Peruvian Journal of Agronomy
http://revistas.lamolina.edu.pe/index.php/jpagronomy/index

Received for publication: 27 September 2024
Accepted for publication: 30 November 2024
Published: 29 December 2024
ISSN: 2616-4477

RESEARCH ARTICLE
https://doi.org/10.21704/pja.v8i3.2201

Optimization of lime application to improve potato (*Solanum tuberosum* L.) productivity in northwestern Amhara, Ethiopia

Optimización de la aplicación de cal para mejorar la productividad de la papa (*Solanum tuberosum* L.) en el noroeste de Amhara, Etiopía

ZELALEM Addis* [1], TADELE Amare[1] , BITWELEGN Kerebih[1] , ABRAHAM Awoke[1] and ABERE Tenagne[1]

[1] Adet Agricultural Research Center, P.O. Box 08, Bahir Dar, Ethiopia

*Corresponding author: zelalemaddis660@gmail.com
https://orcid.org/0000-0002-1869-8596

Abstract

The study was conducted to ascertain the ideal lime rate for the production of potato at Banja and Machakel districts in acid hot spot areas. The experiment comprised twelve levels of calcium carbonate ($CaCO_3$) lime (rate (0 %, 11.1 %, 12.5 %, 14.3 %, 16.7 %, 20 %, 25 %, 33.3 %, 50 %, 75 %, 100 %, 125 %) that were set up using three replications and a randomized complete block design and studied the tuber yield and soil chemical properties (RCBD. The application of lime rates did not significantly affect the tuber yield of Potato. However, the application of 14.3 % lime at Banja gives 6.41 $t.ha^{-1}$ and 4.51 $t.ha^{-1}$ tuber yield advantage over the control at year one site one (Y1S1) and year two site two (Y2S2) respectively. Similarly, the application of 20 % lime at Machakel provides 4.04 $t.ha^{-1}$, 1.13 $t.ha^{-1}$, and 0.94 $t.ha^{-1}$ tuber yields than the control treatment at year one site one (Y1S1), year two site one (Y2S1) and year two site two (Y2S2) respectively. On the other hand, soil properties were changed by the application of lime. This might be due to the reclamation activity of lime through the substitution reaction of ($CaCO_3$) with aluminum (Al^{+3}) and (H^{+1}) on soil exchangeable sites, which leads to the formation of aluminum hydroxide and water rather than free hydrogen and aluminum. Based on this finding the application minimum lime rate of 14.3 % at Banja and 20 % at Machakel is important for acid reclamation with recommended fertilizer (138 N, 69 P_2O_5) for potato production. So that based on the finding application of the minimal rates on the respected districts is very important.

***Keywords**: Potato tuber, soil properties, soil acidity, soil reclamation, crop improvement*

Resumen

El estudio se realizó para determinar la dosis de cal ideal para la producción de papa en los distritos de Banja y Machakel en áreas con puntos altos de acidez. El experimento comprendió doce niveles de cal (0 %, 11.1 %, 12.5 %, 14.3 %, 16.7 %, 20 %, 25 %, 33.3 %, 50 %, 75 %, 100 %, 125 %) que se establecieron utilizando tres repeticiones y un diseño de bloques completos al azar (RCBD). La aplicación de dosis de cal no afectó significativamente el rendimiento de tubérculos de papa. Sin embargo, la aplicación de 14.3 % de cal en Banja tuvo una ventaja de rendimiento de tub*érculos de 6.41* $t.ha^{-1}$ y 4.51 $t.ha^{-1}$ sobre el control en el sitio uno del año uno (Y1S1) y el sitio dos del año dos (Y2S2), respectivamente. De manera similar, la aplicación de cal al 20 % en Machakel proporciona mayor rendimiento de tubérculos (4.04 $t.ha^{-1}$, 1.13 $t.ha^{-1}$ y 0.94 $t.ha^{-1}$) que el tratamiento de control en el sitio uno del año uno (Y1S1), el sitio uno del año dos (Y2S1), año dos sitio dos (Y2S2) respectivamente Por otro lado, las propiedades del suelo cambiaron por la aplicación de cal. Esto podría deberse a la actividad de recuperación de la cal a través de la reacción de sustitución de ($CaCO_3$) con aluminio (Al^{+3}) y (H^{+1}) en los sitios intercambiables del suelo, lo que conduce a la formación de hidróxido de aluminio y agua en lugar de hidrógeno y aluminio libres. Con base en este hallazgo, la aplicación de una dosis mínima de cal del 14.3 % en Banja y del 20 % en Machakel es importante para la recuperación ácida con el fertilizante recomendado (138 N, 69 P_2O_5) para la producción de patatas. Por lo tanto, sobre la base de las conclusiones, la aplicación de las tarifas mínimas en los distritos respetados es muy importante.

***Palabras clave:** Tubérculo de papa, propiedades del suelo, acidez del suelo, recuperación de suelos, mejoramiento de cultivos.*

How to cite this article:
Zalalem, A., Tadele, A., Bitwelegn, K., Abraham, A., & Abere, T. (2024). Optimization of lime application to improve potato (*Solanum tuberosum* L.) productivity in northwestern Amhara, Ethiopia. *Peruvian Journal of Agronomy, 8*(3), 175-185. https://doi.org/10.21704/pja.v8i3.2201.

Introduction

The highlands of Ethiopia are subject to strong acidity due to high rainfall (Regasa et al., 2024) where, applying lime to alleviate soil acidity has challenges for small-scale farmers because of lime availability, transportation, and price (Zerssa et al., 2021) because of that, the research aims to investigate the effect of micro-dosing lime applications on potato yield and yield components in the acidic Nitisols of North western Amhara Region, to find an affordable solution for small-scale farmers. The optimum lime requirements to increase the productivity of potatoes (*Solanum tuberosum* L.) in Northwest Amhara, Ethiopia, considering the limitations faced by smallholder farmers in accessing and affording lime. The application of lime aims to increase soil pH, which in turn enhances nutrient availability for plants. Increased soil pH can lead to increased availability of phosphorus, released nitrogen, and reduced aluminum toxicity (Leta et al., 2024); Micro-Dosing of Lime, where this approach explores whether small, affordable doses of lime can significantly improve potato yields compared to no liming. The small amounts of lime can create a more favorable soil environment for nutrient uptake (Afework et al., 2023); Nutrient Availability and Potato Yield, where potato yield is related to the availability of essential nutrients like phosphorus, potassium, and mineral nitrogen in the soil. Liming can improve the uptake of calcium and promote tuber formation (Jovovic et al., 2021); that aligns with sustainable agriculture principles by seeking cost-effective ways to improve crop production without harming the environment (Romero et al., 2024).

