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Research Article

Effects of Micro-Dosing of Lime on Yield and Yield Components of Potato on Farmer's Field in Banja District, Awi Zone, Amhara Region, Ethiopia

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ABSTRACT

Liming of acidic soil on smallholder farms is one of the major challenges to enhance crop yields in Ethiopian highlands. This may be attributed to the additional investment cost for liming. Therefore, this study was carried out to investigate the effects of micro-dosing of lime on yield and yield components of potato on farmers field in Banja district, Awi zone, Amhara region. Three methods of lime rate determination and eight treatments on lime rate application were used in the field experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) with four replications. Crop samples were collected and analyzed to evaluate the effect of treatments on yield and yield components of potato. Data were analyzed with SPSS version 22.0 and SAS 9.3. Among the eight treatments, the highest tuber yield of potato was obtained from the application of 15 tha^{-1} lime and the lower tuber yield was found from the unlimed plots. The result revealed that, there is no significant difference between micro dose application of lime with other treatments (4.064, 3.57, 2.032 and 1.016 (tha^{-1})) in the production of potato tuber yield. Therefore, micro doses application of lime affordable for small scale farmers with a minimum cost of lime.

Keywords: Liming; Micro-Dosing; Potato yield component; Crop yield

INTRODUCTION

Potato (*Solanum Tuberosum* L.) one of the most vital vegetable crops, constituting the fourth most vital food items within the world. It is a really important food item and crop in Ethiopia, especially within the highland and mid altitude areas. As a result, the country has about 70% of the available agricultural land suitable for potato production. It is also a crucial food item and crop in Amhara regional state. Over half of the rural households are involved in potato production within the region. In Banja district potato production is one among the widely grown food also as income generating crop. The farmers have been growing three times a year: The most season, residual moisture and using irrigation practices.

Even though the practice of potato cultivation is common in the district, the yield is extremely low due to drought, poor production practices and limited access to improved variety seed. Soil acidity is another constraint to low the productivity of potato within the district.

In acidic soil nutrient availability like nitrogen, phosphorus and potassium are usually limited. Phosphorus is sensitive to pH and may become a limiting nutrient in strongly acid soils [1]. Thus, reduced fertilizer use efficiency and crop performance are often expected when soil acidity is not well controlled. Soil Acidity is not only limit nutrient use efficiency but also it facilitates the occurrence of bacteria wilt.

According to, the high lands of Ethiopia are subjected to strong acid due to high incidence of rainfall. Banja district is a part of Ethiopia highlands. Its soil acidity level was found to be

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moderately to strongly acidic. Although potato is one of the most crop of the district, and requires a substantial amount of nutrients. The nutrient availability is affected by soil acidity [2]. Therefore, to alleviate soil acidification, application of lime has been widely practiced and recommended by several researchers. As a result, several experiments are conducted in several parts of Ethiopia with large amounts of lime.

However, the farmers might not be using these huge amounts of lime application due to the subsequent reason: Lime availability, transportation and price of lime. To solve such types of problems this study was aimed to investigate the effect of micro dosing application of lime on yield and yield components of potato in acidic Nitisols of Banja district.

MATERIALS AND METHODS

Description of the study area

The study was conducted in, Janguta Kuanch Kebele, Banja district, Awi administrative zone, Amhara national regional state, Ethiopia in 2018. Geographically, Banja district lies within 10°52' to 11°3' N latitude and 36°38' to 37°8' E longitudes at a distance of 440 km Northwest of Addis Ababa and 120 Km South of Bahir Dar, the capital of Ethiopia and Amhara regional state, respectively (Figure 1).

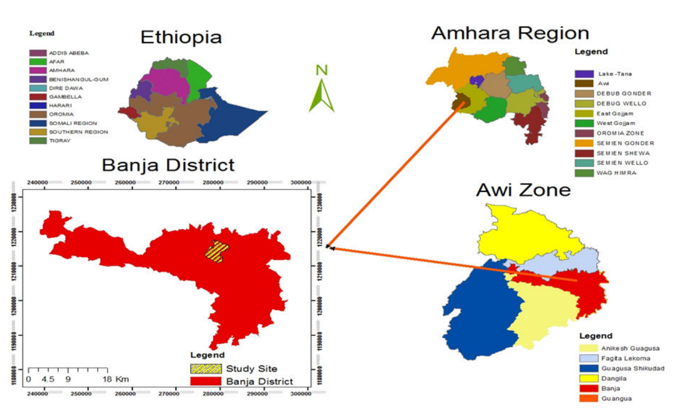

Figure 1: Location Map of the study area, Amhara region, Ethiopia.

