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Research Article

Effects of different dose of nitrogen and lime on soil properties and maize (*Zea mays* L.) on acidic nitisols of Northwestern Ethiopia

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ABSTRACT

This study was carried out on the nitisols of Burie district, Ethiopia to examine the effect of integrated use of lime and nitrogen on soil physicochemical properties and maize yield. Two levels of lime (0 and 0.5 t/ha) and five-level of nitrogen (0, 46, 92, 138 and 184 kg N/ ha) were laidout in randomized complete block design with three replications. The results indicated that among before planting, soil bulk density (BD), pH, soil organic carbon (OC), total nitrogen (TN), available P and CEC were 1.42 g/cm^3, 5.2 (strongly acidic), 1.32% (very low), 0.12% (low), 8.86 mg /kg (very low), and 19.57 cmolc /kg (medium), respectively. The physicochemical properties except bulk density increased. The lowest soil BD (1.21 g/m^3) was from plots treated with 0.5 t/ha lime and 184 kg N/ ha. The maximum soil pH (6.85) was obtained from plots treated with 184 kg N/ ha and 0.5 t/ha lime. The maximum soil CEC (35.38 (cmol$_c$ /kg) was obtained from plots treated with 184 kg N/ ha and 0.5 t/ha lime. Level of lime, nitrogen fertilizer, and interaction effects of lime and nitrogen fertilizer (L×N) significantly affected maize yield ($p<0.001$). Indeed yield of maize has positive correlations with most soil physicochemical properties but negative with BD (r= -0.543). The adjusted yield and net benefits was 6.4 t/ha and 1101.77$. Inherent physicochemical properties of the soil are changed either by sole or combined use of lime and N fertilizer. Soils tilled with 0.5 t/ha lime and 138 kg/ha nitrogen were found in maximum net benefit. Residual long-term effects should be researched. Thus, liming should be given an emphasis on acidic soil amelioration. Moreover, the government may facilitate the supply of lime and nitrogen fertilizer to the farmers.

Keywords: Fertility, Liming, Management practices, Soil acidity, Yield

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INTRODUCTION

Soil fertility management for food and livelihood security is a major concern in the face of persistent poverty and widespread environmental degradation in Sub-Saharan Africa (SSA) including Ethiopia (Bello *et al.*,2010). The same authors reported that around 97% of the agricultural lands in SSA are under a rainfed systemwhich remains the dominant source of food production shortly. Besides, Worku *et al.* (2012) reported that nutrient depletion is the chief biophysical factor limiting small-scale production in Africa.

In Ethiopia, soil degradation and nutrient depletion have gradually increased and become serious threats to agricultural productivity (Kebede & Yamoah, 2009).The same author reported that soil acidity is one of the limiting factors to acid-sensitive crops in the Northwestern highlands of Ethiopia. Its effects on crop growth are those related to the deficiency of major nutrients and the toxicity of aluminum (Al), manganese (Mn), and hydrogen (H) to plants (Mesfin, 2007).

To secure sustainable crop production and reasonable yield, acidic soils have to be corrected by the addition of agricultural lime to a pH range that is suitable for better yield of crop production and to improve soil physicochemical properties (Mesfin, 2007). Liming materials raise the soil pH and increase the productivity of crops. Agricultural lime is a material containing calcium (Ca) and/or magnesium (Mg) compounds capable of neutralizing soil acidity (Moreira & Fageria, 2010).A liming material with a higher Calcium Carbonate Equivalence (CCE) value will have greater effectiveness than one with a lower CCE value. Impurities, such as clay and organic matter that naturally occur in liming materials create variations in CCE among different liming materials (Moreira & Fageria, 2010). The common liming materials used to ameliorate acidity are calcium oxide (CaO) and calcium carbonate ($CaCO_3$) in powdery formulations (Opela *et al.*,2018). Among these, calcite ($CaCO_3$) is available in Ethiopia and recommended to raise the soil pH. However, the appropriate rates of nitrogen and basic cation (Ca^{2+}) nutrients required to maximize the yield, quality and nutrient use efficecency of maize should be known, especially for potential areas including Burie district. The level of acidity in the study area was strongly acidic (5.2) that needs liming materials such as $CaCO_3$. Therefore, this study was initiated to evaluate the effects of sole or combined use of calcite and N fertilizer on maize yield and soil physico-chemical properties on the nitisols of Burie district Northwestern Ethiopia.

MATERIALS AND METHODS

Research site location and soil

The experiment was conducted in Burie district, West Gojjam Zone of Amhara National Regional State (ANRS) during the 2018/2019 main cropping season. The study site is located between latitude of 10°43'0" to 10°47'0" North and longitude of 37°3'0" to 37°6'0" East. It is located in the northwestern part of Ethiopia at a distance of 411 km from Addis Ababa and 148 km southwest of Bahir Dar city. The altitude of the Burie district ranges from 2087 to 2,637 m.a.s.l.The soil of the area is characteristically humic nitisols. In general, soils of the area are well-drained, clay in texture, and strongly acidic nitisols in soil reaction. The districthas a total of 29,629 ha agricultural land from this 42.8% is covered by maize crop in the 2018/2019 crop production year. The mean yield of maize from all varieties under on-farm was 5.55 tha^{-1} which is lowas compared with the production potential of the area. The experimental site was covered by wheat crop during the past cropping seasons. The

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recommended N and NPS fertilizers in the study area are 200 N kg/ha in the form of urea (46%,0,0) and 200 NPS kg/ha (19%, 38%, 7%), respectively.

