Soil Chemical Properties and Plant Nutrient Status as Influenced by Application of Lime, Phosphorus and Compost

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ABSTRACT

Declining soil fertility along with soil acidity are major soil degradation problems affecting crop production in Ethiopian highlands. However, little effort has been done to investigate different soil amendment measures on soil chemical properties and nutrient status of common bean crop on acid soils of Areka. Therefore, field studies were conducted with the objective of investigating the effects of combined application of compost, lime and P-fertilizer on selected soil chemical properties and plant nutrient concentration of common bean at Areka area of southern Ethiopia. Treatments, consisted of factorial combinations of three rates of compost (0, 5 and 10 t ha^{-1}), lime (0, 0.64 and 1.28 t ha^{-1}) and phosphorus (0, 23 and 46 kg P_2O_5 ha^{-1}) were laid out in a randomized complete block design with three replications. Data on several soil chemical properties and tissue nutrient status were collected. The results revealed that relative to the control treatment, the application of 10 t ha^{-1} of compost alone increased soil pH and nitrogen by 7 and 68% in Belg and 7 and 77% in the Meher seasons, respectively. Similarly, sole application of lime increased soil pH by 20 and 10% in Belg and Meher seasons, respectively. The application of compost at the rates of 5 t ha^{-1} also resulted in increase in leaf tissue N concentration during Belg and Meher seasons. Further significant interaction effects of compost × lime × phosphorus were found for soil available P and tissue P concentration in both seasons. Combined application of compost, lime and P at their highest rates resulted in an increase in available P by 221% in belg and 144% in meher seasons compared to the control treatment. In conclusion, separate as well as combined application of compost, lime and P in both seasons can improve the fertility of the soil in the study area.

Keywords: Acid-soil; available-phosphorus; tissue-nutrient-concentrations; soil-fertility; soil chemical properties.

1. INTRODUCTION

Soil fertility depletion in Africa is one of the major problems for agricultural production. Inadequate nutrient and organic matter supply constitutes the

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principal cause for declining soil fertility and productivity in much of sub-Saharan Africa (SSA) [1]. Soil degradation primarily due to intensive cultivation, nutrient depletion and soil erosion is a serious problem in Ethiopian highlands [1, 2, and 3]. Major nutrients such as nitrogen (N) and phosphorus (P) are the most limiting nutrients due to low input application [4]. Fertilizer application rate in the country also have been reported to be minimal [4]. As a result, the average level of nutrient losses in Ethiopia in 2002/2004 cropping season has been estimated at 49 kg ha^{-1} $year^{-1}$ for N, P, and Potassium (K) fertilizer [5], which indicates the extent of nutrient mining and decline in soil fertility mainly due to inadequate input application. Soil P is also insufficient for crop growth in most agricultural systems in the tropics including Ethiopia, and P must be provided as an external input due to low input application, conventional tillage practices, nutrient recycling from organic sources, etc [6].

Further, soil chemical properties including acidity, salinity and nutrient concentration combined with soil texture and bulk-density influence root development and nutrient uptake [7]. Approximately 30% of the total land area in the world consists of acid soils and as much as 50% the world's potentially arable land is acidic [8], which significantly affect crop production worldwide. Soil acidification is also one of the major challenging constraints to increase beans productivity in Ethiopia [9]. [10] reported that out of the total acidic soils of Ethiopia about 28 % are moderate to weakly acidic (pH of 5.5 - 6.7); 13 % are strong to moderately acidic (pH < 5.5) and nearly one-third have aluminum toxicity problem. Soils of the study area also had strong to moderate soil acidity condition [11].

Soil acidity, which is one form of soil degradation, is caused by the release of Al from Al containing clay minerals upon weathering and leaching of cations from the edge of clays by excess precipitation [12, 13]. Further, hydrolysis of hydroxyl-aluminum leads to increase in the hydrogen ions concentration, thereby decreasing the soil pH values below seven. Moreover, mis-management such as intensive use of ammonia-containing fertilizers also counted to be another cause of soil acidification by decreasing the soil pH [12, 14, 15]. [13] and [16] also indicated the decomposition of organic matter to be another source of soil acidity.

The major effects of soil acidity encompasses limited availability of soil nutrients such as phosphorus, calcium (Ca), magnesium (Mg) and molybdenum (Mo) and toxic effects of certain micronutrients such as aluminium (Al) and manganese (Mn), which often lead to reduced root growth [17,15]. In acid soils, P is the major growth limiting nutrient due to fixation by clays dominated with Al and iron (Fe) hydroxides [18]. As a consequence, beside to Al and Mn toxicities, P limitation is indicated to be one of the most important nutrient constraints on acid soils [19]. Particularly, P deficiency has been indicated to be a primary limitation to bean production in developing countries [20]. The majority of Ethiopian soils are also characterized by P deficiency because of high P fixation in highly weathered soils and low P of parental material [21].