Experimental materials

The local variety of potato (*Solanum Tuberosum* L.) was used for this study [3]. This variety is chosen for this study due to lack of improved verities, availability and widely grown in the area by smallholder farmers.

Liming material ($CaCO_3$) made by Abyssinia limestone crushing factory was used as sources of liming material with the purity of 94% with fineness of pass through a 60-mesh. 195 Nitrogen-Phosphate Fertilizer with Sulphur (NPS) and urea 165 kgha^{-1} fertilizers were used as a source of phosphorous and nitrogen, respectively.

Treatments and experimental design

The treatments were full doses of lime using buffer and exchangeable acidity method, 1/2 full doses of lime using buffer and exchangeable acidity method, 1/4 using buffer and exchangeable acidity method by drilling along the row of buffer and exchangeable acidity method, micro-dosing in basal application (0.060 tha^{-1}) and control [4]. The field experiment was conducted for one cropping season of 2018 by rain fed system of production on acidic Nitisols of Banja District. The design was Randomized Complete Block Design (RCBD) with four replications. A gross plot size was 3 m × 3.75 m=(11.25 m^2). One border row from each side of potato plants and two plants each from the end of the row were left for destructive sampling. The net plot size was 3 rows × 0.75 m × 8 plants *0.3 m=5.4 m^2. The spacing between blocks and plots were 1 m and 1 m, respectively.

Land preparation, planting and inputs application

The land was prepared by ploughing four times. Based on the amounts required, finely powdered lime was thoroughly incorporated into the plot and mixed with furrow slices depth of soil to ensure higher reactivity (full reaction) with the soil before 15 days of planting for six treatments, but for the 7th treatment (micro dosing) of lime, 1.35 g of lime for each plant with basal application was applied. While full NPS (4.38 g per tuber) and one-third (1.23 g per tuber) of urea fertilizers were applied during sowing with placement application [5]. The rest urea fertilizer was applied two times for each potato tuber as a top-dressing application immediately after the first and the second cultivation [6]. The inter and intra-row spacing was 0.75 m and 0.3 m respectively, other cultural practice and fertilizer application were constant for all treatments.

Data collection

Days to 50% emergence: Was recorded as the number of days from sowing to the date when 50% of the plants emerged in each plot.

Days to 50% flowering: Refers to the time required to attain 50% of the plant to flower.

Plant height (cm): Refers to the height from the base to the apex of the plant [7]. It was determined by measuring the height of 5 randomly taken plants using a ruler from the central three rows of flowering.

Number of main stems per hill: Was determined by counting the stems that originated from the tuber from 5 randomly taken hills, and taking the average.

Tuber dry matter content (%): Five fresh tubers were randomly selected from each plot and weighed. The tubers were then sliced and dried in an oven at 65°C until a constant weight was obtained and the dry weight was recorded. The dry matter percent was calculated according to the following formula.

$$\% \text{ of tuber dry matter} = \frac{\text{weight of sample after dring (g)}}{\text{Initial weight of sample (g)}} * 100$$

Marketable tuber yield (tha^{-1}): The weights of tubers free from diseases, insect pests, and greater than or equal to 25 g in weight were recorded.

Unmarketable tuber yield (tha^{-1}): The weight of tubers diseased and/or rotted ones and smaller-sized (less than 25 g in weight) were recorded.

Total tuber yield (tha^{-1}): The sum of tuber yield weights of marketable and unmarketable tubers.

Statistical data analysis

The collected data were subjected to Analysis of Variance (ANOVA) by using SPSS version 22.0 and SAS version 9.3. Least Significance Difference (LSD) test at 1% and 5% probability levels were used for mean comparison. When treatments show significant differences, mean separation were.