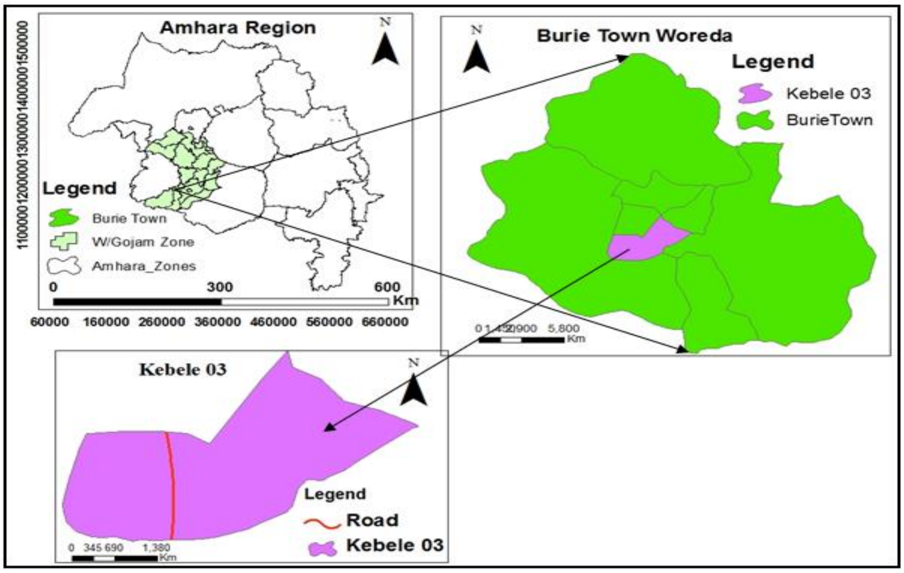

Figure 1: Map of the study area

Based on the Amhara Meteorological Agency report in 2020, the mean annual rainfall of the districtwas 1375.8 mm and the mean minimum, mean maximum and average air temperature of ten years (2010-2019) data in the study area was 12.31 ^oC, 25.93 ^oC, and 19.12 ^oC (Figure 2). Summary of 10 years (2010-2019) mean annual rainfall and temperature data of study area is presented.

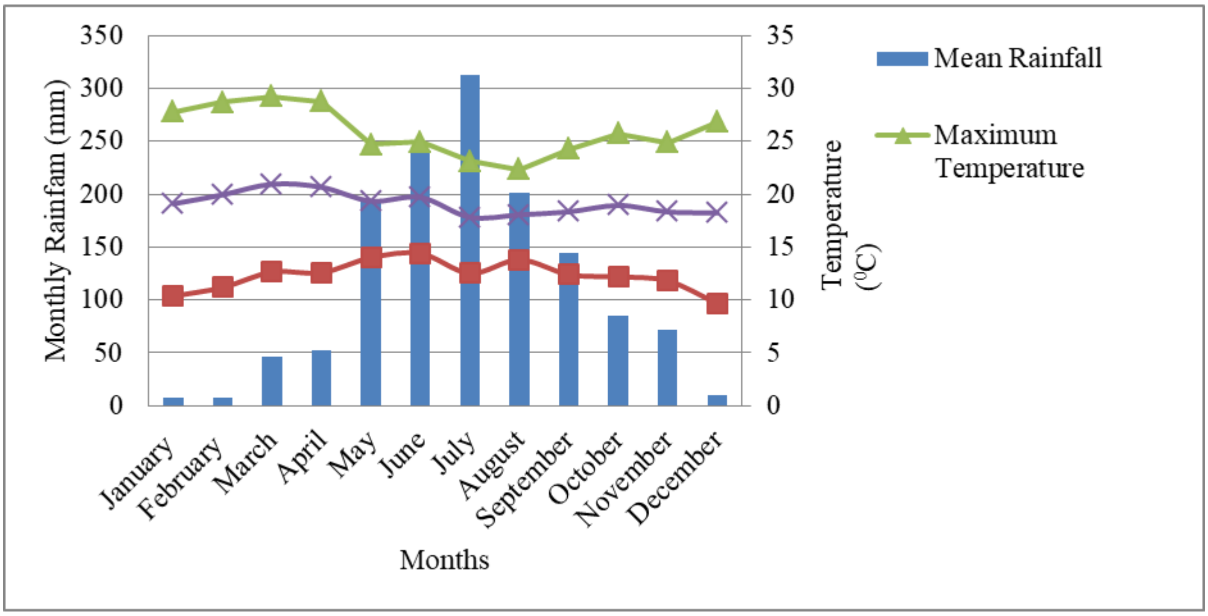

Figure 2: Monthly rainfall (mm), minimum, maximum and average air temperature (^{0}C) of the study area during 2010-2019 (Own Source, 2020)

