Regional Review Workshop on Completed Research Activities

Proceedings of Review Workshop on Completed Research Activities of Natural Resource Research Directorate Held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 08-11 October 2018

Editors: *Kefyalew Assefa, Bikila Mengistu and Tilahun Geleto*

Oromia Agricultural Research Institute

P.O.Box 81265, Finfinne, Ethiopia

Correct citation: Kefyalew Assefa, Bikila Mengistu and Tilahun Geleto (eds), 2019. Proceedings of Review Workshop on Completed Research Activities of Natural Resource Research Directorate Held at Adami Tulu Agricultural Research Center, Adami Tulu, Ethiopia, 08-11 October 2018. Oromia Agricultural Research Institute (IQQO), Finfinne, Ethiopia. 164pp.

Organized by: Communication and Partnership process of IQQO

Contents Page

Soil Resource Survey Research

Soil Fertility Assessment and Mapping of Bedele District of Buno Bedele Zone, Southwest Oromia, Ethiopia

Gedefa Sori*, Abdulmalik Mohammed and Dechassa Mengistu

Bedele Soil Research Center, P.O.Box 167, Bedele, Ethiopia

*Corresponding author: sorigedefa45@gmail.com

Abstract

Soil fertility atlas shows plant nutrient status at required scale and is useful for decision making in fertilizer advisory services for farmers. The objectives of this study were to assess the fertility status of the soils and mapping of the study area. A total of 132 soil samples were collected across Bedele District at 1.5 km grid interval from a depth of 0-20 cm. Soil texture, soil organic carbon (SOC), soil reaction (pH), electrical conductivity (EC), exchangeable acidity (EA), available phosphorus (P), exchangeable bases and cation excheange capacity (CEC) were analyzed following standard laboratory methods at Bedele Soil Research Center laboratory. In order to predict values for not sampled locations the Ordinary Kriging interpolation was used by ArcGIS10.2 software. Clayey textural soils constitute 48.5% of the total soil samples of the District. Soil organic carbon (SOC) range was from 0.3-5.6% indicating 73% of the soil samples collected from the district were low (<4%), while the rest were in medium range. Soil reaction (pH) ranged from 4.5-6.8 in which 69% of the soils were under strongly acidic (pH ≤ 5.5). Available phosphorus ranged from 0.8-38.6ppm whereas nearly 88% of the analyzed samples value was under low category (<10ppm). Exchangeable potassium was from sufficient to very high range, while values of most exchangeable calcium and magnesium were under deficient range. To address these nutrient deficiencies, fertilizers containing P and agricultural lime materials were suggested for optimum crop production in the study area. Setting site-specific critical levels for each of these deficient nutrients and surveillance of each nutrient status to prevent toxicity are recommended to obtain optimum crop yield in the study area. Further integrated soil fertility management (ISFM) intervention technologies will be needed for sustainable soil resource management practices for food and nutrition security of the study area. Generally, the soil fertility map developed for pH, OC, available P, CEC, Ca, Mg, K, and Na clearly indicates areas of the district where these attributes optimum and not optimum for crop production.

Keywords: *Soil fertility mapping, Ordinary Kriging, ArcGIS and lime materials*

Introduction

In any agricultural operations, soil is the utmost importance as it is the cradle for all crops and plants. This natural resource is finite in nature and also impossible for within time span of a human life (Mandal *et al.*, 2009). The top soil having an average depth of about 15–30 cm on which plants to grow and the farming activities flourishes, now-a-days; it is facing serious problems due to human pressure and utilization incompatible with its capacity. Hence, it is important to keep healthy and productive soil to continue our soil to function optimally to increase agriculture production with appropriate soil amendment and crop management practices (Maccarthy *et al*., 2013). In rural areas, the living standards of people mainly depend on agriculture, which is often determined by the fertility and productivity of soil.

Most of sub-Saharan Africa (SSA) soils are naturally less fertile than soils of North America, Europe, and Asia. They are typically low in available nitrogen (N), CEC, soil organic matter (SOM) and commonly deficient in phosphorus (P), sulphur (S) and magnesium (Mg) (John *et al*., 1995). Soil fertility is one of the primary constraints to agricultural production particularly in densely populated and countries characterized by hilly and Rift Valley areas such as Ethiopia, Kenya, Rwanda and Malawi (Roy *et al.*, 2003; Bationo *et al*., 2006). The problem comprises not only in supply of nutrient, but also indicates their nutrient supplying capability; moreover fertility of soil is subject to man's control (Deshmukh, 2012). Ethiopia has potentially rich land resources but agricultural productivity has been below optimum yield mainly due to a range of factors including soil erosion, acidity and nutrient depletion, lack of soil fertility replenishment, nutrient mining and lack of balanced fertilization (Tesfahunegn, *et al*., 2011; Wondwosen *et al*., 2011).Therefore, soil fertility constraints to crop production in region are recognized as the major impediments to food security (Chillot and Hassan, 2010).

