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ORIGINAL ARTICLE

Yield response of wheat (*Triticum aestivum*) to split application of lime in acidic soils of gumer highlands, southern Ethiopia

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Acid soil is a major constraint for crop production in the highlands which affects the growth of crops due to high concentration of toxic acidic cations to plant. Soil acidity are the major yield-limiting factors and barrier to agricultural production in areas where heavy rainfall. Field investigation was carried out under permanent plots to study the influence of split application of recommended lime on yield and yield attributes of wheat in acidic soils during three cropping seasons (2017, 2018 and 2019). Four level splits of lime (full dose of required 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 result revealed that the highest yield was recorded from all plots treated with lime whereas the lowest yield was recorded from un-limed treatment. The highest yield (5.67 ton/ha) was recorded from full dose limed plant while lowest yield (2.4 ton/ha) recorded from control. Thus, resource poor farmers who unable to afford full dose lime to be applied 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 increased yield of limed treatments might be lime application attributed to rising of soils pH and making nutrients plant-available.

Keywords: Lime, 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 (Minot et al., 2019). 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 (Food and Agriculture Organization), 2014). 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 that 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) (Taye, 2007). Alias, (2016) 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 (Chimdi, et al., 2012). Soil acidity enforces plant to be stunted growth and principally limit crop production (Fageria, 2009). 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 H, Al, Fe, Mn and NH_4^+ 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 (Abebe, 2007; Caires et al., 2005; Harter, 2007). Yield loss aggravated by soil acidity or Al toxicity and associated factors ranged from 25 to 80% (Herrero-Estrella, 2003). 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 (Asmare, 2014; Zheng, 2010). Liming acidic soils have 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 Al and Mn in the soil and thereby enhances root development, water, and nutrient uptakes (Crowford et al., 2008; Marschner, 2011). However, lime is obtained not easily and large quantity may be required for highly affected areas and its transportation is also difficult. Splitting the required amount of lime and applying every year could be a key for boosting productivity in acidic soils. Therefore, the present study aimed 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 soils at Gumer Woreda, 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 Gumer woreda, Guraghe Zone, Southern Nations Nationalities and Peoples' Regional State of Ethiopia. Experimental site is situated at 8°01'56.2"N and 38°01'58.3"E, and at altitude of 2767 m.a.s.l 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.
The geographical location of the study area is highlighted at (Fig. 1).

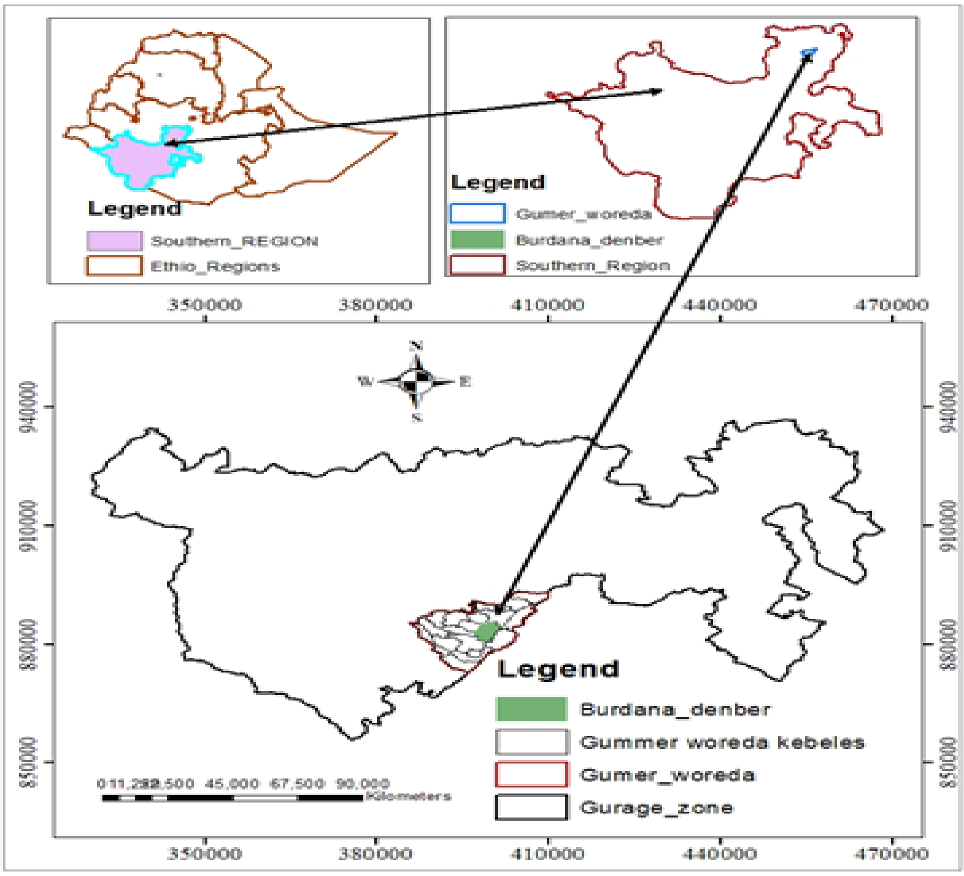

Fig. 1. Location map of the study area.

