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Split Application of Lime on Acid Soil Amelioration and Bread Wheat Yield at Dember, SNNPR Ethiopia

Tarekegn Tefera, Paulos Ketema, Sasahu Lewot and Jemal Mohamed*

Southern Agricultural Research Institute, Worabe Agricultural Research Center, Worabe, Ethiopia

Abstract

Soil acidity is major yield-limiting factors for crop production in the highlands areas with heavy rainfall. Soil acidity affects the growth of crops due to high concentration of toxic acidic cations to plant. Field experiments was conducted under permanent plots to study the influence of splits application of recommended lime rate on yield and yield attributes of wheat in acidic soils during three main cropping seasons. The experiments consisted control, 92 N 69 P kg ha-1, four level of lime (full dose of recommended applied at one time, split in to two applied 50% in 1st and 2nd year, 50% in 1st and 3rd 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 highest yield (5.75 ton ha-1) was recorded from full dose limed plant while lowest yield (2.4 ton ha-1) recorded from un-limed treatment. The result revealed that the highest yield was recorded from all plots treated with lime application over un-limed. Thus, resource poor farmers who can't afford full dose lime one time can split in to two or three and apply every year without significant yield loss compared to one time application of full dose. The increments in yield of limed treatments could be applied lime attributed to rising of soils pH and making nutrients plant-available.

Keywords

Lime, Exchangeable acidity, Soil properties, Wheat, Yield

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important highland cereal crops and used for food and feeds. Ethiopia is one of the largest wheat producing countries in the sub-Saharan Africa [1]. The average productivity of wheat in Ethiopia is 2.3 t/ha which is quite below compared with average yields of Africa and world FAO [2]. Low soil fertility, low levels of input including fertilizer and quality seed, and soil chemical degradation (soil acidity) are the major yield-limiting factors. Soil acidity coverage's in Ethiopia assumed about 40.9% of the total arable land is affected by soil acidity of which about 27.7% is moderately acidic (pH 4.5-5.5) and 13.2% is strongly acidic (pH < 4.5) [3]. Alias [4] reported that 80% of Ethiopia's Nitisols are strongly acidic. Soil acidity is one of the most important factors which is aggravated by high rainfall and cause to leach exchangeable bases cations from the soil surface [5]. Soil acidity enforces plant to be stunted growth and principally limit crop production [6]. Acid soil is a major constraint for crop production in the highlands which affects the growth of crops due to high concentration of acidic cations such as H1+, Al3+, Fe2+, Mn2+ and NH4+ toxicity to plant and inhibit essential microorganisms activity which influences nutrient uptake and crop growth, and causes the deficiency of P, Ca, Mg and Mo in the soil; and thus, the negatively charged ions are strongly tied up by the Al and Fe components of acid soils, thereby the leaching of cations and binding of anions becoming unavailable for plant uptake [7-9]. Yield loss aggravated by soil acidity or Al toxicity and associated factors ranged from 25 to 80% [10]. The low pH affects significantly the fixation and the availability of soil nutrients and the abundance of acidic cations on colloid soil solution can be toxic to crop growth and leads to reduced crop yield [11,12]. Liming acidic soils has been recommended an effective measure to ameliorate acidic soils for the cultivation of crops at highlands areas as lime application improves availability of essential nutrients (Ca, P and Mo), fixation of nitrogen by rhizobium symbiosis and decreasing the solubility of toxic elements Al3+ and Mn2+ in the soil and

***Corresponding author:** Tarekegn Tefera, Southern Agricultural Research Institute, Worabe Agricultural Research Center P.O. Box 21, Worabe, Ethiopia, Tel: +251916067450

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thereby enhances root development, water, and nutrient uptakes [13,14]. However, lime is obtained not easily easy to get and large quantity may be required for highly affected areas and its transportation is also difficult. Therefore, the present study was conducted to determine the efficiency of split application of lime on yield and yield attributes of wheat under rain-fed condition for consecutive three main cropping seasons (2017, 2018, and 2019) in acid Nitosoils at Gummer district, Southern highland of Ethiopia.

Materials and Methods

Description of study area

A field experiment was conducted for two consecutive years (2019 and 2020) under rain fed conditions at Gummer district, SNNPR Ethiopia. Experimental site is situated at 7°59'36."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. Mixed crop-livestock farming is the dominant economic activity in the rural areas.