The proper rates of plant nutrients can be determined by knowledge about the nutrient requirement of the crop and supplying power of the soil (Tilahun, 2007). However, Ethiopian farmers used to apply only chemical fertilizers di-ammonium phosphate (DAP) and urea to increase crop yields for about five decades and this did not consider soil fertility status and crop requirement. For instance, in southern Ethiopia, farmers apply 100/50 $kgha^{-1}$ DAP/Urea for maize irrespective of the heterogeneity of the farm areas. In contrast to this, Flowe *et al*.; 2005: Santr *et al*.,; 2008: Tegbaru, 2014; Fanuel, 2015; & Okubay, *et al*., 2015 reported that agricultural fields are not homogenous and soil macro nutrient status is highly variable.

Describing the spatial variability across a field was difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced. GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data (Burrough, 1998).GIS can be used in producing soil fertility map of an area that helps to understand the status of soil fertility spatially and temporally, which will help in formulating site-specific balanced fertilizer recommendation. These technologies allow mapping fields accurately and computing complex spatial relationships between soil fertility factors. Numerous studies have been conducted based on geo-statistical analysis to characterize the spatial variability of different soil properties (Burrough*et al*., 2010; Liuet *al*., 2013; and Wang *et al*., 2009). Thus, information on spatial variability of soil nutrients is important for sustainable management of soil fertility. Among many Geo-statistical methods, ordinary krining is widely used to map spatial variation of soil fertility. According to Ismaili *et al*., (2014), the ordinary Kriging (using either exponential or spherical models) is more accurate for predicting the spatial patterns of the soil properties pH, OM, P, and K than the two other methods (IDW and splines), because it provides a higher level of prediction accuracy (Song, 2013).

Soil testing provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for optimizing crop yields. Soil fertility maps are meant for highlighting the nutrient needs, based on fertility status of soils and adverse soil conditions which need improvement to realize good crop yields (Verma, 2005). Knowledge about an up-to-date status of soil macronutrients at different landscapes and mapping their spatial distribution play a vital role in site-specific fertilizer recommendation to enhance production and productivity of the agricultural sector on sustainable basis. However, information on the status and spatial distribution of soil macronutrients are limited specifically for study area. Therefore, as part of the institutional initiative, this study was conducted with specific objectives to identify, classify and mapping soil nutrient status of the study area and to avail information on fertilizer and lime application of the study area.

Materials and Methods

Description of the study areas

Bedele district is one of the 9 districts of the Buno Bedele zone of the Oromia regional state, situated in south western Ethiopia. The district is located between 8°14'30"N to 8°37'53"N latitude and 36°13'17"E to 36°35'05"E longitude. The district is characterized by different agro-climatic zone which ranges from 1013 to 2390 masl. It covers a total area of 770.75km^2 and constitutes a total of 41 Peasant Associations (PA) (Figure 1).The physical features of the study area is characterized by a rugged topography dominated by gentle slopes and localized steep slopes, ranging from 2% - 45%.