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Experimental Materials

Plant, fertilizer and lime

The maize variety H-661 (Bako Hybrid-661) which is adapted to the agro-ecology and registered at the national level was collected from Amhara Seed Enterprise and used as a test crop. As a feretilizer urea (46 % N) was applied at five different rates (0,100, 200, 300, and 400 kg ha^{-1}). Baseline status of soil total nitrogen was low. Due to this reason, two levels of the recommended rate above and below were used to conduct this experiment. It was applied in one dose at knee height sage. This fertilizer was applied by banding at a distance 2 to 3 cm away from the plant and at 20 cm depth and covered immediately with soil.The recommended rate of NPS (19 % N, 38 % P_2O_5, and 7 % S) fertilizer was uniformly applied to all plots at the time of planting.Liming material in the form of calcium carbonate ($CaCO_3$) passed a 100-mesh was applied. As described in the district agricultural office manual in the cropping season, there are two ways of lime application. First, during seed sowing (i.e row application) if the lime is a powder, and the secondis broadcasting application for granular type of lime. First, during seed sowing one fourth (2t/ha) of the recommended rate of broadcasting (i.e 0.5 t/ha lime) was applied. Indeed, broadcasting application is recommended to apply one or two months before seed sowing.Lime was added as the district agricultural office extension package manual (2019). Liming rate was used with and without based on the soil pH of the experimental site. According to the same extension package manual when the pH (H_2O) value of the soil is between 5.14 to 5.32, the recommended lime rate for broadcasting application method is 2 t/ha. Liewise, for row application method, 0.50 t/ha of the recommended rate for broadcasting method was used.Since the soil pH of experimental site was 5.2, the amount of lime rate added during maize sowing was 0.5 t/ha.

Data Collection

Evaluation of changes in soil properties

Before sowing the seed, ten disturbed soil samples were taken at a depth of 0 to 20 cm at different points by vertical insertion of a shovel and mixed to get one composite sample. Similarly, ten representative undisturbed samples were taken for bulk density determination using core sampler. Likewise, 30 disturbed soil samples were collected from each plot within a block and reduced into ten composite samples for soil chemical property analysis. On the other hand, after harvest, 30 undisturbed samples were also collected from each plot within a block for BD determination. The composite surface soil and individual soil samples from each plot after treatment were properly labelled and the labels were placed both inside and outside the plastic bags and were transported to the soil laboratory of Amhara Design and Supervision Works Enterprise.

Analysis of soil physical properties

Soil bulk density was measured from undisturbed soil samples collected using a core sampler (which was weighed at field moisture) after drying the pre-weighed soil core samples to constant weight in an oven at 105 ^{0}C as per the procedures described by (Blake, 1965). As same author prescribed that, soil bulk density was calculated by dividing the masses of the oven-dried soils by their respective total volume of the core sampler.

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$$BD = \frac{weight\ of\ oven\ dried\ soil}{core\ volume\ of\ soil} \quad (1)$$

Where, BD: bulk density (g/cm^3), weight of oven dried soil (g) and core volume of the soil (cm^3)

Analysis of soil chemical properties

The composite soil samples were air-dried, mixed well, and passed through a 2 mm sieve for the analysis of selected chemical properties. Soil pH was measured using a pH meter in a 1:2.5 soil: water ratio suspensionas outlined by (Van,1993). Soil OC was determined by the Walkley and Black wet digestion method (Walkley & Black,1934), and the soil OM was calculated by multiplying the percent organic carbon by a factor of 1.724. Total N was determined using the micro-Kjeldahl digestion, distillation, and titration procedure as described by (Bremner & Mulvaney,1982). Available P was determined using the standard Olsen extraction method (Olsen,1954). CEC was measured by ammonium acetate extraction method (Chapman,1965).

Fertilizer application and field activities

The experimental plot plowed three times; the first plowing was done on the first of April with a disc plough. The second and final plowing was conducted by oxen driven local plow c alled “*Maresha*” at first and last dates of May. Spacing of maize plants was 75 cm between rows and 25cm between plants. The experimental field was hand weeded twice at 25 and 45 days after planting. A late-emerging weed were removed by hoeing to avoid mixup between the N applied and non-applied treatments. All other agronomic practices such as fertilization, hoeing, disease, insects, and weeds management were as per the recommendation. Maize plants in the central net plot area were harvested leaving one boarder row from each side of each plot.

Data Analysis

Analysis of variance (ANOVA) was carried out using SAS statistical package program version 9.0. Duncan’s Test was used to assess yield differences among treatment means where significant differences were obtained by the analysis of variance. A soil physicochemical properties bivariate correlation on yield of maize was also carried out. Finally, soil physicochemical properties comparison with critical values was done.