RESULTS AND DISSCUSSION

The effect of micro doses of lime on yield and yield components of potato

Days to 50% of emergence: Based on the analysis of variance, days to 50% of emergence were not significantly affected (p>0.05) by the application of lime. The result revealed the minimum and the maximum days of germination was 19.25 and 20.75 days due to the application of 15 tha^{-1} lime and control plot, respectively (Table 1).

The emergence of potato due to the application of 0.06 tha^{-1} (micro-dosing) was 19.5 days [8]. Emergence of potato was largely dependent on the utilization of reserve material and metabolites in the mother tuber. Furthermore, the result agreed with the finding of that reported, percent emergence of potato plant was not significantly influenced by lime application.

Table 1: The effect of lime rates on agronomic parameters of potato.

Lime (tha^{-1})	50% Germ.	50% Flow§	P.H§	NMS§
0	20.75	48.50^{b}	36.28^{b}	2.25^{b}
0.06	19.5	50.50^{b}	39.35^{ab}	2.45^{b}
1.016	19.5	50.75^{b}	41.95^{ab}	2.50^{b}
2.032	19.5	51.00^{b}	41.45^{ab}	2.75^{b}
3.57	19.5	52.50^{b}	41.70^{ab}	2.85^{b}
4.064	20	53.00^{ab}	43.28^{ab}	2.85^{b}
7.5	20	53.75^{ab}	45.93^{a}	2.90^{b}
15	19.25	58.50^{a}	46.08^{a}	3.63^{a}
CV	5.82	5.27	7.63	12.58
SE ±	0.19	0.65	0.73	0.09
LSD (0.01)	2.3	5.52	6.42	0.7
P	ns	**	**	**

Note: P.H=Plant Height, NMS=No of Main Stem, LSD=Least Significance Difference, SE ± =Standard Error; CV=Coefficient of Variation, p=probability level; **significantly different at p<0.01; ns=not significantly different at p>0.05. §means followed by the same letters in a column are not significantly different at p<0.01 and p<0.05, respectively

Days to 50% of flowering: Days to 50% flowering was highly significant (P<0.01) influenced by the application of lime. The result (Table 1) shows that, dates to 50% of flowering showed increasing trend as the amount of lime decreased and the longest days to flowering (58.50 days) was found from application of the full buffer method (15 tha^{-1}) while shortest was from the control (48.50 days) and micro-dosing of lime (0.06 tha^{-1}) was 53.75 days. The days of flowering increase due to the positive effects of available P through the application of lime. P increased the days to reach flowering.

Plant height: The statistical analysis of the data revealed that there was significant (p<0.01) difference in plant height among the treatments [9]. The tallest mean plant height (46.08 cm) was recorded in plots treated with 15 tha^{-1} (full buffer method) while, the shortest (36.28 cm) was observed in the control plot

(Table 1). Potato plant height was increase as lime rates increase. These might be the neutralize capacity of lime in acidic soil toxicity effect and increase soil nutrient availability by enhancing mineralization. Liming might have reduced the detrimental effect of soil acidity on plant growth due to high concentration of H^+ and Al^{3+} ions in acid soils. Activities of Ca_2 cations, orthophosphate (H_2PO_4), nitrate (NO_3^-) and sulfate (SO_4^{2-}) anions with soil organic matter content and their availability to plant roots might be hampered by acidifying ions.

Plant height had a positive and highly significant correlation (r=0.451**, n=32) with total tuber yield and marketable yield (r=0.544**, n=32) (Table 2) [10]. The positive and significant association of plant height indicates that plant height is an important tuber yield attribute that should be considered in the selection criteria for yield improvement [11]. These results were coinciding with the findings of who reported that applications of lime increased the height of potato plants.

Table 2: Correlations among agronomic parameters, yield and yield components.