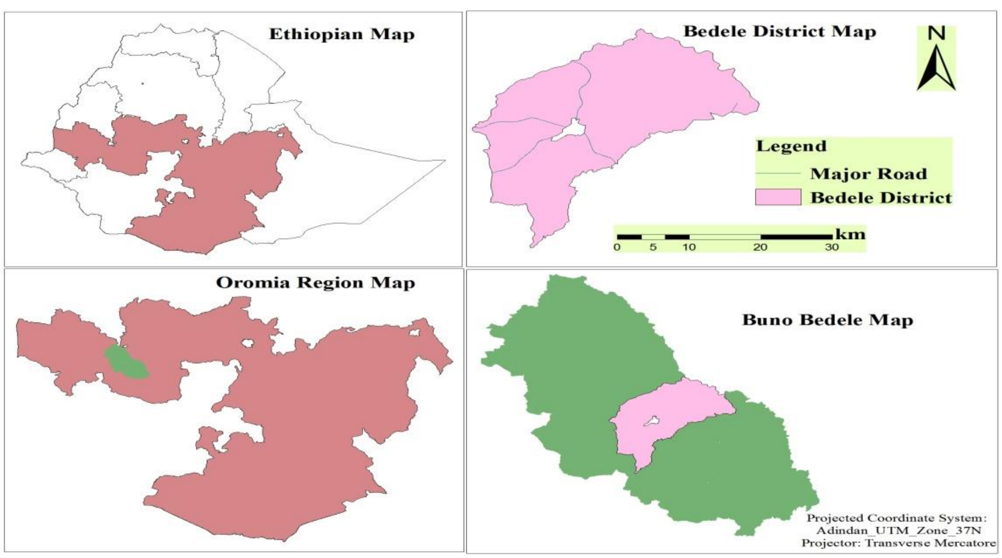


Figure 1. Map of the study area

Climatic condition

The records of twenty years (1997-2016) climatic data showed that the study area receives a unimodal type of rainfall pattern, with the highest rain occurring between May and September. The mean annual precipitation was 1944.9mm; with a large inter annual variability. The mean annual minimum and maximum temperature of the study area is 12.9˚C and 25.8˚C, respectively. The hottest months occur from November to April (maximum 27.5˚C) while the coldest months occur from November to January (minimum 10.9˚C) (Figure 1).

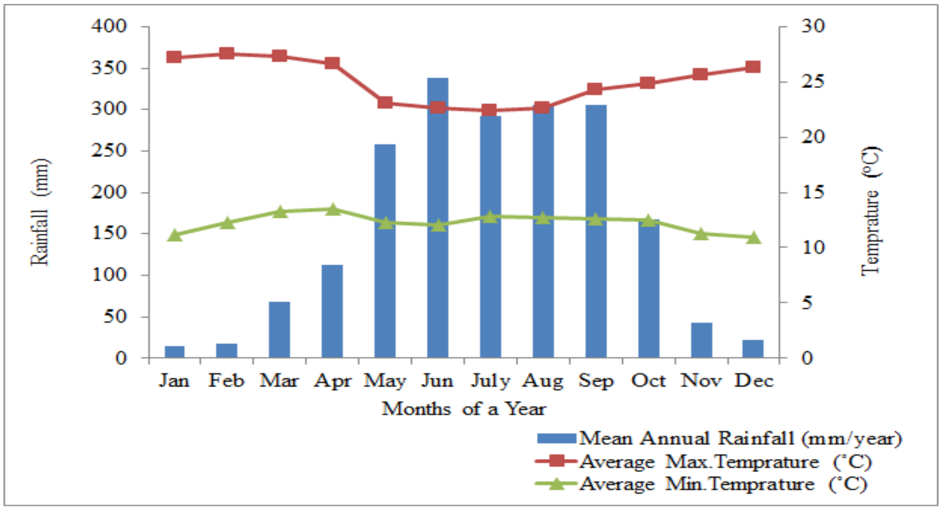


Figure 2. Climatic data of the study area

Source: National Meteorological Agency, Bedele District Branch

Topography and soil

Bedele district is characterized by three major landscapes. The plateau plains, which are moderately elevated, moderately dissected hills and side slopes with great range of elevation and further low land plains (Dhidhessa Valley) up to the minimum elevation of low plain. Different landscape features in the study area is exist with the variation of the altitude. The existence of different landscapes features and altitudinal range demonstrates different land form category and soils types accordingly. The predominant soils type in the plateau and moderately dissected hills and side slopes area are Dystric Nitisols and Letosols on the steep slope. In the lowland plains of Dhidhessa Valley Pellic Vertisols is the dominant soil type (FAO, 1998).

Farming system

The agricultural activities carried out in the area include both crop production and animal husbandry, in which the latter plays an equally important role. The farming system in the area is therefore, denoted by close interdependence & integration of crop cultivation and animal husbandry (animals used for traction, meat and milk), where the production and productivity of one is not separated from the other. The agro-ecology in the district is best suited in agro-climatic condition of warm sub-humid lowlands that is conducive for diverse agricultural production. The main farming system of the district is Maize (*Zea maize*) dominated crop livestock mixed farming system, while wheat (*Triticum aestivum*), sorghum (*Sorghum bicolor*), finger millet (*Eleusine coracana*), coffee (*Coffee arabica* L.) and teff (*Eragrotis abyssinica*) are also cultivated in sizeable quantities in medium to high altitude areas. Pulse crops, especially faba bean (*Vicia faba*) and Field peas (*Cicer arieinum*), are also grown in selected areas. Horticultural crops, mainly vegetables, are produced in home garden. Livestock production is an integral part of the production system. Production of cattle, donkey, sheep, goat and poultry is a very common practice in the study area (BDAO, 2018).