RESULTS AND DISCUSSION

The results of soil analysis before application of calcite and N fertilizer for maize crop is presented in Table 1. Before harvesting, BD of the soil was 1.42 g/cm^3 with clay texture (Table 1). The high BD value might be due to compactness of the soil and lower OM content that resulted from continuous cultivation and removal of plant roots and residues. Thus, as per the critical value rated by Karltun *et al*. (2014), the soil of the study area has a higher BD.This is supported by Karltun *et al.* (2014)who reported an increase in bulk density due to compaction and decreasing soil pore space in Ethiopia. Bulk densities of soils are inversely related to the amount of pore space and soil OM (Gupta, 2000; Brady & Weil, 2008). Any factor that influences soil pore space will also affect the bulk density. For instance, exhaustive cultivation increases bulk density resulting in a decrease of total porosity (Brady & Weil, 2008).

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The soil reaction (pH-H_2O) was strongly acidic with a value of 5.2 (Table 1). According to Karltun *et al.* (2014),pH less than 4.5 is classified as strongly acidic, 4.5-5.5: highly acidic, 5.6-6.5: moderately acidic, 6.6-7.3: neutral, 7.4-8.4: moderately alkaline, >8.5: strongly alkaline. Therefore, soils of the study area are strongly acidic.

The soil OC contents were 1.32% (Table 1), which is rated as very low (< 1.7%) to low (2-4%) as per the rating of soil test values interpretation by (Landon & Manual, 1991). Based on this result, soil OC of the study area rated as very low compared to the critical value (3%).This might be due to the removal of plant tissues and root residue from the soil. For a soil to be productive, it needs to have OC content in the range of 1.8-3% so as to achieve good soil structural conditions and structural stability (Abera & Wolde-Meskel, 2013).

The content of Total Nitrogen (TN) also followed the trend of soil OC which had a value of 0.12% (Table 1). According to Karltun *et al.* (2014), TN rated as very low (< 0.10%), low (0.1-0.15%) and optimum (0.15-0.30%). Based on these ratings, the study area had lower TN content. This minimum soil OC and TN values are expected in the maize-growing fields of the study area where there is complete removal of biomass from the crop field, lower application rate of fertilizers, and continuous cultivation that favors rapid rate of mineralization (Abera & Wolde-Meskel, 2013).

Available P before the application of lime and urea fertilizer was very low (8.86 mg/kg) in acidic Nitosols of the study area (Table1). The value is below the critical level of available P on nitisols of Northwestern Ethiopia for maize is 11.10 mg /kg in Alfisols as suggested by (Yihenew, 2016). This might be attributed to P fixation due to the acidic nature of the soil and is not readily available to plant uptake.The low application rates of P-containing fertilizers, continuous crop uptake, losses due to erosion and fixation by acidic soils in this maize-growing field of the study area might be linked to the inadequate P levels recorded in the studied soils.

Table 1: Plough depth soil physicochemical property status before soil amendment

Soil properties	Baseline Values	Rating	Critical values	Reference
Sand (%)	22.00		---	
Silt (%)	31.00		---	
Clay (%)	47.00		----	
Classes	Clay		----	
BD g/cm^3	1.42		1.20	(Karltun et al., 2014)
pH (H_2O)	5.20	Strongly acidic	7.30	(Karltun et al., 2014)
TN %	0.12	Low	0.20	(Karltun et al., 2014)
Available P (mg/kg)	8.86	Very low	11.10	(Yihenew, 2016)
Organic carbon (%)	1.32	Very low	3.00	(Landon & Manual,1991)
CEC ($cmol_c$/kg)	19.57	Medium	15.00	(Landon & Manual,1991)

The CEC value of Nitisols of the study area was 19.57 $cmol_c$/kg (Table 1), which is rated as a medium as per the ratings of(Landon and Manual,1991). According to this author, soils having CEC of >40, 25-40, 15-25, 5-15, < 5 $cmol_c$/kg categorized as very high, high, medium, low, and very low, respectively (Landon & Manual,1991).

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The level of CEC could be associated with the texture of the soil which is clay. Clay soils have more cations as they have the characteristics of increasing negative surface charges of soil. Soil physicochemical properties before and after amendments were presented as shown in Table 1 and Figure 2.

Effects of lime and nitrogen levels on soil physicochemical properties
Change in soil bulk density
Due to the application of lime, bulk density was declinedin all plots (Table 2). This could be aggregation of soil and improve soil crusting. However, the highest reduction (from 1.42 to 1.21 g/cm^3) was recorded in plots treated with 0.5 t/ha lime with 400 kg urea per ha. This might be due to the increasing effect of soil organic matter (SOM) after harvest that makes the soil less compact and reduces the BD. Similarly, Tesfaye (2017) found a decrease in soil BD as a result of integrated use of soil fertilizers in maize cultivated land at Yilmana Densa districtnorthwestern Ethiopia. This might be due to the applied Ca^{2+} basic cations into the soil. As a result, soil water retention capacity, soil moisture and aggregation will be increased. Indeed, lime could binding adjacent soil particles together to form aggregates. The result was also similar to Muhammed *et al.* (2011) who found lower bulk density as a result of nutrient and crop management on the crops sugarcane, maize, sorghum, and cotton residues at Gatton, Southern Queensland Australia. However, as Bayu *et al.* (2006) reported, the application of inorganic fertilizers alone had no significant effect on the bulk density of the soil. Similarly, Shirani *et al.* (2002) reported a significant decrease in soil bulk density just after harvesting a maize field supplied with integrated use of lime and inorganic fertilizers. Likewise, Onwonga et al. (2010) reported the positive effect of integrated use of lime, manure, and mineral fertilizers on soil physical and chemical properties on maize production at the Kenya Agricultural Research Institute field station.