Potato is one of the key crops used to achieve the United Nations' Millennium Development Goals of ending poverty and ensuring food security. And the United Nations also declared 2008 to be the year of potatoes. It may continue to contribute to food security with a stable price because local supply and demand determine potato prices more than international trade.

It is a short cycle and early maturing additional advantages of double cropping and crop intensification than other crops that take longer days for maturity (Kawar et al., 2018). Ethiopia has enormous potential to boost potato yield and production, particularly in the highlands (Woldegiorgis et al., 2013, Haverkort et al., 2012). According to Food and Agriculture Organization of the United Nations [FAO] (2008), almost 70 % of Ethiopia's arable land can be utilized to produce potatoes; however, only 2 % of this potential has been realized; this may be because the majority of the land is planted with cereal crops rather than vegetables (Hirpa et al., 2012). The South Gonder, North Gonder, East Gojam, West Gojam, and Agew Awi zones of the Amhara region are home to over 40 % of the nation's potato producers (Hirpa et al., 2012), and the Adet Agricultural Research Center is required to support this potential.

In terms of both production and area covered, potatoes rank fourth among all crops worldwide. It is also Ethiopia top root and tuber crop (Central Statistics Authority [CSA], 2016). Due to its high production per unit area, as well as its superior nutritional characteristics compared to other main cereal crops, potatoes are an inexpensive and nutrient-dense crop for food security. However, Ethiopia produces less than 10 t of potatoes per hectare (Hirpa et al., 2012, Haverkort et al., 2012, Hassen et al., 2015). Even if some released potato varieties have high yielding potentials of up to 54 $t.ha^{-1}$ in Ethiopia under farm conditions (Woldegiorgis et al., 2013). Furthermore, (Haverkort et al., 2012) reported up to 64 $t.ha^{-1}$ around Shashemene area. We also recently assured that the achievable potentials of potato with nutrient management (Gudene variety) are above 40 $t.ha^{-1}$ (unpublished data).

In Ethiopia soil fertility is one of the main challenges in agricultural crops including potatoes productivity (Hirpa et al., 2012, Kebede & Ketema, 2017, Amare et al.,2018). Soil acidity that comes from heavy rainfall is one of the challenges of crop production in the high land areas of the country where potato is the staple crop (Agegnehu et al., 2021). About 40 % of the Ethiopia total land area consists of acid soils (< pH 5.5), and as much as 50 % of the Ethiopian potentially arable lands are acidic. (Getaneh & Kidanemariam, 2021) indicated that, due to transportation costs and labor intensiveness, farmers are not interested to apply fully calculated lime at once on their farmland because of that applying one-fourth of lime in rows can be achieved in full lime recommended in four years. Birhanu et al., 2016 reported that 25 % of the lime calculated based on the exchangeable acidity applied in rows at planting gave an equivalent bread wheat yield with a full dose.

As a result of this discovery, Adet Agricultural Research Center launched larger demonstration efforts on lime row application and was effective in producing wheat in locations where it had previously been unavailable (Demil et al., 2020). This result has been scaled up to end users (farmers) that are getting a high rate of acceptance. This method significantly reduces the amount of lime which has a problem for the adoption of the lime technology by the farmers. Due to the large area coverage of acid soils in Ethiopia, it is also difficult for the government to supply the total lime required. That is why using only 25 % by row application at planting is the best approach to increase the rate of adoption and productivity of crops.

Accordingly, the question of other crops to develop the rate of lime with row application at planting has been requested by the stakeholders including the bureau of agriculture. The recommended wheat is not equivalent to other crops. One of the targets of the growth and transformation of the program of the soil and water research directorates is also to enhance the yield of crops in the acid hot spot areas through soil fertility management including acid soil management. Hence, the research was done to fix the ideal rate of lime for the productivity of potato in acid hot spot areas of north West Amhara Region Ethiopia.

Materials and methods

description of the study area

The experiment was conducted at Banja and Machakel districts for two years (2019-2020) on a farmer's six fields in Northwest Amhara region Ethiopia. The sites are located to southwest 175 and 230 km away from Bahir-Dar respectively. Geographically Banja lies at (10^0 55’ 00” to 10^0 58’ 10” latitude and 37^0 05’ 00’ to 37^0 07’ 09” longitude) and Machakel lies at (10˚ 19’ 75” to 10˚ 21’ 81” latitude and 37^0 16’ 46” to 37^0 19’ 00”longitude) (figure 1). The study areas; Banja receives a mean annual rainfall of 1700 mm with an altitude of 2348 m above sea level. similarly, Machakel also receives 2200 mm with an altitude of 2312 m above sea level respectively. The mean annual rainfall and mean maximum &minimum temperature during growing period was indicated in figure 2. Major Crops grown in the areas include Potato, Barley, Wheat, Oat, Teff, Faba-Bean, and Triticale.

Materials for Experiments

An improved potato cultivar called Gudenie (CIP-386423-13) was used as a test crop. The nutrients N, P, and $CaCO_3$ were extracted from lime, TSP, and urea, respectively. An auger and a core sampler were used to collect soil samples. The fungicide Ridomil was used to treat late blight disease by spraying triples.

Design and methodology of the experiment

A randomized complete block design (RCBD) with three replications was used. Spacing between plants, rows, plots, and blocks was 0.3 m, 0.75 m, 1 m, and 1.5 respectively. (4.5×3) meters were used as gross plot size and harvested areas were 7.2 m^2. The experiment had a total of twelve treatments placed in Table 1. Except for urea (138 N), TSP was applied at planting as basal application. Urea was applied in three splits at planting (46 N), 50 % flowering (46 N), and tuber commencement (46 N). while the lime was applied on rows at the planting period of time. Urea, TSP and Ca CO_3 was as source of N, P and lime respectively

Table 1. Treatments setup during experimentation

1) Full amount of Equation 1+25 % (125 %)	7) One-fifth of Equation1 (20 %)
2) Full amount of Equation-1 (100 %)	8) One-sixth of Equation 1 (16.7 %)
3) Three-fourth of Equation-1 (75 %)	9) One-seventh of Equation1 (14.3 %)
4) Half of Equation-1 (50 %)	10) One-eighth of Equation1 (12.5 %)
5) One–third of Equation-1 (33.3 %)	11) One-tenth of Equation 1 (11.1 %)
6) One-fourth of Equation-1 (25 %)	12) Control (without lime) (0 %)

Sampling, preparing, and analyzing of soil

Using an auger, representative soil samples, were taken from the field at depths of 0 cm to 20 cm, both before and after harvest. To test soil texture, exchangeable acidity, CEC, pH, and accessible Phosphorus, the samples were ground using a mortar and then run through a 2 mm sieve size. A 0.5 mm sieve size was used to measure the total nitrogen and soil organic carbon (OC). The bulk density was calculated using a core sampling approach. Main soil chemical properties of soil such as exchangeable acidity,