Experimental design and treatments

A Hidase variety of wheat was used for the experimentation and sown by drilling seed rate of 150 kg·ha^{-1}; 20cm spacing between rows and plot size were 3 m × 3 m. 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), 200 kg NPS+94 kg Urea, Control). Having 98% of neutralizing value and <250 μm in diameter of lime ($CaCO_3$ was used. Lime requirement of the soil was calculated based on its exchangeable acidity (Al^{+3} and H^{+1}). Lime was broadcasted uniformly by hand and incorporated into the soil a month before sowing and the recommended 200 kg NPS+94 kg Urea was applied for all treatments except the control Urea were 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 NPS was applied at sowing in band. The experimental plots were kept fixed permanent during investigation.

Physical and chemical soil characteristics

A Composited Soil sample was collected from 0-15 cm depth for initial determination of soil fertility parameters.

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

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

The soil samples was analyzed for determination of pH, exchangeable acidity, Available P, %T N, and % OM according to the standard procedures. In this manner, soil texture was determined using the Bouyoucos hydrometer method (Bouyoucos, 1962). The pH of the soil was measured in the supernatant suspension of a 1:2.5 soil to water ratio using a pH meter (Dick, W.A., Cheng, L. and Wang, P., 2000). And organic carbon (%) was determined by method as described by (Walkely and Black, 1934). Available P (ppm) was analyzed by employing the Olsen method (Olsen, 1954.) using ascorbic acid as the reducing agent. Total nitrogen was measured using Bremner, J.M., 1960 and exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) and CEC in cmol (+) kg^{-1} soil was determined by ammonium acetate method.

Agronomic data collection

Five plants randomly selected from 250 cm^2 (50 cm * 50 cm), which 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 adjusted to 12% moisture.

Statistical analysis

The collected data were subjected to analysis of variance using SAS software packages and mean separation was done using LSD (Gomez and Gomez, 1984) at 5% probability level.

Results and Discussion

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, combined mean result showed that the highest yield (5.67 ton/ha) was obtained from full dose of lime. All split and full dose of lime application treatments gave statistically significantly ($P<0.05$) yields compared to un-limed treatments that resulted 2.4 ton/ha^{-1}. Increased yield of limed plants could be applied lime increase the availability plant-nutrients 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 with 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. 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.

Table 2. Effect of split application of lime on wheat grain yield (ton ha^{-1}).

Treatments	2017	2018	2019	Combined Mean
T1: Control	2.5^{c}	2.4^{c}	2.32^{c}	2.4^{c}
T2: 200 kg NPS+94 kg Urea	3.98^{b}	3.43^{b}	4.03^{b}	3.81^{b}
T3: Full dose lime	6.08^{a}	5.0^{a}	5.93	5.67^{a}
T4: 50% (1^{st} and 2^{nd} year)	5.7^{a}	4.7^{a}	6.58^{a}	5.66^{a}
T5: 33% every year	5.37^{a}	5.1^{a}	6.1^{a}	5.52^{a}
T6: 50% (1^{st} and 3^{nd} year)	5.6^{a}	4.8^{a}	6.4^{a}	5.61^{a}
Mean	4.87	4.8	5.23	4.78
LSD(0.05)	0.89	1.03	1.31	0.59
CV (%)	10.08	13.37	13.76	12.99

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

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. According to combined mean, 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 microorganism and available plant-nutrients 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 (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.

Table 3. Effect of split application of lime on wheat above ground biomass (ton ha^{-1}).

Treatments	2017	2018	2019	Combined Mean
T1: Control	7.85^{c}	6.26^{c}	7.23^{c}	7.11^{c}
T2: 200 kg NPS+94 kg Urea	13.15^{b}	9.98^{b}	12.63^{b}	11.92^{b}
T3: Full dose lime	16.62^{a}	13.13^{a}	17.44^{a}	15.73^{a}
T4: 50% (1st and 2nd year)	15.71^{a}	11.96^{a}	18.9^{a}	15.53^{a}
T5: 33% every year	14.99^{ab}	13.26^{a}	18.15^{a}	15.47^{a}
T6: 50% (1st and 3nd year)	15.37^{ab}	12.8^{a}	18.51^{a}	15.56^{a}
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.

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.

Table 4. Effect of split application of lime on plant height (cm).