Change pH of soil
Soil pH was affected by integrated nutrient management that increased with the application of lime and N fertilizer (Table 3). In the sole application of urea fertilizer, the maximum (5.51) and minimum pH (4.98) were recorded in plots treated with 100 and 400 kg/ha urea, respectively (Table 2). Though, nitrogen fertilizers increase crop yield, at the same time they also increase soil acidity. This is because during ammonium is converted to nitrate, and released hydrogen-ions which is one of the contributing factors leading to acidification. Hence, the application of N fertilizers containing NH_4^+ or even adding large quantities of organic matter to the soil can ultimately increase soil acidity and lower the pH (Guo et al., 2010). Similarly, Opela *et al.(*2018) found that the pH of soil treated with inorganic urea fertilizer was 5.21 as compared to the control pH (4.92) on maize cultivated acidic soils of Western Kenya. Conversely, the sole application of lime effectively increased the soil pH from 5.2 to 5.85 (Table 2). This rise in pH of the soil is associated with the presence of basic cations (Ca^{2+}) and anions (CO_3^{2-}) in lime that can exchange H^+ ions from exchangeable sites to form H_2O and CO_3^2. The increase in soil pH resulting from the application of lime provides a more favorable environment for soil microbiological activity which increases the rate of release of plant nutrients, particularly N. Reduced acidity due to liming increased the availability of other plant nutrients mostly P (Dinkecha & Tsegaye, 2017)

Similarly, Opela *et al.(*2018) reported an increase in soil pH (5.26) after the application of lime as compared to the control that had a pH value of 4.92 in acidic soils of Western Kenya

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correspondingly, Demissie *et al.* (2017)found increased soil pH after the application of lime, where it was changed from extremely acidic pH of 3.8 to medium and neutral pH of 6.63-6.86 in acid Soils of Wolmera district, West Showa Ethiopia. Likewise, Nadir *et al.* (2005)reported the effect of lime in raising the soil pH and increase the availability of soil P by unlocking the soil fixed P into available P for crop use. Lime increases the availability of other nutrient elements mostly basic cations essential to crop use especially Ca which forms plant structure (Dinkecha & Tsegaye, 2017).

The combined application of lime and inorganic fertilizer improved soil pH. The highest pH (6.85) was recorded from plots treated with 0.50 t/ha lime mixed with 400 kg/ha urea (Table 2). This is due to the dissociation of urea which releases NH_4^+, during plant up take of NH_4^+ and the release of HCO_3^- that reacts with H^+ and form H_2CO_3 acid. This acid is a weak acid and dissociates into H_2O and CO_2. Eventually, CO_2 is released to the atmosphere and water stays in the soil increasing pH by decreasing H^+ ion concentration in the soil solution. Similar increases in pH using integrated soil fertility management have been reported by (Buni, 2014;Moreira & Fageria, 2010;Whalen *et al.,* 2002). This might be due to the synergetic effect of lime integrated with N fertilizers.

Change in soil organic carbon

The maximum SOC content (2.51%) was recorded in plots treated with 0.5 t/ha lime with 400 kg urea per ha which was an increase by 52.6% from the initial soil OC analysis result (1.32%). The minimum SOC (2.23%) was recorded from plots treated with 0.5 t/ha lime and 100 kg ha^{-1}N (Table 2). The increase in SOC could be associated with the decomposition of dead plant tissue like roots and leaves that contributed to plant biomass after the addition of lime. The increased microbial activities by liming are likely to increase SOC mineralization when the soils are cultivated and exposed to increased microbial activity (Six *et al.*,2000).

Similarly, Aye *et al.* (2016) found that the higher OC of the soil after the application of lime integrated with NP fertilizers at Haryana Agricultural University, India. Besides, Antill *et al.* (2001) also reported greater levels of SOC under integrated treatments of lime with inorganic fertilizer in acidic soil in the western Himalayas on maize crop. In a similar study, Moges et al. (2018) reported increased amounts of OC from 2.23%, to 2.49% after the application of lime with integrated inorganic fertilizers in the malt barley crop in Angolela Tera district Northwestern Ethiopia. However, the sole application of lime reduced SOC from 1.32% to 1.29%. This is supported by Moges et al. (2018) found in the sole application of lime 4 t/ha$^-$ and 6 t/ha decreased SOC from 2.12% to 2.07%.

Total Nitrogen content

The maximum TN (0.231%) was recorded in plots treated with 0.5 t/ha of lime and 400 kg/ha N. The lowest TN (0.205%) was recorded in plots treated with 0.50 t/ha of lime and 100 kg urea per ha (Table 2). Hence, it is clear that the application of lime with chemical fertilizers increased TN, which may be attributed to the mineralization of N from OM during the decomposition of organic matter. Generally, the combined application of lime and mineral fertilizers at different rates affected the contents of total N in the study area. Similarly, Kebede and Yamoah (2009)reported increased amount of TN in the Vertisols of the Central Highlands of Ethiopia after the application of lime with mineral fertilizers. An increase in TN

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after the application of organic integrated with inorganic fertilizers has also been reported by(Agegnehu & Bekele, 2005; Bayu *et al.*,2006) in different part of Ethiopia.