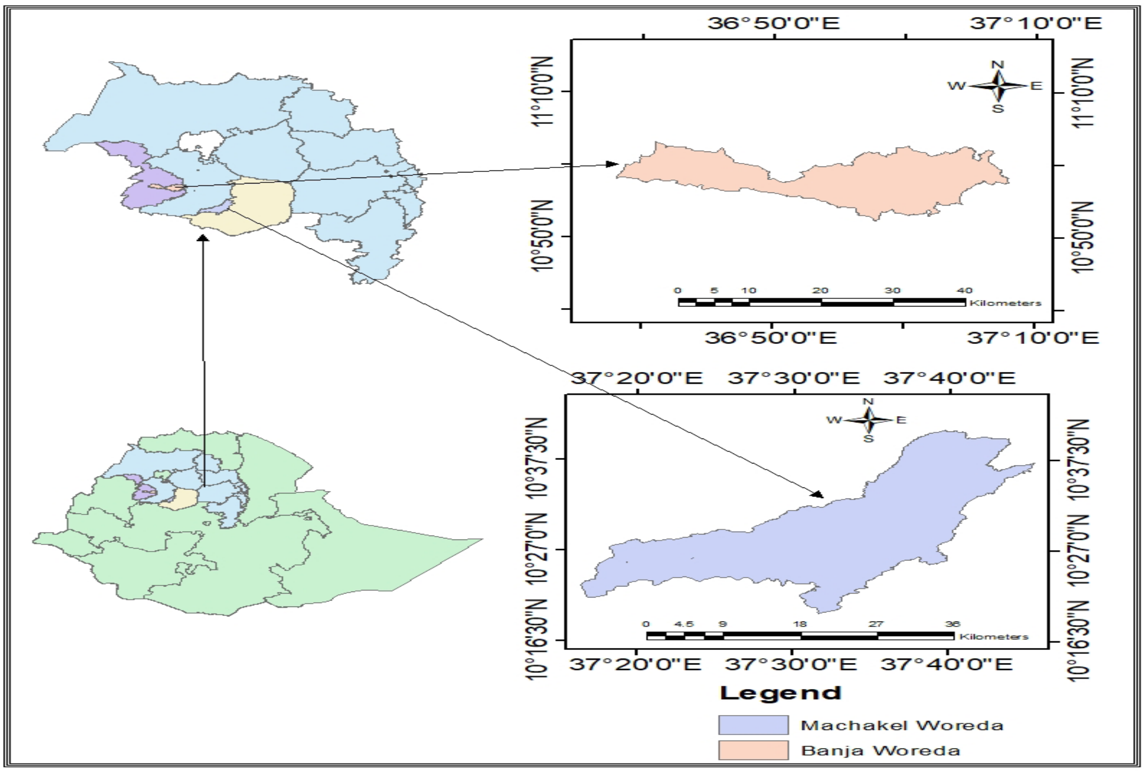

Figure 1. Map of the study districts

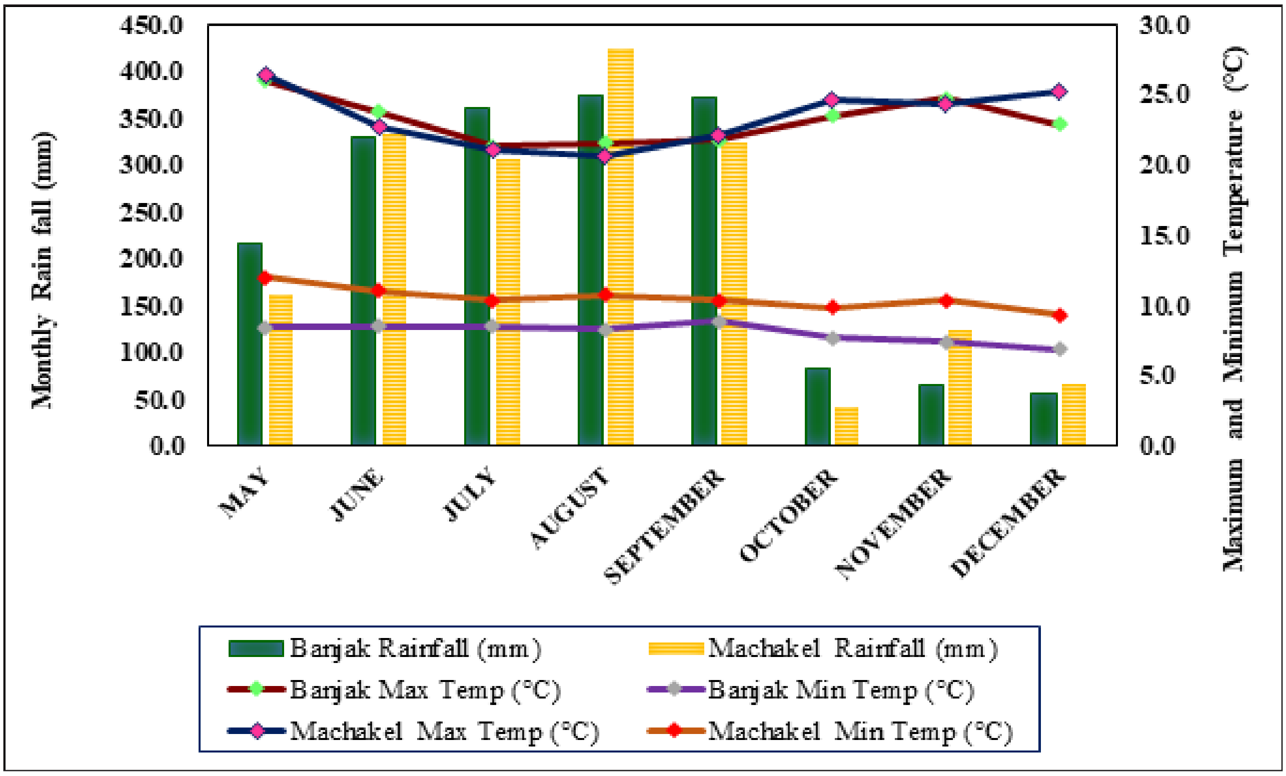

Figure 2. Cropping season rainfall, high and low temperatures are determined by the Ethiopian Meteorological Service Agency (EMSA), North West branch, Bahir Dar. Rainfall from RF

OC, pH, CEC, total N, and accessible P were tested in accordance with the produced laboratory manual of (Sahlemedihn & Taye, 2000). A glass electrode pH meter was used to measure the pH of soil in water at a 1:2.5 ratio. The soil OC content was evaluated using the wet digestion method described by Walkley and Black, which involved digesting the OC in soil samples with potassium dichromate ($K_2Cr_2O_7$) in sulphuric acid solution. The Olsen extraction method was used to determine the available phosphorus. The total N content of the soil sample was evaluated using the Kjeldahl method. CEC was evaluated by extracting soil samples with ammonium acetate (1N NH_4O Ac), followed by repeated washing with ethanol (96 %) to remove the excess ammonium ions in the soil solution. Percolating sodium chloride into the NH^{4+} saturated soil would displace the ammonium ions adsorbed in the soil, and the ammonium freed by distillation was titrated with 0.1 N NaOH. Simultaneously, core samples from each location were collected to determine the bulk density (BD), which is required to calculate the amount of lime, as indicated below. The soil samples were air-dried, crushed, and sieved in accordance with standard laboratory protocols (Sahlemedihn & Taye, 2000). The exchangeable acidity (sum of exchangeable Al^{+3} and exchangeable H^{+}) of the obtained soil samples was then evaluated at the Adet Agricultural Research Centre Laboratory. After determining the sample's exchangeable acidity, the lime need was estimated using equation one.