Experimental design and treatments

The improved Hidase variety of wheat was used for the experimentation and sown by drilling seed rate of 150 $kg \cdot ha^{-1}$; 20cm spacing between rows and plot size were 3mx3m. The experiment was laid out in randomized complete block design (RCBD) with three replications. Totally six levels of treatments were investigated during experiment (lime was applied by splitting in to four levels of treatments (100% applied one time, 50% applied in 1st and 2nd years, 50% applied in 1st and 3nd year, 33% in every year), 92N 69P kg/ha, Control). Having 98% of neutralizing value and <250 µm in diameter of lime (CaCO3 was used. Lime requirement of the soil was calculated based on its exchangeable acidity Al+3 and H+1 Kamprath [15]. Lime was broadcasted uniformly by hand and incorporated into the soil a month before sowing. 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 whereas the entire rate of phosphorus was applied at sowing in band. The experimental plots were kept permanent during investigation.

Physical and chemical 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).

Agronomic data collection

Five plants randomly selected was measured from the center of the plot, and determined different agronomic parameters such as plant height, spike length, were measured in cm and tiller numbers were counted. Above ground dry biomass yield was weighed and grain yield was taken by threshing the harvested plants.

Statistical analysis

The collected data were subjected to analysis of variance using SAS version 9.4 Software packages and mean separation was done using LSD [16] at 5% probability level.

Result and Discussions

Influence of split application of lime on soil chemical properties

Application of lime influenced soil chemical properties. All split lime and full rate application increased pH. Split of 50%, 33% and full dose application of lime equivalently lowered exchangeable acidity of the soil. According to Dawid and Hailu [17] application of all split lime and full rate application significantly ($p<0.05$) increased pH. However, 25%, 33% and Full dose application of lime significantly lowered exchangeable acidity of the soil but difference was not observed among them. 50% application even significantly decreased exchangeable acidity of Hurumu soil over those of 25%, 33% and Full dose applications. The finding of Anetor and Ezekiel [18] also indicated that lime increased pH and available P. Liming can increase the soil pH, and modify soil physical, chemical and biological properties.

Effect of split application of lime on yield and yield attributes of lime on barley

The result of the experiment revealed that yield of wheat was not statistically significantly ($P < 0.05$) affected by split application of lime in this study area (Table 2). Split application of lime into consecutive years gave similar grain yield with full rate application of lime. Even splitting into three was gave similar grain yield with splitting lime into two and full dose. Numerically, the highest yield (5.67ton/ha) was obtained from full dose of lime over years. All split and full dose of lime application gave statistically significantly ($P < 0.05$) yields compared to un-limed that resulted 2.4 ton ha^{-1}. Increased yield of limed plants could be applied lime increase the availability plant-nutrients Anetor and Ezekiel [18] while induced declining the yield of plants treated with only inorganic fertilizers might be phosphorus fixation nature of acidic soils. The result of the experiment revealed that splitting the required amount of lime into 33% and 50% is possible if to be grown on this soil. This result finding agrees

Table 1: Soil physico-chemical properties of soil prior to planting.

pH	EA	Ex H	BD	%OC	%TN	Ava.P (ppm)	CEC (cmol/kg	Textural class			
								%sand	%clay	%silt	Texture
4.9	2.69	1.6	0.99	1.1	0.094	1.28	41.2	70	14	16	Sandy loam

Table 2: Effect of Split Application of Lime on Wheat Grain Yield (ton ha-1)

Treatments	2017	2018	2019	Combined Mean
T1: Control	2.5d	2.4c	2.32c	2.4c
T2: 92N 69P kg/ha	3.98c	3.43b	4.03b	3.81b
T3: Full dose lime	6.33a	5.0a	5.93a	5.75a
T4: 50% (1st and 2nd year)	5.7ab	4.7a	6.58a	5.66a
T5: 33% every year	5.37c	5.1a	6.1a	5.52a
T6: 50% (1st and 3nd year)	5.6ab	4.8a	6.4a	5.61a
Mean	4.91	4.8	5.23	4.8
LSD(0.05)	0.8	1.03	1.31	0.59
CV (%)	8.92	13.37	13.76	12.93

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

Table 3: Effect of Split Application of Lime on Wheat above ground biomass (ton ha-1)

Treatments	2017	2018	2019	Combined Mean
T1: Control	7.85c	6.26c	7.23c	7.11c
T2: 92N 69P kg/ha	13.15b	9.98b	12.63b	11.92b
T3: Full dose lime	16.62a	13.13a	17.44a	15.73a
T4: 50% (1st and 2nd year)	15.71a	11.96a	18.9a	15.53a
T5: 33% every year	14.99ab	13.26a	18.15a	15.47a
T6: 50% (1st and 3nd year)	15.37ab	12.8a	18.51a	15.56a
Mean	13.95	9.44	15.48	13.55
LSD(0.05)	2.34	1.92	3.98	1.8
CV (%)	9.45	9.44	14.14	13.9