Change in available phosphorus

In the sole application of inorganic fertilizer, the highest and lowest available P was 26.04 and 15.28 mg/kg recorded in plots treated with 400 and 100 kg urea per ha without lime, respectively (Table 2). After the combined application of lime and urea, the maximum and the minimum values of available P were 30.43 mg/kg and 22.84 mg/kg in treatments T10 and T7, respectively. Thus, the combined use of lime and chemical fertilizers increased available P content in the soil by mineralization or solubilizing of the native P reserves in soil (Haynes and Naidu,1998). As a result, soil available P after harvesting was much higher than the initial levels of lime-treated plots. Therefore, the major benefits of liming acid soils are the increased utilization of residual fertilizer phosphorus by maize crops. This might be due to the mineralization of OM and plant residues. The incorporation of lime has been shown to increase the amount of soluble organic matter which were mainly organic acids that increase the rate of desorption of phosphate and thus improves the available P content in the soil (Zsolnay & Gorlitz,1994). Similarly, Wanjiru (2018) showed an increase in soil available P after the application of lime, combined with manure and P fertilizer. Generally, the application of lime and mineral fertilizer increased P content.

Change in Cation exchange capacity

After application of mineral fertilizer, the highest CEC was 23.36 cmolc/kg in T5 and the lowest 22.19 $cmol_c$/kg in treatments T2 (Table 2). This might be due to increased pH, so do the number of negative charges on soil colloids that increased the CEC. Similarly, Tesfaye Bayu (2017)found an increase in CEC value after the application of mineral fertilizers in the soils of the Yilmana Desnsa district. After the application of lime alone, CEC increased from 22.17 $cmol_c$ /kg to 27.25 $cmol_c$/kg in the control plot (T1) and plots treated with 0.50 t/ha lime (T6). This increase in CEC could be linked to an increase in pH that increased the negative surface charges of soil colloids which subsequently increase the cation holding capacity of the soil. Similarly, Buni (2014) reported higher values of CEC after lime treatment was reported in Sodo Zuria district. Likewise, Yirga et al. (2009) found the highest values of CEC in soils treated with the highest lime rate (3.75 t/ha) in Welmera and Endibir district Southwestern Ethiopia. Besides, in the combined application of lime and N fertilizer, the highest and lowest CEC value was 35.38 $cmol_c$/kg and 31.43 $cmol_c$/kg recorded in treatments T10 and T7, respectively. This indicates that the combined application of lime and mineral fertilizer increased CEC to hold a higher amount of nutrients and that readily available to plants. The result was similar to Yirga *et al.* (2009) who found higher CEC value due to integrated nutrient management.

As shown in Table 2lime and N fertilizer interaction had a significant ($P \leq 0.01$) effect on grain yield of maize Therefore; application of 0.5 t/ha lime with 300 kg/ha nitrogen fertilizer is economical with marginal rate of return value 805.24 %. Soil physicochemical properties have positive correlations on yield of maize except BD (Table 2).

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Table 2. Interaction effect of lime and nitrogen fertilizer on soil physicochemical properties and maize yield after amendment

	Soil physicochemical properties								
Treatment	**BD (g/cm^3)**	**pH (H_2O)**	**SOC (%)**	**OM (%)**	**TN (%)**	**C:N**	**Available P (mg/kg)**	**CEC ($cmol_c$/kg)**	**Grain yield (kg/ha)**
Intial values	1.42	5.20	1.32	2.27	0.12	11.00	8.86	19.57	-----
T1	1.40	5.56	1.33	2.29	0.124	10.75	12.24	22.17	$3,442.47^{j}$
T2	1.39	5.51	1.36	2.34	0.126	10.03	15.28	22.19	$5,294.73^{h}$
T3	1.37	5.49	1.39	2.39	0.129	10.78	16.30	22.64	$5,766.53^{g}$
T4	1.35	5.21	1.59	2.73	0.147	10.82	17.78	22.68	$6,116.14^{e}$
T5	1.32	4.98	1.86	3.18	0.179	10.39	26.04	23.36	$6,892.8^{c}$
T6	1.26	5.85	1.29	2.22	0.120	10.75	18.60	27.25	$3,758.42^{i}$
T7	1.24	6.59	2.23	3.84	0.205	10.87	22.84	31.43	$6,062.35^{f}$
T8	1.23	6.71	2.45	4.21	0.226	10.84	24.73	33.21	$6,516.03^{d}$
T9	1.22	6.76	2.48	4.28	0.228	10.88	25.62	34.46	$7,122.44^{b}$
T10	1.21	6.85	2.51	4.33	0.231	10.86	30.43	35.38	$7,669.88^{a}$
Mean	1.23	5.95	1.85	3.18	0.17	10.69	20.98	27.47	---
LSD (0.05)									49.87
SE±									59.74
CV									0.50
p									**