Research results emanating from different locations suggest combined use of organic and inorganic nutrient sources to address soil fertility problems in a sustainable manner [22, 1]. There are also immense research works in Ethiopia and elsewhere in the world which, demonstrated the possibility of addressing soil fertility decline problems by separate application of inorganic and organic nutrient sources, combined application of both inorganic as well as organic nutrient sources [1, 23, 24], separate application of lime [25], combined application of lime with organic nutrient sources [26, 27, 25] as well as lime with inorganic nutrient sources. [11] also suggested the need of improving the fertility status of the soils of Areka owing to its low fertility in terms of both micro and macronutrients status.

This study was to investigate the effects of combined application of lime, P and compost on selected soil chemical properties and plant tissue nutrient status.

2. MATERIALS AND METHODS

2.1 Description of the Study Site

The field experiment was conducted at Areka Agricultural Research Centre (AARC), which is situated in the SNNPRS between $7^0$3'25' north latitude and from $37^0$40'52'' east longitude. The altitude of the experimental site reaches to 2230 meters above sea level [11]. The Center has a bimodal rainfall pattern. Accordingly the first rainy season is *belg* starting from April and extending to mid-July, while *Meher* season begins in late July and extends to October. The mean annual rainfall for 12 years (1988 to 2000) was 1520 mm [11]. The major soil type of the center is Haplic

Alfisols (FAO, classification), which is very deep and clayey in texture [11].

2.2 Description of the Experimental Material

The cultivar used for this experiment was *Dinkinesh*, which was P-efficient and promoted from the greenhouse experiment. Triple super phosphate (TSP) [Ca $(H_2PO_4)_2$] (21% P) and Urea [CO $(NH_2)_2$] (46% N) was used for this experiment as source of P and N, respectively.

The liming materials used for this experiment were CaO and $CaCO_3$. The purity of lime ($CaCO_3$) used for field experiment was 89%, while the purity of CaO used for incubation experiment was 98%.Well prepared and decomposed compost was used for this experiment.

2.3 Experimental Procedures

2.3.1 Lime requirement determination

For determination of lime requirement of soils of Areka, lime (CaO) was applied at the rates of 0, 0.56, 1.12, 1.68, 2.24, 3.36 g kg^{-1} to soil samples each weighing 1 kg and were uniformly mixed. Then, the soils were added in triplicate into a polythene tube with a capacity of containing 1 kg soil. Water was added into the samples approximately to field capacity. The field capacity was determined initially by weighing the dry soil together with the polythene tube (dry soil + ploythen tube) followed by watering the soil in the polythene tube to saturation. Then, the soil in the polythene tube watered to saturation was left for 24hrs until all the gravitational water drained out and the soil at this stage assumed to attain its field capacity. To estimate the moisture content of the soil in the polythene tube at this stage (at field capacity), the wet soil (wet soil + polythen tube) was weighted and the weight difference between the wet (wet soil + polythen tube) and dry soil (dry soil + polythen tube) was converted into liter to know the volume of water retained at field capacity. Then, the next day the soil in the polythene tube left for one day without watering and reweighed and the weight difference between the moisture content at field capacity and the moisture content of the soil after one day was converted into liter and taken as the amount of water needed to maintain the moisture content of the soil to field capacity throughout the incubation period. Hence, the amount of water estimated earlier was added to the soil everyday to maintain the moisture content of the soil to the approximately to field capacity throughout the incubation period. The soils in the polythene tube were thoroughly mixed and incubated under room temperature for a period of two weeks. Then, the soils were ground, all plant debris and root were removed and its pH measured. The relationships between the amounts of CaO applied and the pH values obtained were plotted and the level of CaO sufficient to raise the pH of the soil to desired pH was determined. The $CaCO_3$ equivalent of CaO was used for subsequent liming experiment.

2.4 Soil Sampling, Sample Preparation and Analysis

Soil sampling and analysis was done before and after harvesting of the crops. Samples were randomly collected using an auger to the soil depth of 30 cm in a zigzag pattern from the experimental field before planting. The samples were mixed thoroughly in a bucket and composite sample were taken to analyze soil texture, soil pH, available P, soil organic carbon (SOC), cation exchange capacity (CEC) and exchangeable bases (Ca, Mg and K) following standard laboratory methods and procedures. Accordingly, soil texture was determined by the Bouyoucas hydrometer method [28]. Soil bulk density was be determined by the undisturbed core sampling method after drying the soil samples in an oven at 105°C to constant weights [29].

Available P was determined by Bray I method using ammonium fluoride as extractant and measuring the concentration of P as described by Bray and Kurtz [30]. Soil organic carbon was determined by the Walkley-Black wet digestion method [31]. Total N was determined by wet oxidation procedure of the KjeldhalKjeldhal method [32]. The CEC was determined with ammonium acetate saturated samples using Na from percolating NaCl solution to replace the ammonium ions. The displaced ammonium ion was measured using the modified Kjeldahl procedure and was reported as CEC [33]. Soil pH was determined potentometrically in supernatant suspension of 1:2.5 soils: water ratio using a combined glass electrode pH meter [34]. Exchangeable bases (Ca, Mg, and K) in the soil were estimated by the ammonium acetate (1M NH OAc at pH 7) extraction method as described by [35].

Compost was also analyzed for determining total P, N and K after wet digestion of the samples following the same procedure for soil analysis.