Data collection

By counting tubers from five randomly chosen plants and averaging them for a single reading, the quantity of tubers per plant was ascertained at harvest. Fresh marketable and non-marketable tubers were mechanically harvested from the 7.2 m^2 net middle plot area in order to calculate the total tuber yield and reduce border effects.

Statistical analysis of data

All data were subjected to variance analysis using SAS software version 9.4 (SAS Institute, 2014) and the general linear model (GLM). The list significant test (LSD) at the 0.05 probability level was used to distinguish treatment means when there were significant differences (Gomez & Gomez, 1984).

Result and discussion

Chemical properties of soil at Banja and Machakel

Table 2, 3 and 4 results indicated that the soil chemical properties before and after harvest at each experimental site. Before planting, soil investigation found that the soil was acidic with exchangeable acidity 2.78, 1.52 and 3.55 cmol.kg^{-1} (Figure 3) and pH 5.03, 5.30, and 5.13 (Table 2) at Banja, on first- and second-year sites one and two, respectively. Similarly, the composite soil sample results at Machakel district also indicated that the soil was highly acidic, with exchangeable acidity 6.09, 6.44, and 5.12 cmol.kg^{-1} (Figure 3) and pH 4.8, 4.76, and 4.73 (Table 2) on first- and second-year sites one and two, respectively, which is outside the critical range of optimum soil exchangeable acidity and low pH for crop production (Tekalign, 1991). After harvesting, soil pH and exchangeable acidity were modified by applying different lime rates (Table 3 & 4 and Figures 4 & 5) in Banja and Machakel regions, respectively. These could be attributed to the chemical reaction of the applied calcium carbonate ($CaCO_3$) with aluminum (Al^{+3}) and hydrogen (H^{+1}) in the soil exchangeable site. This makes them unavailable in soil solution due to a substitution reaction of calcium (Ca^{+2}) by aluminum and hydrogen, which reduces exchangeable acidity by increasing soil pH. The findings were consistent with those of (Athanase, 2017), who discovered that the application of various lime sources and rates altered exchangeable acidity and soil pH. The same author observed that the application of 4.2 t.ha^{-1} Rusizi lime decreased exchangeable acidity by a unit of 2.67 cmol.kg^{-1} when compared to the control treatment.

Total tuber yield of potato at Banja and Machakel

The analysis of variance showed that the tuber yield of potato is not significantly affected ($p < 0.05$) due to the application of lime rates across testing sites (Table 5 & 6 and figure 6 & 7). Even if the application lime rate reaches 125 % t.ha^{-1} it doesn't give a significant tuber yield as compared to other lower rate treatments including control. Although the results statistically were not significant some treatments have a yield advantage as compared to the control that gives the lowest fresh total tuber yield in Banja and Machakel testing sites (Table 4 & 5). For instance, in Banja, the application of 14.3 % of recommended lime gives 4.57 t.ha^{-1} and 6.41 t.ha^{-1} tuber yield advantage as compared to control on year one site one (Y1S1) and year two site two (Y2S2) respectively. Similarly, in Machakel, the application of 20 % full recommended lime gives 4.04 t.ha^{-1}, 1.13 t.ha^{-1}, & 0.94 t.ha^{-1} of total tuber yield advantage over control treatment at year one site one (Y1S1), year two site one (Y2S1) and year two site two (Y2S2) respectively.

This might be due to neutralization activity of lime that helps to plant get nutrients in the plant root system, especially phosphorus delivers into the soil solution beyond its sorption by Aluminum and Iron in acidic soil conditions. In addition, non-significant results in all lime-applied treatments as compared to the control and even with each other might be from the biological acid tolerance capacity of potato as compared to other crops like Barley, Faba-bean, wheat, and Maize. The finding in agreed with the study of (Assunção et al., 2020) who revealed that the supplement of dolomitic limestone did not rise plant growth and tuber yield of potato even when soil improvement was performed with calcitic limestone to increase the base saturation to 60 %. Another study done by (Hajduk et al., 2017) indicated that the application of lime had not significant impact on potato tuber yields even if the mean value of potato yield from non-limed and limed fields varied depending on mineral NPK nutrition; the yield from the non-limed field ranged from 19.3 t.ha^{-1} to 29.7 t.ha^{-1}. while the limed field was 20.6 t.ha^{-1}-32.5 t.ha^{-1}.

Table 2. Before planting soil chemical properties at Banja and Machakel

Campsite sample	pH	Ex H^{+1}	Ex Al^{+3}	Ex A (cmol.kg^{-1})	BD (g.cm^{-3})	TN %	OC%	Av.P (mg .kg^{-1})	CEC (cmol .kg^{-1})	LR (t.ha^{-1})
Banja										
Y1S1	5.03	1.14	1.64	2.78	1.2	0.28	3.55	15.64	27.70	5.1
Y2S1	5.30	0.34	1.18	1.52	1.27	0.19	2.67	17.43	30.92	2.9
Y2S2	5.13	1.25	2.3	3.55	1.30	0.12	1.57	10.15	29.04	6.9
Machakel										
Y1S1	4.80	1.27	4.82	6.09	1.23	0.12	1.71	15.04	28.56	10.3
Y2S1	4.76	1.11	5.33	6.44	1.16	0.17	2.47	9.36	24.80	11.2
Y2S2	4.73	0.32	4.79	5.12	1.27	0.18	1.91	4.94	20.72	9.7

Y1S1= year one site one, Y2S1=year two site one, Y2S2=year two site two LR= calculated lime for each site and Ex A=exchangeable acidity