*T1-control (200 kg/ha NPS); T2- NPS (200 kg/ha) + Urea (100 kg /ha); T3- NPS (200 kg/ ha) + Urea (200 kg/ ha); T4- NPS (200 kg/ha +Urea (300 kg/ha); T5- NPS (200 kg/ha)+ Urea (400 kg/ha);T6-Lime (500 kg/ha) +NPS (200 kg ha^{-1});T7-Lime (500 kg ha^{-1})+ NPS (200 kg ha^{-1})+ Urea (100kg ha^{-1}); T8- Lime (500 kg ha^{-1})+ NPS (200 kg/ha)+ Urea (200 kg/ha);T9- Lime (500 kg/ha)+ NPS (200 kg/ha)+ Urea (300 kg/ha); T10- Lime (500 kg/ha)+ NPS (200 kg/ha)+ Urea (400 kg/ha), GY=grain yield, LSD= Least significance difference, SE± =Standard error;CV=Coefficient of Variation, p=probability level; **= significantly different at p<0.05. Means followed by the same letters in a column are not significantly different at p<0.05*

Correlation studies

Statistically, highly significant positive correlation was observed between the grain yield and P and TN (Table 3). As shown in Table 3 the comparison of correlation coefficients between siol physicochemical properties and yield showed that available P gave a higher correlation coefficient (r = 0.838**) to the number of other soil properties followed by the soil total N (r = 0.803**). On the other hand BD,pH and CEC of the soil are not significantly affect ($p<0.01$) on maize yield.

Table 3. Soil physicochemical properties bivariate correlations on maize yield

	BD ($g\ cm^{-3}$)	**pH (H_2O)**	**SOC (%)**	**OM (%)**	**TN (%)**	**Available P ($mg\ kg^{-1}$)**	**CEC ($cmol_c\ kg^{-1}$)**	**Yield ($kg\ ha^{-1}$)**
BD	1	-0.840^{**}	-0.836^{**}	-0.837^{**}	-0.830^{**}	-0.840^{**}	-0.950^{**}	-0.543^{ns}
pH		1	0.806^{**}	0.810^{**}	0.782^{**}	0.599^{ns}	0.954^{**}	0.403^{ns}
OC			1	1.000^{**}	0.999^{**}	0.880^{**}	0.899^{**}	0.799^{**}
OM				1	0.998^{**}	0.878^{**}	0.902^{**}	0.797^{**}
TN					1	0.893^{**}	0.885^{**}	0.809^{**}
P						1	0.794^{**}	0.838^{**}
CEC							1	0.564^{ns}
Yield								1

**. Correlation is significant, ^{ns} non-significant ^{at} 0.01 level (2-tailed).

As shown in Figure 2 bulk density, soil pH, TN, available P, OC and OM are below the critical values of the soil for crop production. But cation exchange capacity of the study area soil is optimum because of the soil textural class. Thus application of lime and N fertilizer

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improves soil chemical properties through improving organic matter and total nitrogen in the soil.