Land use/cover

The dominant land use type in Bedele district is cropland which covers 48.6% while forest land, pasture/grazing land and others account for 7.9%, 1.9% and 41.6% of the total land area respectively. The land cover is dominated by scattered trees and shrubs which are found around settlements, in farmlands, and coffee, shrubs, trees and grasses in the closure areas. Important forest lands include the government-protected forest areas such as Beli, Abalo, Cebeli, Gema and Yabala community forests (BDAO, 2018).

Site selection and soil sample collection

The tentative sampling points were distributed at 1.5 km grid intervals throughout the district by the use of ArcGIS version 10.1 and the area of interest for soil sampling was prepared to establish the pre-defined sampling points (Figure2). The region of interest for soil sampling location was prepared by stratifying the non- agricultural land from the country's land use/land cover map by using a Google Earth map displayed. The context of this research, agricultural land includes land covers such as low land shrub, low land open woodland, grassland, fallow land and principally currently cultivated land was identified. The tentative sampling points that fall out of agricultural land were excluded and the predefined sampling points that fall on agricultural land were surveyed.

Surface (0-20cm) soil samples were collected during the off season of 2015/16 using systematic sampling technique. During sampling, the predefined sampling points were navigated by using Garmin GPS_78 and letting the GPS average the location for 3-5 minutes to increase accuracy. At the plot level, basic site characteristics were described and recorded on the standard description sheet provided for each sampling plot. After locating the center of sampling point by GPS, soil samples were collected from 15-20 subplots by using auger to the depth of 20 cm and mixed to make a composite sample. The sub-samples taken from each subplot were pooled into one bucket and thoroughly mixed and homogenized after which a representative sample of approximately 1.0 kg was taken and placed in a properly labeled sample bag to represent one composite sample and transported to the laboratory properly (Bedele Soil Research Center, soil Laboratory). A total of 132 composite soil samples were collected from agricultural land of the entire district (Figure 3).