Table 3. After harvesting soil chemical properties at Banja sites

	Y1S1				Y2S1				Y2S2			
Treatment	pH	Ex H^{+1}	ExAl^{+3}	ExA (cmol.kg^{-1})	pH	Ex H^{+1}	Ex Al^{+3}	Ex A (cmol.kg^{-1})	pH	Ex H^{+1}	ExAl^{+3}	ExA (cmol.kg^{-1})
125 % lime	6.05	0.0	0.12	0.12	5.40	0.33	0.0	0.33	6.53	0.18	0.0	0.18
100 % lime	6.80	0.0	0.59	0.59	5.15	0.53	0.0	0.53	6.20	0.26	0.0	0.26
75 % lime	6.89	0.0	0.20	0.20	4.80	0.55	0.54	1.09	6.97	0.11	0.0	0.11
50 % lime	6.56	0.0	0.09	0.09	4.83	0.77	0.0	0.77	6.51	0.15	0.0	0.15
33.3 % lime	5.93	0.15	0.58	0.73	5.26	0.34	0.46	0.80	5.87	0.26	0.0	0.26
25 % lime	6.48	0	0.15	0.15	4.98	0.52	1.01	1.53	6.02	0.16	0.0	0.16
20 % lime	4.78	3.6	0.05	3.6	4.89	0.49	1.18	1.67	5.67	0.19	0.0	0.19
16.7 % lime	6.08	0.27	0.31	0.58	4.94	0.60	1.25	1.85	5.88	0.22	0.0	0.22
14.3 % lime	5.72	0.75	0.15	0.90	4.74	0.69	1.52	2.21	5.78	0.31	0.0	0.31
12.5 % lime	4.96	2.27	0.33	2.61	4.85	0.42	1.20	1.62	6.72	0.16	0.0	0.16
11.1 % lime	5.13	2.15	0.08	2.23	4.76	0.56	1.65	2.21	5.90	0.21	0.0	0.21
0 % lime	4.76	5.15	0.04	5.19	4.82	0.43	1.47	1.90	5.46	0.74	0.0	0.74

Y1S1=year one site one, Y2S1=year two site one, Y2S2=year two site two, pH=concentration of hydrogen and ExA=exchangeable acidity

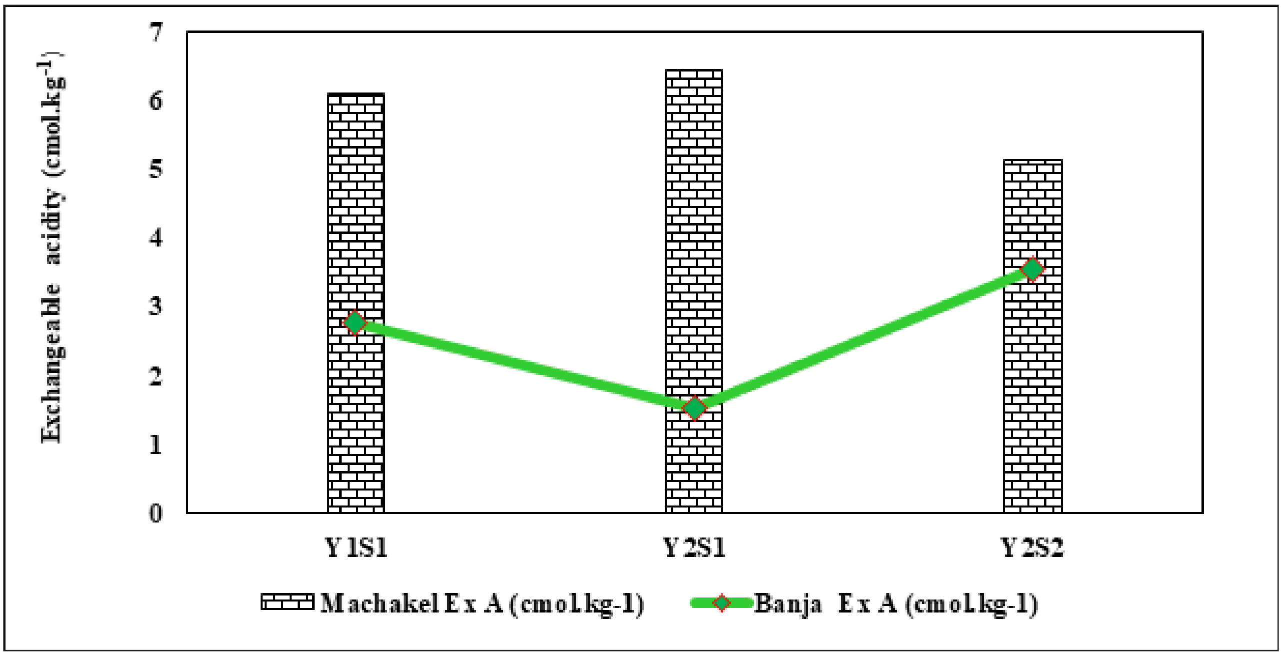

Figure 3. Extenent of exchangeable acidity across districts on experimental sites