2.5 Plant Sampling, Sample Preparation and Analysis

Just before flowering three fully developed leaves at the top of the plant were sampled from twenty randomly selected common bean plants per plot [36] and the samples were taken for analysis of tissue P and N. The samples were analyzed following standard methods and procedures as described by [37].

2.6 Treatments and Experimental Design

The treatments consisted of three levels of P (0, 23 and 46 kg P_2O_5 ha^{-1}), three levels of lime (0, 0.64 and 1.28 tons ha^{-1}) and three levels of compost (0, 5, and 10 tons ha^{-1}). The experiment was laid out as a randomized complete block design in a factorial arrangement and replicated three times. Each treatment was randomly assigned to each plot.

2.7 Agronomic Practices

Land preparation of the experimental field was done properly both during *belg* and *meher* seasons. In each season, the experiment was done at different experimental fields. In other words, the experiment was not repeated across *belg* and *meher* seasons on the same land. The field was tractor ploughed three times before planting so as to ensure better crop emergence and crop stand. Lime was applied two months prior to planting of the crop. Compost was applied in broadcast one month prior to the planting of the crop. Nitrogen was applied at the rate of 18 kg N ha^{-1} in the form of urea, at the active stage of vegetative growth before flowering [38]. Phosphorus fertilizer was applied in band at planting.

2.8 Data Collection

Data on soil chemical properties such as soil texture, bulk density, soil pH, available P, total N, soil organic matter, soil exchangeable bases (Ca, Mg and K), and CEC were collected. Similarly, data on leaf tissue N, and P concentration were collected.

2.9 Statistical Analysis

The data of the two seasons were tested for homogeneity of variance using F-test [39]. The F-test indicated that the treatment means were significantly different and heterogeneous for the parameters between the two seasons. Accordingly, separate analysis was done. All data were subjected to analysis of variance using SAS version 8, Statistical software (SAS Institute, Cary, North Carolina, U.S.A). Significant means were separated using LSD test.

3. RESULTS AND DISCUSION

3.1 Pre-planting Soil Physico-chemical Properties and pH Curve

The physico-chemical properties of the soils of the experimental field for the surface layer (i.e., 0-30 cm) are presented in Table 1. According to the ratings given by [40], the pH of the soil is strongly acidic, whereas the organic matter and total nitrogen contents of the soil are high; the CEC of the soil is moderate; the base saturation percent is high. However, according to the latter author, the available P content of the soil is low. This shows that the soil has limitations in soil pH and P availability for crop production. Accordingly, managing soil pH and P availability is important for enhancing plant growth and production in the study area.

Based on the pH curve, the CaO level needed to raise the soil pH to the desired pH level *i.e.,* 6.5 was found to be 2.76 g kg^{-1} (Fig. 1). Accordingly, the $CaCO_3$ equivalent of CaO to obtain the optimum pH of 6.5 was 5.426 g $CaCO_3$ (lime) kg^{-1} soil, which is equivalent to 1.28 t ha^{-1} assuming 89% purity of lime, 20 cm plough depth and 1.18 g cm^{-3} soil bulk density.

3.2 Status of Available Phosphorus

Combined application of compost, lime and P significantly (*$P<0.001$*) increased soil available P. Generally, an increasing trend in soil available P was observed across the compost and lime as well as P rates in both seasons. The values in *belg* season ranged from 4.17 to 13.4 mg/kg, while in *meher* season it ranged from 4.56 to 10.7 mg/kg. In both seasons, the highest available P was obtained when the highest rates of compost, lime and P were applied compared to plots applied with neither of these soil amendments. Hence, combined application of compost, lime and P at rates of 10 t, 1.28 t and 46 kg P_2O_5 ha^{-1}, increased available P by more than two and one fold in *belg* and *Meher* seasons respectively, compared to the control (Table 3). Further, without application of lime and compost, application of P alone at rates of 46 kg P_2O_5 ha^{-1} increased soil available P nearly by 30 and 27%

in *belg* and *meher* seasons, respectively compared to the control (Table 3).

Different researchers reported a significant increase in available P as a result of application of lime, compost and inorganic P [41, 42, and 26]. Hence, the increase in soil available P is perhaps due to combined effect of the active CaO component of lime in releasing fixed and precipitated P by correcting the pH [42, 26]. Similarly, the increase in concentration of soil solution P also related to the direct addition of P from the applied inorganic P as well as nutrients released upon mineralization from the applied compost [25, 43]. Further, liming might have enhanced mineralization of organic matter added as compost thereby facilitating the release of some of the essential macronutrients such as P [44]. Corroborating the results, [26] also reported that combined application of lime and manure increased available P on acid soils of North Western Ethiopia. In a similar study, [45] also reported high values of available P in different locations ranging from 8.44 to 10.30 mg kg^{-1} as a result of combined application of the highest rates of lime and compost on acid soils.

3.3 Effect on Soil pH

Mean values for soil pH showed a significant increase as a result of the interaction effect of compost and lime in *Belg and Meher* seasons (Table 4). The values for soil pH ranged from 5.2 to 6.94 in both seasons. The highest value for soil pH (6.94) in was recorded in *Meher* season, while the lowest (5.2) value recorded in *Belg* season. However, the highest value recorded during *Meher* season was statistical at par to the values recorded during *Belg* season. The highest value was recorded as a result of application of compost at rates of 10 t ha^{-1} along with 1.28 t ha^{-1} lime, which increased soil pH by about 30% in *Belg* season and 33.5% in *Meher* season compared to the control (Table 4).

