring soil acidity [9]. However, the lime application time varies greatly across the border and at different times recommended by various researchers. Therefore, the experiment was started to determine the appropriate timing of lime application for better barley yields for three main growing seasons with rain-field (2018, 2019 and 2020) on acidic soils in Gummer District, Guraghe Zone, SNNPR Ethiopia.

Materials and Methods

Description of study area

The field investigation was conducted in 2018, 2019 and 2020 under rainy conditions in Gummer Woreda, Guraghe Zone, Southern Nationalities and Peoples Regional State of Ethiopia. The test site is located at $7^0$57'10''N and $38^0$02'07''E and at an altitude of 2820 m above sea level. The area receives bimodal rainfall with an average annual rainfall of 1,200 mm. The amount of precipitation is distributed over the middle rainy season (March to April) and the main rainy season (June to October). Mixed cultures are the predominant economic system in the study area.

Experimental design and treatments

A HB: 1307 improved barley cultivar was used during the study and sown by seeding at a seed rate of 150 kg•ha^{-1}; the row spacing was 20 cm and the plot size was 3 × 3 m. A total of six treatment levels were studied during the experiment (lime was incorporated 15, 30, 45, 60, 75 and 90 days before sowing) and arranged in a three-replicate randomized complete block design (RCBD). With 98% neutralization value and < 250 µm lime ($CaCO_3$) diameter was used. The lime requirement of the soil was calculated based on its exchangeable acidity Al^{3+} and H^+ [10]. Lime was evenly spread by hand and incorporated into the soil accordingly. Recommended rate of 92 nitrogen, 69 P_2O_5 kg ha^{-1} and applied evenly to all treatments. Urea was used as the N source and its application was in two splits, half at planting and half at the tillering stage, while the total phosphorus dose was applied at band planting.

Physical and chemical properties of the soil

Before the start of the experiment, the experimental field was characterized for selected physical and chemical properties of the soil. Soil samples were taken at a depth of 0.15 cm for the initial determination of soil fertility parameters such as available phosphorus, exchangeable acid, % Nitrogen, and % Organic Carbon. Soil samples were then taken post-harvest to assess the changes in the soil as a result of the treatments applied (Table 1).

Collection of agronomic data

Five randomly selected plants from the center were measured in (cm) to determine various agronomic parameters such as plant height, stem length, spike and the number of tillers were counted. Dried biomass yield was weighed and grain yield was measured by threshing harvested plants adjusted to 12% moisture.

Statistical Analysis

The data collected were subjected to analysis of variance using SAS software packages version 9.4 and mean separation was performed using LSD with a probability level of 5%.

Results and Discussions

Influence of split lime application on soil chemistry after treatments

Lime application influenced soil chemistry. All of the liming treatments equally increased the pH and decreased the exchangeable acidity of the soil. The finding of [11] showed that lime increases pH and available P. Liming can increase soil pH and alter soil physical, chemical, and biological properties (Table 2) [8].

Effect of timing of lime application on yield and yield characteristics of barley

The result showed that the yield and yield attributes of barley were influenced in a statistically significant ($P < 0.05$) by the time of lime application in this study area (Table 3). The highest spike length, above ground biomass, and highest grain yield were recorded from lime incorporated into the soil 30 or more days prior to planting, while the lowest yield was recorded with lime applied 15 days prior to planting. Extended lime application time one month or more before planting gave a yield advantage over lime application 15 days before planting. Due to lime slowly improves soil acidity, early application of lime starting 30 days or more before planting is critical to allow a lime enough reaction time to release essential nutrients by ameliorate acid soil, raising the pH of acidic soils and thereby the availability of essential nutrients for plants is improved. According to [12], the pH of incubated acidic soils was significantly affected by the incubation time ($P < 0.05$); the pH of soils increases when the lime incubation time is long and suggested that to optimize the soil pH, the lime incubation time would be one month before planting, if soil moisture remains optimal. Liming increases plant productivity in acidic soils by improving nutrient availability for plants [11], according to [13] the increase in crop yield through the application of lime can be attributed to the neutralization of Al^{3+} supply Ca^{2+} and increased availability of some plant nutrients such as P. This indicated that lime application significantly improved initial soil acidity, eventually resulting in significant yield improvement [14]. [15] Positive reaction also reported the responses of barley root growth and yield upgrades on acidic Andosols because of liming. Liming may have decreased the adverse impact of soil acidity on plant growth because of excessive concentration of H^+ and Al^{3+} ions in the acidic soils [2]. However, plant height and tiller numbers have been now no longer statistically significantly ($P < 0.05$) affected by time of lime application at this study area during experimentation (Table 3).

Table 1: Chemical and physical properties of the soil before planting.

pH	Ex. H	EA	BD	%OC	%TN	AP	CEC	Soil type			
								%sand	%clay	%silt	Texture Class
4.7	1.6	2.88	0.96	1.1	0.094	1.26	31.64	31.08	22.28	46.64	Silty clay loam

Table 2: After application of treatment or after-effects of lime on soil physico-chemical properties.

Treatments	pH	Ex. Acidity (Cmol kg^{-1})	Ava. P (ppm)	%N	%OM
T1: 15 days before sowing	5.3	1.3	4.3	0.26	5.9
T2: 30 days before sowing	5.4	1.4	4.4	0.27	6.0
T3: 45 days before sowing	5.3	1.3	4.5	0.31	5.9
T4: 60 days before sowing	5.2	1.4	4.8	0.29	5.9
T5: 75 days before sowing	5.3	1.3	4.5	0.29	6.1
T6: 90 days before sowing	5.3	1.3	4.8	0.3	6.1

Table 3: Combined mean of yield and yield characteristics of barley affected by time of lime application.

Treatments	Plant height (cm)	Tiller number	Spike Length (cm)	Biomass ton ha^{-1}	Grain yield ton ha^{-1}
T1: 15 days before sowing	94	3.6	5.2b	9.71b	4.05b
T2: 30 days before sowing	114	4.6	6.2a	12.4a	5.06a
T3: 45 days before sowing	112	4.3	6.2a	11.66ab	4.62ab
T4: 60 days before sowing	108	4.6	5.9ab	11.88ab	4.77ab
T5: 75 days before sowing	110	4.0	5.7ab	11.42ab	4.59ab
T6: 90 days before sowing	105	4.0	5.4ab	12.38a	4.66ab
Mean	107	4.2	5.8	11.58	4.63
LSD (0.05)	NS	NS	0.99	2.66	0.96
CV (%)	10.2	14.3	9.3	12.6	11.4

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

Conclusion and Recommendation

The result revealed that yield and yield attributes of barley were statistically significantly influenced by the timing of lime application in this study area. The maximum yield was recorded from lime integrated earlier than a month's and above before planting. The present result suggested that the reaction time of lime in soils has to be increased for lime to effectively neutralize the exchangeable acid. Therefore, probable practice application of lime beginning from 30 days and above earlier than planting to enhance the productivity of barley in study area and comparable agro-ecologies.

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Conflicts of Interest

Authors claim that there aren't any conflicts regarding publication of this paper.

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