	GER	FLO	PH	SN	TDM	TY	MY
FLO	0.249						
PHE	-0.022	-0.486**					
SN	-0.354*	-0.455**	0.591**				
TDM	0.072	0.326	-0.602**	-0.504**			
TY	-0.415*	-0.409*	0.455**	0.619**	-0.457**		
MY	-0.380*	-0.516**	0.544**	0.684**	-0.547**	0.978**	
UMY	0.125	0.687**	-0.644**	-0.650**	0.649**	-0.546**	-0.710**

Note: GER=50% emergency, FLO=50% flowering; PH=Plant Height; SN=Stem Number; TDM=Tuber Dry Matter; TY=Total Tuber Yield; MY=Marketable Yield and UMY=Unmarketable Yield. **correlation is significant at the 0.01 level. *correlation is significant at the 0.05 level, n=32

Number of main stem: According to the analysis of variance, application of different levels of lime had a significant (p<0.01) effect on the number of stems per hill. The maximum number of main stems (3.63) was observed in 15 tha^{-1} (full buffer method) treatment; whereas, the minimum number of main stems (2.25) was observed in unlimed treatment. Stem number per hill increased significantly with increasing the level of lime application [12]. This may be attributed to the positive role the lime may have played in bringing the soil pH to normal levels for growth and development of the potato plant.

A positive and highly significant (P<0.01) correlation was observed between the number of main stems per hill and total tuber yield (r=0.619**). Likewise, positively correlated with marketable tuber yield (r=0.684**). These relationships indicated that factors that lead to increase in the number of main stems per hill might also increase the total tuber yield and marketable tuber yield [13]. Similarly, the number of main stems had positive relationships between and total yield.

Percent of tuber dry matter yield: Based on the analysis of variance, application of lime had a significant effect (p<0.05) on potato tuber dry matter. The highest dry matter content (23.21%) was obtained in potato tubers harvested in control plots while the lowest dry matter content (19.46%) due to the high lime application 15 tha^{-1} (full buffer method) (Table 3) [14]. This could be attributed to the differential loss of water content in big and small size potato when dried. It is an indication that when fresh yield increased, the water content in potato also increased and could reduce dry matter accumulation.

The plots that yielded the highest quantity of fresh tubers were found to have the lowest quantity of potato dry matter [15]. The positive effects of liming on soil properties and increase in tuber yield in acidic soils, which consequently affected dry matter inversely.

Table 3: The effect of lime rates on yield of potato tuber.

Lime (tha^{-1})	% of TDM	Marketable yield (tha^{-1})*	Unmarketabe yield (tha^{-1})*	Total tuber. Yield (tha^{-1})*
0	23.21ᵃ	15.07ᶜ	2.10ᵃ	17.17ᶜ
0.06	22.88ᵃ	16.58ᵇᶜ	1.86ᵇ	18.44ᵇᶜ
1.016	21.94ᵃᵇ	16.70ᵇᶜ	1.87ᵇ	18.57ᵇᶜ

2.032	21.93[ab]	16.73[bc]	1.61[c]	18.34[bc]
3.57	21.29[ab]	16.85[bc]	1.24[d]	18.10[bc]
4.064	20.69[ab]	17.41[b]	1.16[d]	18.56[bc]
7.5	20.34[ab]	18.54[ab]	1.10[d]	19.64[ab]
15	19.46[b]	19.71[a]	1.10[d]	20.80[a]
CV	6.31	5.79	5.98	5.21
SE ±	0.3	0.28	0.07	0.23
LSD (0.01 and 0.05)	2.71	1.99	0.18	1.95
P	*	**	**	**

Note: LSD=Least Significance Difference, SE ± =Standard Error; CV=Coefficient of Variation, p=probability level; TDM=Tuber Dry Matter. **significantly different at p<0.01 and *significantly different at p<0.05. *Means followed by the same letters in a column are not significantly different at p<0.01 and p<0.05, respectively

Marketable potato tuber yield: A significant difference (P<0.01) was observed in the amounts of marketable tuber yields due to application of different lime rates. Micro dose application of lime was not showed significant difference with 4.064, 3.57, 2.032 and 1.016 tha^{-1} of lime. Therefore, it is feasible and affordable for small scale farmers in comparison with four treatments. The highest marketable yield was gained from 15 tha^{-1} (full buffer method) with tuber yield of 19.71 tha^{-1}; whereas, the lowest was found in the control plot had (15.07 tha^{-1}) [16]. The above result showed that the increments of lime application had the direct relation to marketable tuber yield of potato production. These indicated that lime might enhance the nutrient availability of the soil by increased soil pH and available phosphorous released nitrogen and also reduced aluminum toxicity. Nutrients enhance the quality of tubers and make them more marketable. Potato yield was attributed to the availability of phosphorus, potassium and mineral nitrogen in the soil.