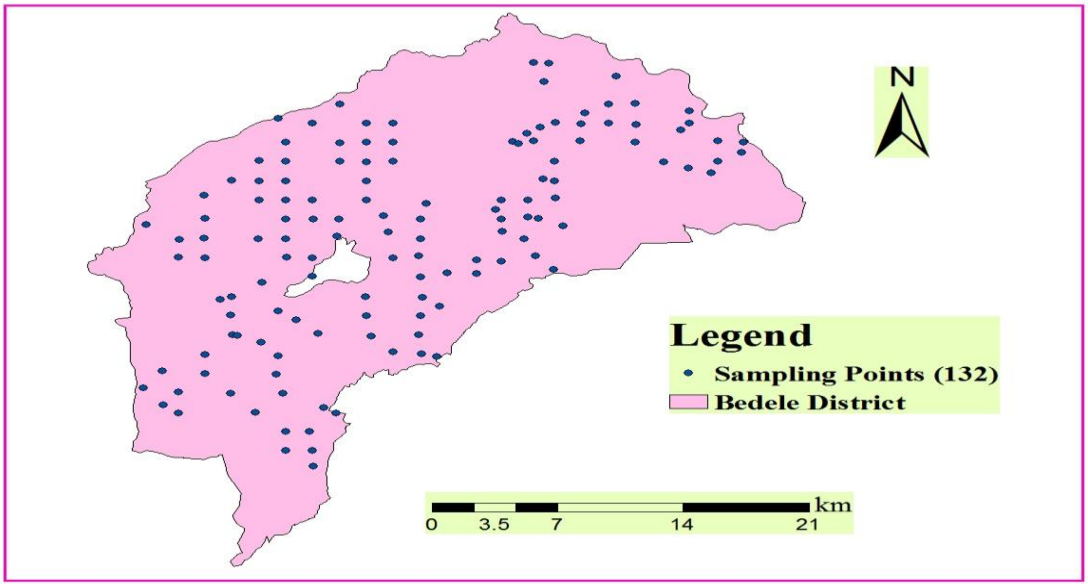


Figure 3. Sampling locations of Bedele District

Soil sample preparation and soil laboratory analysis

Soil samples preparation and analysis was conducted at Bedele Soil Research Center, Soil laboratory. The samples were air dried and crushed using mortar and pestle and sieved through a 2mm mesh sieve size. Organic Carbon was determined using the wet oxidation method (Walkley and Black, 1934). Available Phosphorus was extracted by Olsen method (Olsen *et al*., 1954). The pH was measured potentiometrically using a digital pH-meter in the supernatant suspension of 1:2.5 soils to water ratio. electrical conductivity, exchangeable acidity, Exchangeable Basic Cation (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+},) was analyzed using atomic absorption spectrophotometer following an ammonium acetate extraction method and measured by using flame photometer (Rowell, 1994). Similarly, CEC was measured after leaching the NH_4OAc extracted soil samples with 10% NaCl solution and particle size was analyzed by the hydrometer method.

Soil fertility mapping

Based on soil analysis results, soil fertility indices were generated and ratings made (FAO, 2006). Accordingly, the soils were classified into different fertility categories, i.e., very low, low, medium, high and very high on the basis of the content of each selected soil parameters. Fertility maps of the study area for required soil parameters were developed through ArcGIS 10.1 software by using ordinary Kriging method. For each fertility class, different symbol, colors, and patterns were selected from symbol selector of ArcMap. Finally, the fertility status of the land units was mapped by using the respective legend symbols.

Results and Discussion

Soil particle size distribution

The soil textural class of the district constituted more of clay particles than sand and silt (Table 1 and Figure 4). Six different textural classes were identified in the study area, namely: clay, clay loam, sandy clay, sandy clay loam, sandy loam and sandy textural classes which accounted about 48.5, 22.0, 10.6, 15.2, 2.3 and 1.5% of the total collected samples, respectively.

The maximum clay, silt and sand of samples collected from Bedele district were 72, 34 and 68% respectively whereas the minimum values were 14, 8, and 10% respectively (Table 1). Soils with high clay content have sufficient particle-to-particle contact points to form strong bonds when the soil dries which can lead to the formation of a strong crust (FAO, 2006). According to Buol *et al*. (2003), high clay content is an indication of complete alteration of weatherable minerals into secondary clays and oxides. Similarly, frequent cultivation might have enhanced weathering of primary particles and contributed for the high clay fraction. On the other hand, the contents of sand in the soils were very low compared to clay and silt separates.

Table 1. Particle size distribution of soils in Bedele District

		Particle size range (%)	
Texture	**Observations (No.)**	**Minimum**	**Maximum**
Clay	132	14	72
Silt	132	8	34
Sand	132	10	68

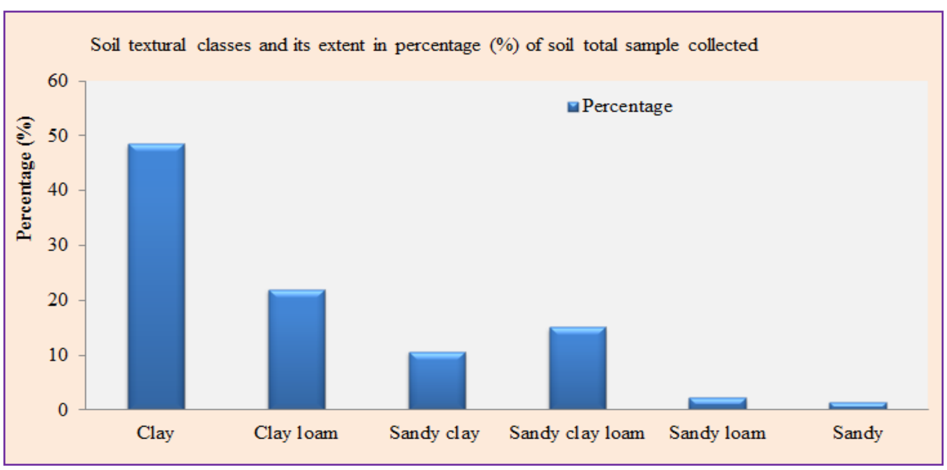


Figure 4. Soil textural class categories and its extent in percentage of total samples collected across Bedele District

Soil reaction, exchangeable acidity and electrical conductivity

The results revealed that the soil reaction, pH (H_2O) of the surface soil of the district ranged from 4.5 to 6.8 (Table 2). Based on acidity class established by FAO (2006) the soils acidity of the study area ranged from very strongly acidic to slightly acidic. The minimum value of soil pH was observed in the higher altitude of the study area which was intensively cultivated, while the maximum value was observed in the lower altitude. Accordingly, very strongly acidic, strongly acidic, moderately acidic and slight acidic soils were accounted for about 4%, 52%, 33% and 11% of the total area of the Bedele district (Figure 5 and Figure 6).