Table 1. Physico-chemical properties of the study area before planting during *Belg* and *Meher* seasons

Seasons	P^H (1:2.5)	Total N (%)	OC (%)	OM (%)	Available P (mg Kg^{-1})	Exchangeable cations cmol(+)/kg soil				CEC ($cmol_c$(+)/ kg soil)
						Na	K	Ca	Mg	
Belg	5.29	0.2	2.9	5.1	3.5	0.1	0.1	10.1	11.3	26.9
Meher	5.08	0.2	2.7	4.7	3.2	0.1	0.2	14.5	1.1	24.7

OC-Organic carbon, OM- Organic matter

Table 2. Chemical properties of compost used for the experiment during *Belg* and *Meher* seasons

Seasons	p^H	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Belg	6.2	1.7	0.4	0.1	0.7	0.3
Meher	6.0	1.5	0.4	0.1	0.8	0.3

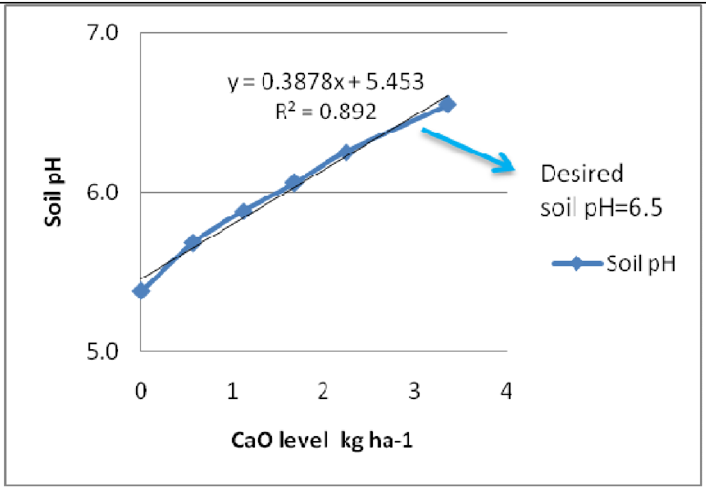

Fig. 1. Soil pH plotted against CaO level (g kg^{-1})

Table 3. Interaction effect of compost, lime and P on available P during *belg* and *meher* seasons

Compost (t ha^{-1})	Lime (t ha^{-1})	Phosphorus rates (kg P_2O_5 ha^{-1})					
		0		23		46	
		Available phosphorus (ppm)					
		Belg	***Meher***	***Belg***	***meher***	***Belg***	***meher***
0	0	4.17^{n}	4.56^{r}	4.76^{nm}	5.23^{p}	5.40^{lkm}	5.8^{on}
	0.64	4.67^{nm}	4.9^{q}	5.27^{lkm}	5.6^{o}	6.03^{kj}	6.63^{mkl}
	1.28	5.23^{lkm}	5.23^{p}	6.03^{kj}	5.83^{on}	6.57^{ihj}	6.40^{m}
5	0	5.13^{lm}	6.47^{ml}	5.80^{lkj}	6.97^{ji}	7.16^{igh}	7.46^{g}
	0.64	6.37^{ij}	6.0^{n}	7.26^{ghf}	6.60^{mkl}	8.43^{ed}	7.16^{hi}
	1.28	7.57^{egf}	6.70^{jkl}	7.97^{egdf}	7.40^{hg}	8.46^{d}	8.07^{f}
10	0	7.3^{ght}	6.83^{jk}	8.10^{edt}	7.37^{hg}	9.90^{c}	8.0^{t}
	5	8.27^{ed}	8.0^{f}	9.70^{c}	9.0^{d}	9.67^{c}	10.17^{b}
	10	9.83^{c}	8.37^{e}	11.03^{b}	9.50^{c}	13.40^{a}	10.7^{a}
LSD (0.05) =		0.8668	0.2763	0.8668	0.2763	0.8668	0.2763

Means followed by the same letters are not statistically different at 5% probability level

Table 4. Soil pH as influenced by interaction effect of compost and lime in *Belg* and *Meher* seasons of 2013

Compost rates (t ha^{-1})	***Belg***			***Meher***		
	Lime rates (t ha^{-1})			Lime rates (t ha^{-1})		
	0	0.64	1.28	0	0.64	1.28
0	5.27^{e}	6.03^{c}	6.09^{c}	5.2^{e}	5.88^{d}	6.25^{c}
5	5.22^{e}	6.14^{c}	6.53^{b}	5.8^{d}	6.25^{c}	6.51^{b}
10	5.60^{d}	6.21^{c}	6.83^{a}	5.9^{d}	6.44^{c}	6.94^{a}
LSD (0.05)=	0.1986			0.1351		

Means followed by the same letter are not statistically different at 5% probability level