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

Table 4: Effect of Split Application of Lime on Plant height (cm)

Treatments	2017	2018	2019	Combined Mean
T1: Control	75b	72b	63b	70b
T2: 92N 69P kg/ha	91a	100a	93a	95a
T3: Full dose lime	100a	100a	98a	100a
T4: 50% (1st and 2nd year)	95a	98a	98a	98a
T5: 33% every year	91a	99a	104a	98a
T6: 50% (1st and 3nd year)	91a	105a	91a	96a
Mean	91	96	91	92
LSD(0.05)	13	16	17	8
CV (%)	8.28	9.2	10.2	9.18

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

with Dawid and Hailu [17] 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. Therefore, resource poor farmers who cannot afford the full dose lime to be applied at one time can split in to two, three and apply every year without yield loss significantly. Lime alone could not boost crop production. Thus, to be increased production, recommended amount of fertilization should be incorporated with lime.

The combined result showed that split application of lime was not statistically significantly($P < 0.05$) affected above ground biomass (Table 3) compared at one time application of full dose whereas all limed treatments affected above ground biomass yield of wheat statistically significantly ($P < 0.05$) compared to un-limed. Combined mean showed that numerically the highest above ground biomass (15.57 ton/ha) obtained from full dose of lime applied at one time which could be resulted from applied lime improves soil essentials

Table 5: Effect of Split Application of Lime on Spike Length (cm)

Treatments	2017	2018	2019	Combined Mean
T1: Control	5.5b	6c	5.5b	5.6c
T2: 92N 69P kg/ha	7.3a	7.4bc	7.6a	7.4b
T3: Full dose lime	7.5a	8.9ab	8.4a	8.3a
T4: 50% (1st and 2nd year)	7.8a	8.8ab	8.4a	8.4a
T5: 33% every year	7.6a	9.1ab	8.2a	8.3a
T6: 50% (1st and 3rd year)	7.4a	9..6a	8.0a	8.3a
Mean	7.2	8.3	7.7	7.7
LSD(0.05)	1.13	1.9	1.34	0.71
CV (%)	8.66	11.2	9.6	9.75

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

Table 6: Effect of Split Application of Lime on Tiller number

Treatments	2017	2018	2019	Combined Mean
T1: Control	1.2b	1.8c	3.1b	2.0c
T2: 92N 69P kg/ha	2.8a	2.8b	5.0a	3.5b
T3: Full dose lime	4.0a	4.1a	4.5a	4.2ab
T4: 50% (1st and 2nd year)	4.3a	3.6a	4.8a	4.2ab
T5: 33% every year	2.9a	3.5a	4.4a	3.6ab
T6: 50% (1st and 3rd year)	3.7a	4.0a	4.3a	4.0ab
Mean	3.1	3.3	4.4	3.6
LSD(0.05)	1.5	0.8	0.79	0.68
CV (%)	26	13	9.6	19

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

microorganism and available plant-nutrients Anetor and Ezekiel [18] thereby resulting significant increased biomass yield compared with un-limed that gave the lowest biomass(7.11 ton ha^{-1}). Application of splitting lime into 33% and 50% and full dose treatments increased dry matter (DM) of wheat. This finding in line with Dawid and Hailu [17] 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 was not significantly ($p < 0.05$) affected during experimentation by splitting lime (Table 4). The highest plant height (100 cm) was recorded from full dose lime applied at one time, while which is statistically similar with all limed plants and statistically significant ($p < 0.05$) compared to un-treated plants with lime that gave the lowest plant height (70 cm). The increased plant height of wheat could be lime application attributed to rising of soils pH which enhances vigor plant growth.

Spike Length (Table 5) and **Tiller number** (Table 6) also were not significantly ($p < 0.05$) affected by the split application of lime while significant difference was recorded among limed and un-limed treatments. The highest tillers and spike length was scored from all lime treatments whereas the lowest recorded form un-limed. Similarly, Dawid and Hailu [17] 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 fertility status of acid soil.

Conclusion

Application of lime significantly affect grain yield of wheat**.** Application of lime over years at the rate of Ex. Acidity combined with mineral NPS fertilizer improved grain yields without a significant yield loss, splitting lime into 33% and 50% and applying in three and two consecutive years gave similar yield with full rate of lime applied once in the first year. Therefore, resource poor farmers who cannot afford cost of lime to be applied at one time could split up to one-third and can cultivate crops under acid soil in 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 wheat yields. Furthermore research needs to be carried out to evaluate residual effect of split and full dose application of lime amelioration on physico-chemicals properties of acidic soil.

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Conflicts of Interest

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

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