Treatments	2017	2018	2019	Combined Mean
T1: Control	75^{b}	72^{b}	63^{b}	70^{b}
T2: 200 kg NPS+94 kg Urea	91^{a}	100^{a}	93^{a}	95^{a}
T3: Full dose lime	100^{a}	100^{a}	98^{a}	100^{a}
T4: 50% (1st and 2nd year)	95^{a}	98^{a}	98^{a}	98^{a}
T5: 33% every year	91^{a}	99^{a}	104^{a}	98^{a}
T6: 50% (1st and 3nd year)	91^{a}	105^{a}	91^{a}	96^{a}
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.

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 (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 fertility status of acid soil.

Table 5. Effect of split application of lime on spike length (cm).

Treatments	2017	2018	2019	Combined Mean
T1: Control	5.5^{b}	6^{c}	5.5^{b}	5.6^{c}
T2: 200 kg NPS+94 kg Urea	7.3^{a}	7.4^{bc}	7.6^{a}	7.4^{b}
T3: Full dose lime	7.5^{a}	8.9^{ab}	8.4^{a}	8.3^{a}
T4: 50% (1st and 2nd year)	7.8^{a}	8.8^{ab}	8.4^{a}	8.4^{a}
T5: 33% every year	7.6^{a}	9.1^{ab}	8.2^{a}	8.3^{a}
T6: 50% (1st and 3nd year)	7.4^{a}	9..6^{a}	8.0^{a}	8.3^{a}

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	1.2^{b}	1.8^{c}	3.1^{b}	2.0^{c}
T2: 200 kg NPS+94 kg Urea	2.8^{a}	2.8^{b}	5.0^{a}	3.5^{b}
T3: Full dose lime	4.0^{a}	4.1^{a}	4.5^{a}	4.2^{ab}
T4: 50% (1st and 2nd year)	4.3^{a}	3.6^{a}	4.8^{a}	4.2^{ab}
T5: 33% every year	2.9^{a}	3.5^{a}	4.4^{a}	3.6^{ab}
T6: 50% (1st and 3nd year)	3.7^{a}	4.0^{a}	4.3^{a}	4.0^{ab}
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.

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. Further more 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.

References

Abebe, M. (2007). Nature and management of acid soils in Ethiopia.

Alias, E. (2016). Soils of the Ethiopian highlands: Geomorphology and properties.

Asmare, M. (2014). Phosphorus status, adsorption characteristics, kinetics and availability to wheat crop as influenced by applications of various amendments on acid soils of Farta District, Northwestern Highlands of Ethiopia.

Bouyoucos, G.J. (1962). Hydrometer method improved for making particle size analyses of soils[1]. Agronomy Journal, 54:464-465.

Bremner, J.M. (1960). Determination of nitrogen in soil by the Kjeldahl method. The Journal of Agricultural Science, 55:11-33.

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

Chimdi, A., Gebrekidan, H., Kibret, K., Tadesse, A. (2012). Effects of liming on acidity-related chemical properties of soils of different land use systems in Western Oromia, Ethiopia. World Journal of Agricultural Sciences, 8:560-567.

Crawford, J.T.W., Singh, U., Breman, H. (2008). Solving agricultural problems related to soil acidity in central africa's great lakes region catalist project report. International Center for Soil Fertility and Agricultural Development (IFDC), Kigali, Rwanda, pp:1-133.

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

Dick, W.A., Cheng, L., Wang, P. (2000). Soil acid and alkaline phosphatase activity as pH adjustment indicators. Soil Biology and Biochemistry, 32:1915-1919.

Fageria, N.K. (2009). The use of nutrıents in crop plants. Section: Calcium. CRC Press.

FAO (Food and Agriculture Organization). (2014). Food balance sheets. FAOSTAT.

Harter, R.D. (2007). Acid soils of the tropics. ECHO Technical Note, ECHO.

Herrero-Estrella, L. (2003). How can life sciences contribute to the production under marginal conditions. Towards Sustainable Agriculture for Developing Countries: Option from Life Sciences and Biotechnology.

Marschner, H. (2011). Marschner's mineral nutrition of higher plants. Academic press.

Minot, N., Warner, J., Lemma, S., Kasa, L., Gashaw, A., Rashid, S. (2019). The wheat supply chain in Ethiopia: Patterns, trends, and policy options. Gates Open Research, 3:174.

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

Olsen, S.R. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Department of Agriculture.

Taye, B. (2007). An overview of acid soils their management in Ethiopia paper presented in the third International Workshop on water management (Waterman) project. Haromaya, Ethiopia.

Walkely, A., Black, I.A. (1934). An examination of the degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science.

Zheng, S.J. (2010). Crop production on acidic soils: overcoming aluminium toxicity and phosphorus deficiency. Annals of Botany, 106:183-184.

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