Compost fertilization has an important benefit through its liming effect by adding Ca mainly in the form of calcium carbonate [46], which might have contributed to increases in soil pH. Further, addition of lime increases soil pH through the Ca added from the lime, which react with H^+ in the exchange site and neutralizes it, thereby increasing the pH of the soil [47]. Consequently, lime and compost application might have contributed to improvement in soil pH due to the liming effect of compost and lime through the Ca added to the soil from both. In other words, the rise in soil pH as a result of application of compost and lime might be ascribed to the release of calcium ions into the soil solution through mineralization of the applied compost, which in turn hydrolyzed to form calcium hydroxide and the calcium hydroxide formed reacts with Al^{3+} ion in the soil solution to give insoluble $Al(OH)_3$, and further the hydroxide of the calcium hydroxide reacts with hydrogen ions to form water thereby decreasing H^+ ion and lower the pH [22] following application of compost. In a similar manner, the likely increased Ca^{2+} ions due to lime application might have contributed to increase in soil pH, which in turn react with Al^{3+}, H^+, and Fe^{3+} ions prevalent in acid soils [48], which otherwise aggravate the soil acidity condition. Furthermore, the same authors obtained the highest pH of 6.00 with the combined application of lime and 5 t ha^{-1} compost.

3.4 Total Nitrogen

The results revealed that compost application significantly ($P<0.001$) increased soil N in *Belg and Meher* seasons. Consequently, in comparisons to the control, application of compost improved soil total N. During the *Belg* season, application of compost at rates of 5 and 10 t ha^{-1} increased total N by 32 and 64%, respectively compared to the control treatment (Table 5). Similarly, in the *Meher* season, application of compost at rates of 5 and 10t ha^{-1} increased total N by about 35 and 77%, respectively (Table 5).

Table 5. Total nitrogen as influenced by main effects of application of compost during *Belg* and *Meher* seasons

Compost (t ha^{-1})	**Soil parameters**	
	N (%)	
	Belg	***Meher***
0	0.19^{c}	0.17^{c}
5	0.25^{b}	0.23^{b}
10	0.32^{a}	0.30^{a}
CV (%)	6.24	4.2
LSD (0.05) =	0.0086	0.054

Means followed by the same letter are not statistically different at 5% probability level

Soil N increased with increase in the levels of compost, which might be related to the release of N from the applied compost through mineralization. Corroborating the results, [1] reported highest increase in soil N from plots applied with compost and farm yard manure. Similarly, the results agree with the findings of [49], who recorded the highest nitrogen value (0.42 g Kg^{-1}) for plots applied with 8 t ha^{-1} poultry manure on an Ultisol of Southeastern Nigeria.

3.5 Soil Potassium

Experimental results revealed that application of compost significantly ($P<0.001$) increased soil K in both seasons. Accordingly, soil K increased due to the application compost in both seasons (Table 6). For instance, during the *Belg* season, 56 and 80% increase in soil K compared to the control was recorded due to application of compost at rates of 5 and 10 t ha^{-1}, respectively.

Table 6. Exchangeable K as influenced by application of lime and compost during *Belg* and *Meher* seasons

Compost (t ha^{-1})	**K (%)**	
	Belg	***Meher***
0	0.25^{c}	0.15^{c}
5	0.39^{b}	0.16^{b}
10	0.45^{a}	0.18^{a}
Lime (t ha^{-1})		
0	0.37	0.40
0.64	0.36	0.40
1.28	0.36	0.40
CV (%) =	3.7	2.3
LSD(0.05)=	0.006	0.010

Means followed by the same letter are not statistically different at 5% probability level

The improvement in soil K might be linked to release of the nutrient from the applied compost upon decomposition [50, 24]. In agreement with the results, [51] reported significant ($P < 0.001$) increase in exchangeable soil K as a result of application of manure as compared to control in one of their experimental year 2013.

Table 7. Effects of compost on leaf tissue nitrogen concentration during the *belg* and the *meher* seasons

Compost (t ha^{-1})	**Leaf tissue N concentration (%)**	
	Belg	***Meher***
0	3.92^{b}	3.81^{c}
5	4.09^{a}	4.0^{b}
10	4.16^{a}	4.15^{a}
CV (%) =	3.32	3.38
LSD (0.05) =	0.074	0.074

Means followed by the same letter in the same column are not statistically different at 5% probability level

Table 8. Interaction effect of compost, lime and phosphorus on leaf tissue phosphorus concentration during the *belg* and the *meher* seasons