Unmarketable potato tuber yield: Based on the analysis of variance there was highly significance difference (P<0.01) in the amounts unmarketable tuber yields. The highest unmarketable yield (2.10 tha^{-1}) gained from control plot had (15.07 tha^{-1}) while the lowest was (1.10 tha^{-1}) with the incorporation of 15 tha^{-1} (full buffer method) [17]. The result indicated that the amount of lime applied in the soil and its unmarketable tuber yield inversely related which means, as the lime rate decreased, the soil pH, available phosphorous and CEC reduced and aluminum toxicity increased. Thus, as these parameters are reduced the size of potato tuber also diminished. Al toxicity at low pH level seemed to be the major limiting factor in the growth of plants in highly weathered acid soil of the tropics. Furthermore, indicated that the importance of phosphorus in potato production and lack of it during growth drastically reduced yield.

Total potato tuber yield: The amounts of lime applied with different rates significantly (p<0.01) affected the total tuber yield of potato. Application of 15 tha^{-1} (full buffer method) gave the highest fresh total potato tuber yield (20.80 tha^{-1}) and the lowest was obtained in the control plot (17.17 tha^{-1}) [18]. The highest yield obtained in plots that were limed, was probably due to the positive effects of liming on soil properties. This implies that, the soil systems become good for crop production.

Likewise, the significant effect of potato yield due to liming was attributed to increased availability of calcium, magnesium, sulphur, phosphorus, organic carbon and other micronutrients and decreased the availability of iron and manganese in soil [19]. Application of lime increased calcium uptake as well as tuber formation. Field research on potato has documented that calcium application to low CEC can improve the yield of tuber. The maximum yield of potato was obtained at the highest rate of limestone application.

Furthermore, also reported that, application of 3.5 t ha^{-1} lime NPK produced significantly superior potato tuber yield compared with the control.

The national average tuber yield of potato reported by FAOSTATA (2018) is 13.76 tha^{-1}. The highest tuber yield of this study was 20.80 tha^{-1}. Even though the total tuber yield of potato gained was above the national average it was still below the reports by who reported that Belete potato variety produced 40.257 tha^{-1} yields of potato tuber over the testing year of 2013 and 2014. The observed variation may be probably due to the difference in its seed sources.

However, application of micro-dose (0.06 tha^{-1}) produced 18.44 tha^{-1} of total potato tuber yield. The result implies that, there was no significance difference among the treatments except full dose (15.07 tha^{-1}) and half buffer (7.5 tha^{-1}). Therefore, small amounts of lime, micro-dosing (0.06 tha^{-1}) application in acidic soil produced more or less the same amounts of potato tuber yield as application of doses of 4.064, 3.57, 2.032 and 1.016 tha^{-1} of lime [20]. Little amount of lime was applied in acidic soils; it resulted in the changes in soil pH and other nutrients which can affect potato production positively. Also reported that, without a significant yield loss and harming soil health, splitting lime into one third and half and applying in three and two consecutive years, give similar yield with the full rate of lime applied once in the first year. This confirms that micro dose of lime is more effective than single heavy applications of lime.

CONCLUSION

The study was conducted to investigate the effect of micro-dosing of lime on yield and yield components of potato. Using the information obtained from the results of this study, the following conclusions were made. Plant height and number of main stems per hill had a positive and highly significant correlation with total tuber yield and marketable yield. Lime application is important for achieving higher yield of potato. However, there is no significant difference between micro dose application of lime and other treatments (4.064, 3.57, 2.032 and 1.016 tha^{-1}) in the production of potato tuber yield. Therefore, smallholder farms could use this technology to solve acidity problem with a minimum expenditure of lime.

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