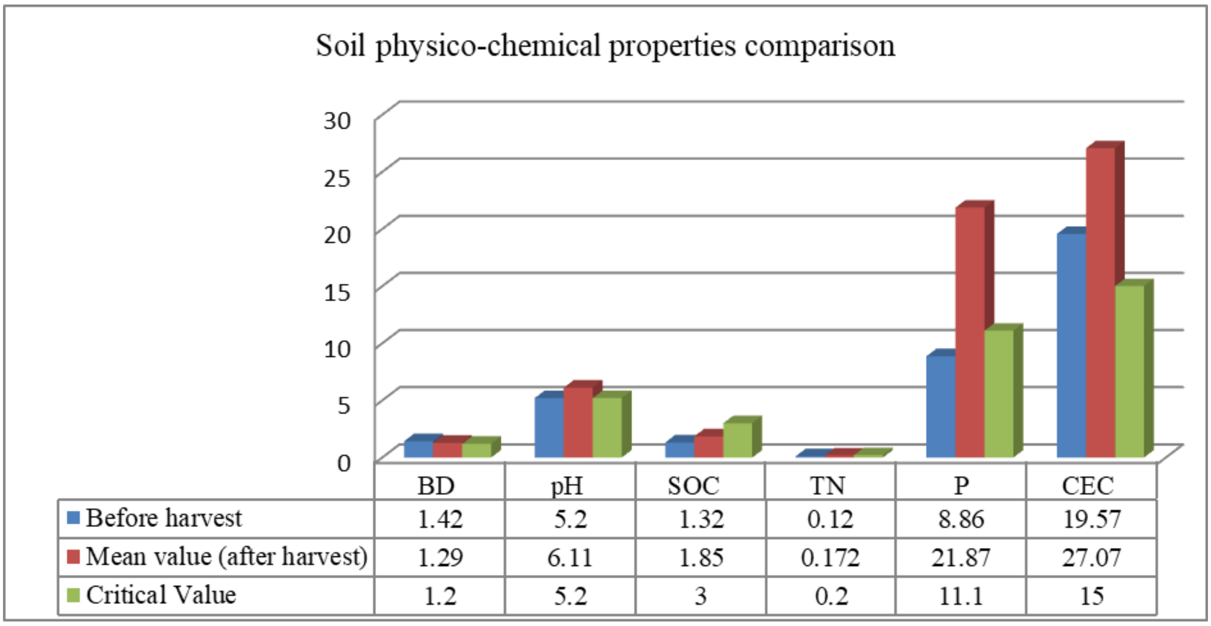

Figure 3: Plough depth soil physicochemical properties before and after harvest

Effects of Integrated soil fertility management on grain yield

Nitrogen fertilizer (urea), lime and their interaction had a significant ($p<0.01$) effect on grain yield of maize (Table 4). The ANOVA result indicated that the maximum grain yield (7,669.88 kg/ha) was recorded from plots treated with 0.50 t/ha lime with 400 kg/ha N while the minimum grain yield (6062.35 kg/ha) was recorded from plots treated with 0.50 t/ha lime and 100kg/ha N (Table 5). This might be due to improved soil condition as both Ca and N nutrient was efficiently taken by the plant. Similarly, Demissie *et al.* (2017) reported barley grain yield of 2,744.00 kg/ha that made a significant differencedue to the synergistic effect of lime and plant nutrition. Besides, Shiferaw and Anteneh (2014) reported that a significant increase of barley yield over the control after the application of lime and all combinations of inorganic fertilizers, either alone or combined.

Table 4. Interaction effect ANOVA table for grain yield of maize

Source	**DF**	**Type I SS**	**Mean Square**	**F value**	**Pr> F**
Urea	4	46885701.17	11721425.29	13769.90	<.0001
Lime	1	3923591.48	3923591.48	4609.30	<.0001
Rep	2	1977.34	988.67	1.16	0.3607
Urea*lime	4	377347.59	94336.90	110.82	<.0001
Rep*urea	8	6808.13	851.02	1.00	0.5001
Rep*lime	2	1595.84	797.92	0.94	0.4308

The marginal rate of return (MRR) analysis result indicates that, the maximum adjusted grain yield (6,410.20 kg/ha) was recored from plot treated with 0.50 t/ha) lime with 300 kg/ha N fer tilizer while the minmumgrain yield (3,177.14 kg/ha) was from the control (Table 5).The

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maximum marginal rate of return (805.24 %) was recorded from plots treated with urea@ 300 kg/ha and lime @ 0.50 t/ha. This could be due to the improvement of soil properties.

Grain yield has positive correlation with soil chemical properties but negative correlation wit h bulk density (r= -0.543). This is because integrated soil fertility practices improve soil physical properties by improving soil organic matter and soil carbon. As a result it improves soil aggregation conditions. This is in line with Opela etal. (2018)maximum maize yield (2.35 t/ha) was obtained from application of 2.00 t/ha $CaCO_3$ + 26 kg P + 60 kg N compared with the control (1.38 t/ha). Similarly, Tolcha Tufa (2018) reported that BH-661 maize yield potential varies between 9500 and 12000 kg/ha at research field and 6 and 8.50 t/ha at farmers' field under integrated fertility managements.

Table 5. Marginal rate of return analysis

Treatments	Grain Yield (kg/ha)	Adjusted yield (-10%) (kg/ha)	Gross return (ETB per ha)	TVC(ETB per ha)	Net benefit (ETB per ha)	MRR (%)
T1	3530.15	3177.14	31771.35	5928.92	25842.43	---
T6	3671.75	3304.60	33045.75	6689.27	26356.49	67.60
T2	5294.73	4765.26	47652.57	8599.70	39052.889	664.50
T7	6062.35	5456.12	54561.15	9598.29	44962.87	591.80
T3	5766.53	5189.88	51898.77	9899.13	41999.64	---
T8	6516.03	5864.44	58644.27	10943.23	47701.04	203.59
T4	6116.14	5504.52	55045.26	11281.57	43763.69	---
T9	7122.44	6410.20	64101.96	12332.93	58891.47	805.24
T5	6892.80	6203.52	62035.20	12630.82	51769.03	---
T10	7669.88	6902.90	69028.92	13667.99	55360.93	---

CONCLUSION

Based on the result of this study we can conclude that; inherent physicochemical properties of the soil changed either by sole or combined use of lime and N fertilizer. Based on the baseline data before treatments, soil fertility status of the study area soil was poor. However application of lime and urea fertilizer improves most soil physicochemical properties.Soil available phosphorus is highly correlated with grain yield while bulk density has no significant effect on it. The leftover effects of lime and inorganic fertilizers (urea) should be researched using on-farm and trial experiments. Moreover, the government may facilitate the supply calcite ($CaCO_3$) and urea fertilizer to the farmers.

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Authors' Contributions

BA and EM conceptualized the activity. BA drafted the paper, EM, YG and TB revised. BA andHT implemented activities in the field and laboratory, collected data and analyzed.

Conflict of interest

The author declares no conflicts of interest regarding publication of this manuscript.

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