Compost (t ha^{-1})	**Lime (t ha^{-1})**	**Phosphorus (kg P_2O_5 ha^{-1})**					
		0		**23**		**46**	
		Leaf tissue P concentration (%)					
		Belg	***meher***	***Belg***	***meher***	***Belg***	***Meher***
0	0	0.15^{n}	0.13^{k}	0.20^{kjl}	0.21^{igh}	0.21^{ijh}	0.25^{ced}
	0.64	0.17^{nm}	0.20^{ij}	0.21^{ijh}	0.22^{igh}	0.22^{ijh}	0.24^{fged}
	1.28	0.17^{nm}	0.19^{j}	0.21^{ijh}	0.23^{fge}	0.24^{fegd}	0.25^{cbd}
5	0	0.18^{ml}	0.20^{ihj}	0.20^{kij}	0.22^{fgh}	0.22^{figh}	0.24^{fed}
	0.64	0.18^{kml}	0.19^{j}	0.25^{fecd}	0.24^{fed}	0.26^{becd}	0.25^{ced}
	1.28	2.0^{lmn}	0.19^{ij}	0.26^{bcd}	0.24^{fed}	0.28^{ba}	0.26^{ij}
10	0	0.23^{hjfg}	0.24^{fed}	0.24^{hfg}	0.24^{fed}	0.24^{hfg}	0.24^{fed}
	0.64	0.19^{mn}	0.20^{ihj}	0.24^{hfg}	0.25^{ced}	0.27^{bc}	0.27^{cb}
	1.28	0.20^{lmn}	0.21^{igh}	0.27^{bc}	0.28^{b}	0.29^{a}	0.31^{a}
LSD (0.05) =		0.0196	0.0235				

Means followed by the same letter are not statistically different at 5% probability level

3.6 Leaf Nitrogen

Compost application significantly (*P< 0.001*) increased leaf tissue N concentration in both seasons. Leaf tissue N concentration improved when the rate of compost increased in both seasons (Table 7). Accordingly, increasing the rate of compost from nil to 5 t ha^{-1} resulted in a corresponding 4 and 5% increase in leaf N concentration during *belg* and *meher* seasons.

The increase in leaf tissue N concentration might be attributed to the increased supply of N from the applied compost through mineralization and subsequent uptake by the crop [50]. In agreement with the result, [52] reported significant increase in cabbage leaf N concentration. The mean values recorded for leaf tissue N concentration are in agreement with the optimum range reported for legumes [53].

3.7 Leaf Tissue P Concentration

Mean values for leaf tissue P concentration showed significant increase due to combined application of compost, lime and P in both seasons (Table 8). The highest tissue P concentration in both seasons was obtained by applying compost, lime and P at corresponding rates of 10 and 1.28 t ha^{-1} and 46 kg P_2O_5, respectively, which exceeded the control by nearly one fold in both season (Table 8).

The tissue P concentrations reported in the present study are similar to leaf tissue P concentration reported elsewhere for common bean [18].The increase in leaf tissue P concentration is attributed to improved soil P status as a result of combined application of compost, lime and P [50]. In agreement with the results, [54] obtained significantly higher shoot P concentration in maize as a result of integrated application of organic amendments with DAP.

4. CONCLUSION

The results of this study have shown that application of compost, combined application of compost with lime, as well as combined application of (compost, lime and P) significantly improved soil chemical properties and levels of nutrients in plant tissues. The improvement in soil pH due to combined application of compost with lime and increase in available P as a result of application of (compost, lime and P) is an indicator of the potential of the soil amendments for correcting the soil fertility problem in the study area. Hence, it can be concluded that application of compost, lime and P in combination or separately has the potential to mitigate soil fertility problems at Areka.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Balesh Tulema. 2005. Integrated plant nutrient management in crop production in the Central Ethiopian highlands. Doctoral Dissertation, Norwegian University, Norway .
2. Chilot Yirga. 2007. The dynamics of soil degradation and incentives for optimal management in the central highlands of Ethiopia. Doctoral Dissertation, University of Pretoria, South Africa.
3. Workneh Bedada.2015. Compost and Fertilizer - Alternatives or Complementary? Management Feasibility and Long-Term Effects on Soil Fertility in an Ethiopian Village. Doctoral Thesis Swedish University of Agricultural Sciences Uppsala.
4. International Fertilizer Development Center (IFDC). 2015. Assessment of Fertilizer Consumption and Use by Crop In Ethiopia.
5. Henao, J.O. and Baanante, C. 2006. Agricultural Production and Soil Nutrient Mining in Africa: Implications for Resource Conservation and Policy Development: An International Center for Soil Fertility and Agricultural Development , U.S.A.
6. Fairhurst, T., Lefroy, R. Mutret, E. and Batjes, N. 1999. The importance, distribution and causes of Phosphorus deficiency as a constraint to crop production in the tropics. *Agroforestry Forum*, (9) (4): 2-8.
7. Alley, M.M. and Vanlauwe, B. 2009. *The Role of Fertilizers in Integrated Plant Nutrient Management, 1st Edition.* IFA, Paris, France.
8. Von Uexkull, HR, E.Mutert, 1995.Global extent, development and economic impact of acid soils. pp. 5-19. *In*: Date, RA Grundon, NJ Raymet, GE Probert, ME (eds.), *Plant-Soil Interactions at Low pH: Principles and Management*. Dordrecht, TheNeth: KluwerAcademic.
9. Mesfin Abebe. 2007. *Nature and Management of Acid Soils in Ethiopia*. Addis Abeba, Ethiopa.