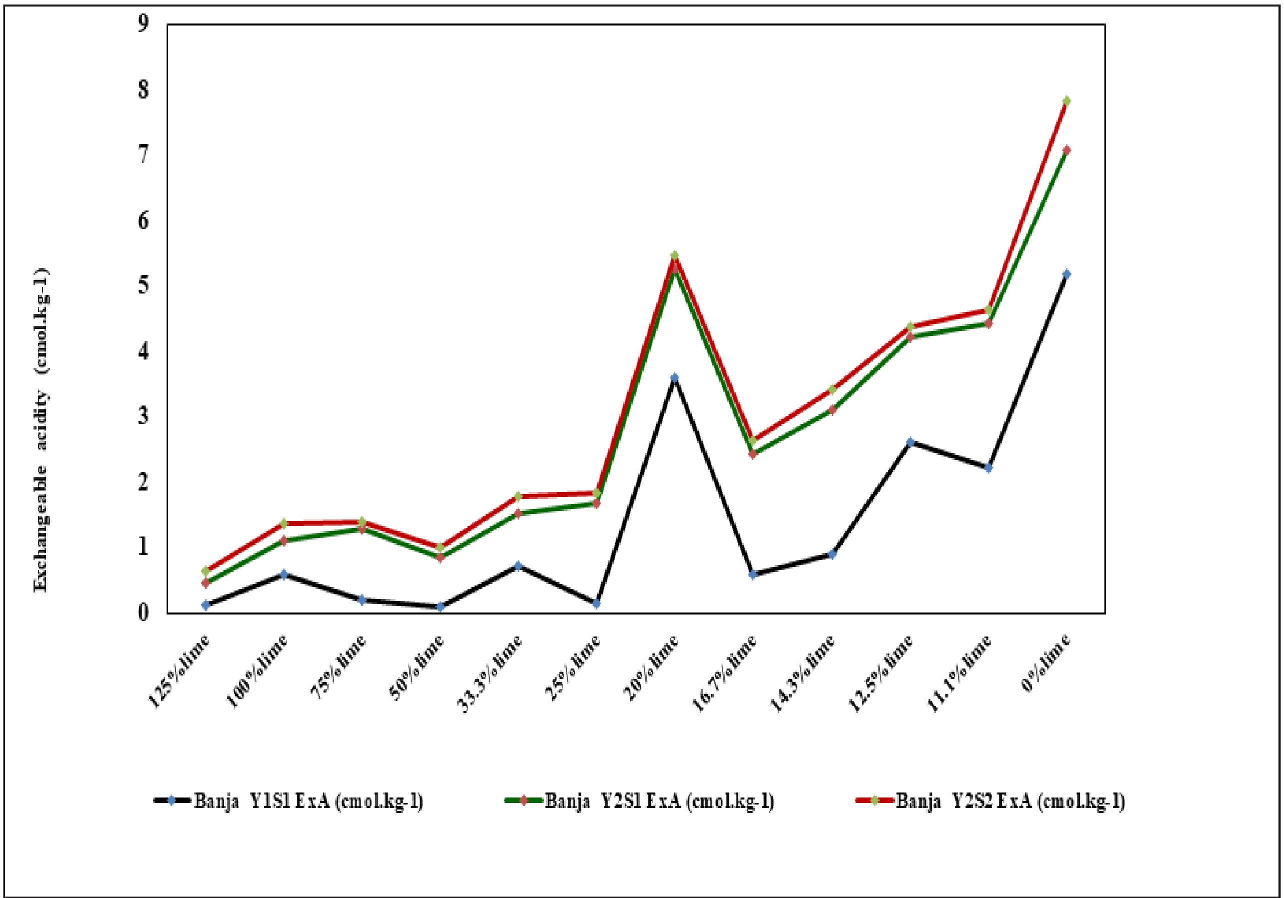

Figure 4. Effect of lime rates on exchangeable acidity at Banja

Table 4. After harvesting soil chemical properties at Machakel sites

	Y1S1				Y2S1				Y2S2			
Treatment	pH	Ex H^{+1}	Ex Al^{+3}	Ex A ($cmol.kg^{-1}$)	pH	Ex H^{+1}	Ex Al^{+3}	Ex A ($cmol.kg^{-1}$)	pH	Ex H^{+1}	Ex Al^{+3}	ExA ($cmol.kg^{-1}$)
125 % lime	5.53	0.81	1.96	2.77	5.47	0.05	1.60	1.65	7.03	0.39	0.0	0.39
100 % lime	5.12	0.27	3.63	3.90	5.40	1.03	4.16	5.19	6.83	0.21	0.0	0.21
75 % lime	5.17	0.71	3.57	4.29	4.88	0.27	4.46	4.73	6.78	0.12	0.0	0.12
50 % lime	5.20	0.88	3.52	4.40	4.86	0.46	3.47	3.93	6.15	0.19	0.0	0.19
33.3 % lime	5.07	0.40	4.01	4.41	4.84	1.11	3.86	4.97	6.09	0.18	0.0	0.18
25 % lime	4.74	0.50	4.64	5.14	4.82	0.37	3.69	4.06	6.27	0.20	0.0	0.20
20 % lime	4.89	0.33	4.55	4.88	4.47	0.82	4.42	5.24	6.42	0.12	0.0	0.12
16.7 % lime	4.76	0.68	4.46	5.14	4.76	0.92	3.50	4.42	5.76	0.23	0.0	0.23
14.3 % lime	4.79	0.25	4.65	4.90	4.93	0.42	4.27	4.69	5.14	0.29	1.27	1.56
12.5 % lime	4.76	0.53	4.61	5.14	4.69	0.55	4.10	4.65	4.80	0.62	2.25	2.87
11.1 % lime	4.70	0.53	4.60	5.13	4.77	0.87	4.07	4.94	4.99	0.43	1.89	2.32
0 % lime	4.78	0.54	4.61	5.15	4.87	0.43	4.78	5.21	4.76	0.56	4.42	4.98

Y1S1=year one site one, Y2S1=year two site one, Y2S2=year two site two, pH= concentration of hydrogen and ExA=exchangeable acidity

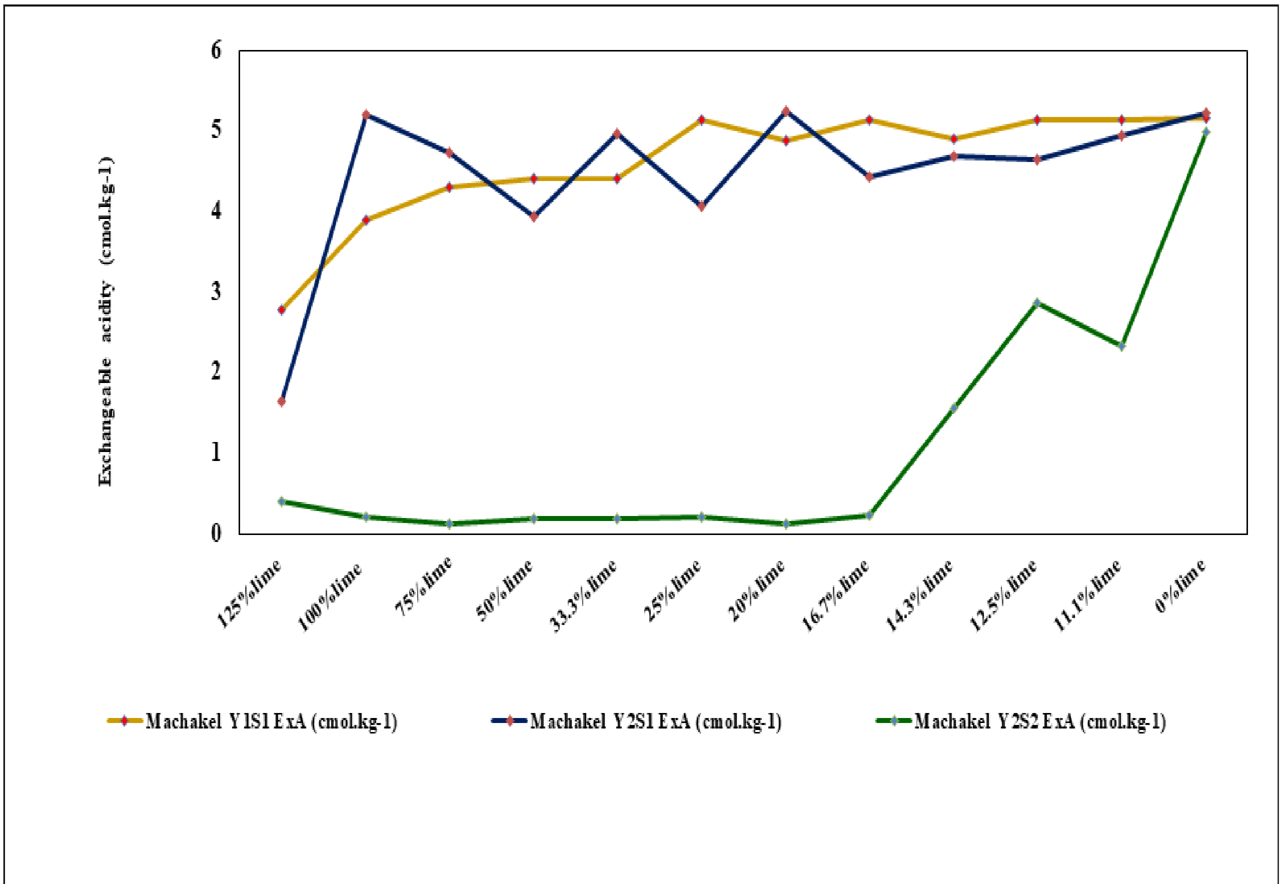

Figure 5. Effect of lime rates on exchangeable acidity at Machakel

Table 5. Effect of lime rate on tuber yield and yield components of Potato at Banja

Treatment	Y1S1			Y2S1			Y2S2		
	MY (t.ha^{-1})	UMY (t.ha^{-1})	TY (t.ha^{-1})	MY (t.ha^{-1})	UMY (t.ha^{-1})	TY (t.ha^{-1})	MY (t.ha^{-1})	UMY (t.ha^{-1})	TY (t.ha^{-1})
125 % lime	12.82	0.63	13.44	20.52	2.22	22.74	13.37	0.3	13.67
100 % lime	11.7	0.24	11.94	21.78	4.15	25.93	13.5	0.29	13.79
75 % lime	11.89	0.57	12.46	19.89	2.78	22.67	13.44	0.2	13.64
50 % lime	12.3	0.4	12.70	17.15	1.85	19.00	18.14	0.28	18.42
33.3 % lime	10.74	0.19	10.93	16.59	2.41	19.00	17.72	0.33	18.05
25 % lime	11.56	0.38	11.94	18.41	2.37	20.78	10	0.31	10.31
20 % lime	10.52	0.35	10.87	16.93	1.7	18.63	14.89	0.3	15.19
16.7 % lime	11.78	0.22	12.00	19.37	2.07	21.44	14.39	0.76	15.15
14.3 % lime	13.93	0.62	14.55	18.74	2.07	20.81	16.78	0.24	17.02
12.5 % lime	11.7	0.23	11.93	18.96	3.04	22	17.78	0.25	18.03
11.1 % lime	10.74	0.72	11.46	19.56	2.74	22.3	14.59	0.16	14.75
0 % lime	9.63	0.35	9.98	14.44	2.33	16.77	10.17	0.44	10.61
LSD	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV	22.3	80.6	22.1	25.2	90.0	23.1	30.2	45.6	29.8

Y1S1= year one site one, Y2S1=year two site one, Y2S2=year two site two, MY=marketable tuber yield, UMY=unmarketable tuber yield and TY =total tuber yield.

Figure 6. Filed performance of potato at Banja during growing period

Table 6. Effect of lime rate on tuber yield of Potato at Machakel

Treatment	Y1S1			Y2S1			Y2S2		
	MY (t.ha^{-1})	UMY (t.ha^{-1})	TY (t.ha^{-1})	MY (t.ha^{-1})	UMY (t.ha^{-1})	TY (t.ha^{-1})	MY (t.ha^{-1})	UMY (t.ha^{-1})	TY (t.ha^{-1})
125 % lime	10.1	0.67	10.78	6.2	0.88	7.1	7.19	0.42	7.61
100 % lime	8.96	0.22	9.19	8.1	0.71	8.82	5.59	0.66	6.27
75 % lime	10.1	0.96	11.04	7	0.7	7.74	5.41	0.26	5.67
50 % lime	9.41	0.26	9.67	8.8	0.92	9.73	6.59	0.3	6.89
33.3 % lime	8.89	1.7	10.59	8.7	0.86	9.57	6.3	0.61	6.91
25 % lime	9.44	0.52	9.96	7.3	0.74	8.0	6.37	0.42	6.79
20 % lime	10	0.85	10.89	9.7	0.58	10.3	6.56	0.45	7.01
16.7 % lime	9.67	0.93	10.59	6.6	0.78	7.33	5.93	0.56	6.49
14.3 % lime	7.96	0.89	8.85	8.4	0.64	9.01	5.41	0.78	6.19
12.5 % lime	7.15	1.93	9.07	8.8	0.43	9.21	6.52	0.16	6.68
11.1 % lime	8.52	0.52	9.04	9.4	0.89	10.3	6	0.83	6.83
0 % lime	5.67	1.19	6.85	7	0.36	7.36	5.78	0.29	6.07
LSD	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV	20.2	79.5	18.6	22.3	37.3	21.2	27.1	69.4	28.1

Y1S1= year one site one, Y2S1=year two site one, Y2S2=year two site two, MY=marketable tuber yield, UMY=unmarketable tuber yield and TY =total tuber yield.

Figure 7. Filed performance of potato at Machakel during growing period

Conclusion

The addition of lime on acidic soils of Banja and Machakel did not significantly improve the tuber yield of Irish potato as compared with control. The soil properties were affected due to the application of different lime rates. This might be due to the reclamation (neutralization) activity of lime through the substitution chemical reaction of ($CaCO_3$) with aluminum (Al^{+3}) and Hydrogen (H^{+1}) on soil exchangeable sites. So, in the study areas, further cost to lime for potato production is not necessary, but in order to reclaim or amend acidic soil for production of subsequent crops, it is important to use the minimum rate of lime. Based on this application of 14.3 % of the lime rate at Banja and 20 % of the lime rate at Machakel with recommended fertilizer (138 N, 69 P_2O_5) would be important for potato production and acidic soil reclamation in small-scale farmers filed.

Acknowledgment

The Authors express their gratitude to Amhara Agricultural research Institute (ARARI). And their acknowledgment is extended to the Adet Agricultural Research Center for facilitating different resources and funds.

Conflict of interests

The authors have no conflict of interest.

Funding Declaration

This work was supported by the Amhara Agricultural research institute Adet Agricultural Research Center.

Author Contributions

Conceptualization: ZA, TA. Data curation: ZA, BK, AA. Formal analysis: ZA. Investigation: ZA, TA, BK, AA , AT. Methodology: ZA, TA. Project administration and Software: ZA. Resources: ZA, TA, BK, AA, AT. Supervision and Validation: ZA, TA. Writing – original draft: ZA, TA. Writing – review and editing: ZA.

ORCID and e-mails

Zelalem Addis zelalemaddis660@gmail.com
https://orcid.org/0000-0002-1869-8596

Reference

Afework, S., Selassie, Y. G., Ejjigu, W., Lewoyehu, M., & Abera, T. (2023). Effects of micro-dosing of lime on yield and yield components of potato on farmers' field in Banja district, Awi Zone, Amhara Region. *Ethiopia. J Agri Sci Food Res, 14*(2), 2161–1025.