10. Schlede, H. 1989. Distribution of acid soils and liming materials in Ethiopia. Ethiopian Institute of Geological Surveys, Minstry of Mines and Energy. Addis Ababa, Ethiopia.
11. Abayneh Esayas, Demeke Taffesse, Gebeyehu Belay and Kebede Agazie. 2003. Soils of Areka Agricultural Research Center, National Soil Research Center (NSRC).Technical Paper No.77.
12. Foth, H.D., 1990. *Fundamentals of Soil Science, 8th Edition*. Wiley and Sons, New York, USA.
13. Crowford, T.W., Singh, U. and Berman, H. 2008. Solving Agricultural problems related to Soil Acidity in Central Africa's Great Lakes Region: CATALIST Project Report. IFDC: An International Center for Soil Fertility and Agricultural Developmen, Albama, USA.
14. Eyasu Elias, 2002. Farmers' Perceptions of Soil Fertility Change and Management. SOS-Sahel and Institute for Sustainable Development. 252pp.
15. Certini G.and R. Scalenghe, 2006. *Soils: Basic Concepts and Future Challenges*. Cambridge University, United Kingdom.
16. Bohn, H.L., Mcneal, B.L. O'conner, G.A. 2001. *Soil Chemistry, 3rd Edition*. Willey and Sons, Newyork.
17. Lopes, A.S.1996. Soils under Cerrado: A Success Story in Soil Management: *Better Crops International*, 10(2): 9 – 12.
18. Fageria, N.K. 2009. *The use of nutrients in crop plants*. Taylor and Francis Group, Newyork, USA.
19. Kochian, L.V., Hoekenga, O.A. and Pineros, M.A. 2004. How do Crop Plants Tolerate Acid Soils? Mechanisms of Aluminum Tolerance and Phosphorous Efficiency. *Annual Review of Plant Biology,* 55:459–93.
20. Lynch, J. 1995. Root Architecture and Plant Productivity. *Plant Physiology,* 109: 7-1 3.
21. Mesfin Abebe. 1998. *Nature and Management of Ethiopian Soils.* Alamaya University of Agriculture. Alemaya, Ethiopia.Fairhurst, T., Lefroy, R. Mutret, E. and Batjes, N. 1999. The importance, distribution and causes of Phosphorus deficiency as a constraint to crop production in the tropics. *Agroforestry Forum*, (9) (4): 2-8.
22. Ano, A.O. and Ubochi, C.I. 2007. Neutralization of soil acidity by animal manures: mechanism of reaction. *African Journal of Biotechnology,* 6 (4): 364-368.
23. Tilahun Tadesse, Nigussie Dechassa, Wondimu Bayu, Setegn Gebeyehu, 2013. Effects of Farmyard Manure and Inorganic Fertilizer Application on Soil Physico-Chemical Properties and Nutrient Balance in Rain-Fed Lowland Rice Ecosystem. *American Journal of Plant Sciences*, 4: 309-316.
24. Celestin, N.P. 2013. Effects of Inorganic and Organic Fertilizers on Nutrient Uptake, Soil Chemical Properties and Crop Performance in Maize based Cropping Systems in Eastern Province of Rwanda. A Thesis submitted in partial fulfillment for the Degree of Master of Environmental Studies (Agro-forestry and Rural Development) in the School of Environmental Studies of Kenyatta University.
25. Verde, B.S.M.M. 2014. Effects of manure, lime and phosphorus fertilizer on soil properties and soybean (*Glycine max* L.) yields in Embu County, KENYA. MSc. Thesis, Kenyatta University, Nirobi, Kenya.
26. Mekonnen Asrat, Heluf Gebrekidan, Yli-Halla, M., Bobe Bedadi, Wakene Negassa. 2014. Effect of integrated use of lime, manure and mineral P fertilizer on bread wheat (Triticum aestivum) yield, uptake and status of residual soil P on acidic soils of Gozamin District, north-western Ethiopia. *Agriculture, Forestry and Fisheries* 3(2): 76-85.
27. Olivera, M., Tejera, N., Iribarne, C., Ocan, A. and Lluch, C. 2004. Growth, nitrogen fixation and ammonium assimilation in common bean (*Phaseolus vulgaris* L.): effect of phosphorus. *Physiologia Plantarum,* 121: 498–505.
28. Bouycous, G.H. 1951. A reclamation of hydrometer for making mechanical Analysis of soils. *Agronomy Journal,* 43: 434-438.
29. Black, C.A. 1965. Determination of exchangeable Ca, Mg, K, Na, Mn, and effective cation exchange capacity in soil. pp. 9. *Methods of soil analysis*. Amer. Soc. Agronomy, Madison, Wisconsin.
30. Bray, R.H., and Kurtz, L.T.1945. Determination of total, organic and available forms of phosphorus in soils. *Soil Science* 59: 39–45.
31. Walkley, A. and Black, C.A. 1934. An experimentation of Degtjareff method for determining soil organic matter and the proposed modification of the chromic acid titration method. *Soil Science,* 37: 29-38.

32. Bremner, J.M. 1965.Total Nitrogen. pp. 119-178. *In*: Black, C.A. (ed.), *Method of soil analysis*, Part 2. American Society of Agronomy, Madison, WI.
33. Chapman, H.D. 1965. Cation exchange capacity by ammonium saturation. pp. 891-901. *In*: C.A. Black (ed.). *Methods of soil Analysis*. Agron. Part II, No. 9, Am. SoSc. Agron. Madison, Wisconsin, USA.
34. Chopra, S.H. and Kanwar, J.S.1976. Analytical Agricultural Chemistry. Kalyani publisher Ldiana, New Delhi. *Communications in Soil Science and Plant Analysis,* 33(9-10): 1537-1575.
35. Rowell, D.L.1994. *Soil science: Methods and Applications.* Addison Wesley Longman Singapore Publishers (Pte) Ltd., England, United Kingdom.
36. Jones, J.B. J. 2003. *Agronomic Handbook: Management of Crops, Soils, and Their Fertility*. CRC Press, London, United Kingdom.
37. Okalebo, J.R., Gathua, K.W., and Woomer, P.L. 2002. *Laboratory Methods of Soil and Plant Analysis: A working Manual. 2nd Edition*, TSBI-KARI, SSEA, SACRED Africa, Nairobi, Kenya.
38. MoARD (Minstry of Agriculture and Rural Development). 2008. *Crop Development. Issue No.3.* Addis Ababa, Ethiopa.
39. Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research, 2nd Edition*. John Wiley and Sons Inc., New York.
40. Landon, J.R. 1991. *Booker Tropical Soil Manual: A hand book for soil survey and agricultural land evaluation in the Tropics and Subtropics*. Longman Scientific and Technical, Essex, New York.
41. Achalu Chimdi, Heluf Gebrekidan, Kibebew Kibret and Abi Tadesse. 2012. Effects of Liming on Acidity-Related Chemical Properties of Soils of Different Land Use Systems in Western Oromia, Ethiopia.*World Journal of Agricultural Sciences*, 8 (6): 560-567.
42. Barasa, J.N., Omami, E.N., Okalebo, J.R. and Othieno, C.O. 2013. Effect of Lime and Phosphorus fertilizer application on performance of French Beans in Uasin Gishu district, Kenya. *Global journal of biology, agriculture and health sciences*, 2(3): 35- 41.
43. Abay Ayalew. 2011. Integrated Application of Compost and Inorganic Fertilizers for Production of Potato (*Solanum tuberosum* L.) at Angacha and Kokate in Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare*, 1(2): 15 - 24.
44. Bolan, N.S. Adriano, Domy, C. and Curtin, D. 2003. Soil Acidification and Lliming Interactions with Nutrient and Heavy Metal Transformation and Bioavailablity. pp. 215-272. *In*: Sparks, D. L. (eds.), *Advances in Agronomy,* 78. Academic Press, New York, USA.
45. Oluwatoyinbo, F.I., Akande, M.O., Makinde, E.A. and Adediran, J.A. 2009.Growth and Yield Response of Okra to Lime and Compost on an Acid Soil in the Humid Tropics. *Research Journal of Agriculture and Biological Sciences,* 5(5): 858-863.
46. Amlinger, F., Peyr, S., Jutta, G., Dreher, P., Weinfurtner, K. and Nortcliff, S. 2007. Beneficial effects of compost application on fertility and productivity of soils: Literature study. Federal Ministry for Agriculture and Forestry, Environment and Water Management. Germany.
47. Anderson, N.P. Hart, J.M. Sullivan, D.M. Christensen, N.W. Horneck, D.A. and Pirelli, G.J. 2013. Applying Lime to Raise Soil pH for Crop Production (Western Oregon). Oregon State University extension publication.
48. Osundwa M.A., Okalebo, J.R. Ngetich,W.K. Ochuodho, J.O.C Othieno, Langat, O.B. and Omenyo,V.S. 2013. Influence of Agricultural Lime on Soil Properties and Wheat (*Triticum aestivum L.*) Yield on Acidic Soils of Uasin Gishu County, Kenya. *American Journal of Experimental Agriculture,* 3(4): 806-823.
49. Unagwu, B.O. 2013. Comparative effects of lime, poultry manure and NPK compounds fertilizer on soil physicochemical properties and yield of maize in an Ultisol of Southeastern Nigeria. PhD Dissertation. University of Nigeria, Nsukka, Nigeria.
50. Dubey, P.K., Pandey, C.S., Khanday, A.S. and Mishra, G. 2012. Effect of Integrated Nutrient Management on Nutrient uptake, protein content and yield of Fenugreek, *International Journal of Food, Agriculture and Veterinary Sciences,* 2012: 2 (1):1-12.
51. Samake, A. 2014. Use of Locally Available Amendments to Improve Acid Soil Properties and Maize Yield in the Savanna Zone of Mali. Doctoral Dissertation, Kwame Nkrumah University, Kumasi, Ghana.
52. Brito, L.M. Monteiro, J.M. Mourão, I. and Coutinho, J. 2013. Compost, Lime, and

Rock Phosphate Effects on Organic White Cabbage Growth and Nutrient Uptake, Communications in Soil Science and Plant Analysis, 44:21, 3177-3186.

53. Barker, A.V. and Bryson G.M. 2007. Nitrogen. pp 22-43. *In*: Allen V. Barker David J. Pilbeam (eds.), *Handbook of Plant Nutrition*. Taylor and Francis Group, New York, USA.

54. Mujeeb, F.R., Akhtar, J. and Ahmad, R. 2010. Integration of organic and inorganic P sources for improving P use efficiency in different soils. *Soil and Environment,* 29(2): 122-127.