Agegnehu, G., Amede, T., Erkossa, T., Yirga, C., Henry, C., Tyler, R., … Sileshi, G. W. (2021). Extent and management of acid soils for sustainable crop production system in the tropical agroecosystems: a review. *Acta Agriculturae Scandinavica, Section B — Soil & Plant Science, 71*(9), 852–869. https://doi.org/10.1080/09064710.2021.1954239

Amare, T., Bazie, Z., Alemu, E., Wubet, A., Agumas, B., Muche, M., ... & Fentie, D. (2018). Crops Response to Balanced Nutrient Application in Northwestern Ethiopia. *Blue Nile Journal of Agricultural Research, 1*(1), 1–14.

Assunção, N. S., Ribeiro, N. P., da Silva, R. M., Soratto, R. P., & Fernandes, A. M. (2020). Tuber yield and allocation of nutrients and carbohydrates in potato plants as affected by limestone type and magnesium supply. *Journal of Plant Nutrition, 43*(1), 511–63

Athanase N. (2017). Effects of Different Limes on Soil Properties and Yield of Irish Potato (*Solanum tuberosum* L.). In Burera District, Rwanda. [Master dissertation, Kenyatta University]. http://ir-library.ku.ac.ke/handle/123456789/8980

Birhanu, A., Anteneh, A., Dereje, A., Kenzemed, K., Genet, T., & Gebreyes, G. (2016). Effect of lime and phosphoruson wheat (*Triticum aestivum*) wheat, Tef Eragrostisteff), and Barley (*Hordium Vulgars* L.) yields in the Amhara highlands. *Proceeding of the 7th and 8th annual regional conference on completed research activities of soil and water management research*, *25-31*, 29–42).

Central Statistics Authority [CSA] (2016). *Agricultural Sample Survey Report on Area and Production of Crops*.

Demil, A., Amare, T., Awoke, Y., Derebe, A., & Adera, T. (2020). Bridging the yield gaps of bread wheat at a scalethrough an innovative method of lime application in the acidic soils of Northwestern Ethiopia. *Cogent Food & Agriculture, 6*(1), 1803578.

Food and Agriculture Organization of the United Nations [FAO], (2008). International Year of the Potato. https://www.fao.org/agriculture/crops/core-themes/theme/hort-indust-crops/international-year-of-the-potato/en/

Getaneh, S., & Kidanemariam, W. (2021). Soil acidity and its management: a review. International Journal of Advanced Research in Biological Sciences, 8(3), 70–79.

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

Hajduk E., Gąsior J., Właśniewski S., Nazarkiewicz M., & Kaniuczak J. (2017) Influence of liming and mineral fertilization on the yield and boron content of potato tubers (*Solanum tuberosum* L.) and green mass of fodder sunflower (*Helianthus annuus* L.) cultivated in loess soil. *J. Elem., 22*(2), 411–426.

Hassen, A., Worku, A., Tafere, M., Tolla, M., Ahmed, A., Dagnew, S., ... & Abebe, T. (2015). Best Fit Practice Manual for Potato Production and Utilization. *BDU-CASCAPE working paper,* 8.

Haverkort, A. J., Van Koesveld, M. J., Schepers, H. T. A. M., Wijnands, J. H. M., Wustman, R., & Zhang, X. X. (2012). Potato prospects for Ethiopia: on the road to value addition (No. 528). Praktijkonderzoek Plant & Omgeving.

Hirpa, A., Meuwissen, M. P., Van der Lans, I. A., Lommen, W. J., Oude Lansink, A. G., Tsegaye, A., & Struik, P. C. (2012). Farmers' opinion on seed potato management attributes in Ethiopia: A conjoint analysis. *Agronomy Journal, 104*(5), 1413–1424. https://doi.org/10.2134/agronj2012.0087

Jovovic, Z., Dolijanovic, Z., Spalevic, V., Dudic, B., Przulj, N., Velimirovic, A., & Popovic, V. (2021). Effects of Liming and Nutrient Management on Yield and Other Parameters of Potato Productivity on Acid Soils in Montenegro. *Agronomy, 11*(5), 980.

Kawar, P. G., Kardile, H. B., Raja, S., Dutt, S., Raj Kumar, R. K., Manivel, P., ... & Chakrabarti, S. K. (2018). Developing early-maturing and stress-resistant potato varieties (pp. 143–167). http://dx.doi.org/10.19103/AS.2017.0016.07

Kebede, D., & Ketema, M. (2017). Why do Smallholder Farmers Apply Inorganic Fertilizers below the Recommended Rates. *Empirical Evidence from Potato Production in Eastern Ethiopia. Adv Crop Sci Tech, 5*(2), 265

Leta, R., Dechassa, N., Legesse, H., Schulz, S., & Gameda, S. (2024). Determining Rate of Liming for Attaining Optimum Soil PH and Tolerable Aluminum Saturation Level for Producing Bread Wheat in Strongly Acidic Soil of Guto-Gida District, East Wollega Zone, Western Ethiopia. *East African Journal of Sciences, 18*(2), 107–24, https://doi.org/10.20372/eajs.v18i2.2155

Romero Antonio, M. E., Faye, A., Betancur-Corredor, B., Baumüller& Joachim von Braun, H. (2024). Productivity effects of agroecological practices in Africa: insights from a systematic review and meta-analysis. *Journal of Food Security, 17*, 207–229. https://doi.org/10.1007/s12571-024-01504-6

Regasa A, Haile W, Abera G (2024) Soil acidity and fertility status of surface soils under different land uses in Sayo district of Oromia, western Ethiopia. *PLoS ONE, 19*(12), e0316009. https://doi.org/10.1371/journal.pone.0316009

Sahlemedihn S. & Taye B. (2000). *Procedures for soil and plant analysis.* National Soil Research Centre. Ethiopian Agricultural Research Organization.

Tadesse, T., Haque, I., & Aduayi, E. A. (1991). Soil, plant, water, fertilizer, animal manure and compost analysis manual.

Woldegiorgis, G., Schulz, S., & Berihun, B. (2013). Seed potato production and dissemination, experiences, challenges and prospects. *Proceedings of the National Workshop on Seed Potato Tuber Production and Dissemination*. Ethiopian Institute of Agricultural Research (EIAR), Amhara Regional Agricultural Research Institute (ARARI)

Zerssa, G., Feyssa, D., Kim, D.-G., & Eichler-Löbermann, B. (2021). Challenges of Smallholder Farming in Ethiopia and Opportunities by Adopting Climate-Smart Agriculture. *Agriculture, 11*(3), 192. https://doi.org/10.3390/agriculture11030192