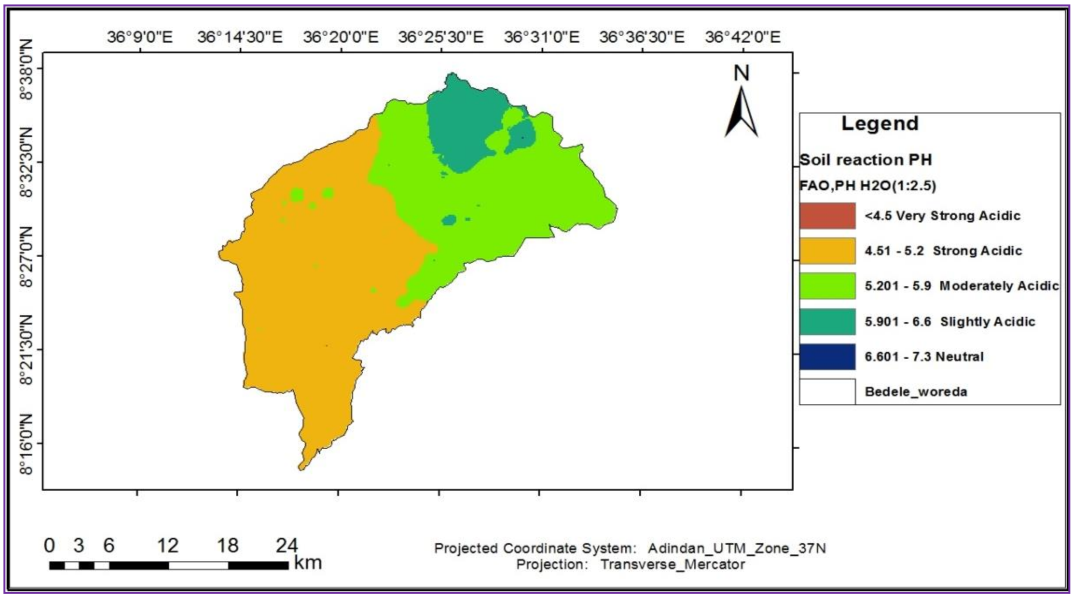


Figure 5. Map showing surface soil pH classes and status of Bedele District

Considering the optimum pH for many plant species to be 5.5 to 6.8 (Amacher *et al.*, 2007)and absence of free exchangeable Al in this range, only about 31% of the pH of the soils in study area could be considered as suitable for most crop production (Figure 6) whereas according to critical levels adopted by EthioSIS and Tekalign (1991) at pH (1:2.5) 69% of the soils of the study area fall under strongly acidic (pH $\leq$ 5.5), where the solubility of essential nutrients needed for plant grow this reduced. This could be due to high rainfall received by the area that caused leaching of bases and clay particles. Moreover, the acidic nature with low soil pH might be obtained from the entire district may be attributed to the fact that, soils were derived from weathering of acidic igneous granites and leaching of basic cations such as K, Ca and Mg from the surface soil (Frossard *et al.*, 2000).

As a result this condition also usually lead to Al and Mn toxicity plus deficiency in N, P, K, Mg, Ca and various micronutrients. This has multiple implications for plant growth and other soil fertility issues including reduced response to ammonium phosphate and urea fertilizers, stunted root and plant growth due to nutrient deficiency (yields frequently reduced), increased incidence of disease, and toxicity (e.g. for Mn: black spots and streaks on leaves).

Table 2. Soil reaction (pH), electrical conductivity (EC), exchangeable acidity, organic carbon (OC) and available phosphorus of soils in Bedele District

Soil property	Observations (No.)	Range	
		Minimum	Maximum
pH (H_2O)	132	4.5	6.8
EC(dS/m)	132	0.0	0.2
EA ($cmol_c kg^{-1}$)	132	0.1	5.1
OC (%)	132	0.3	5.6
Av. P (ppm)	132	0.8	38.6

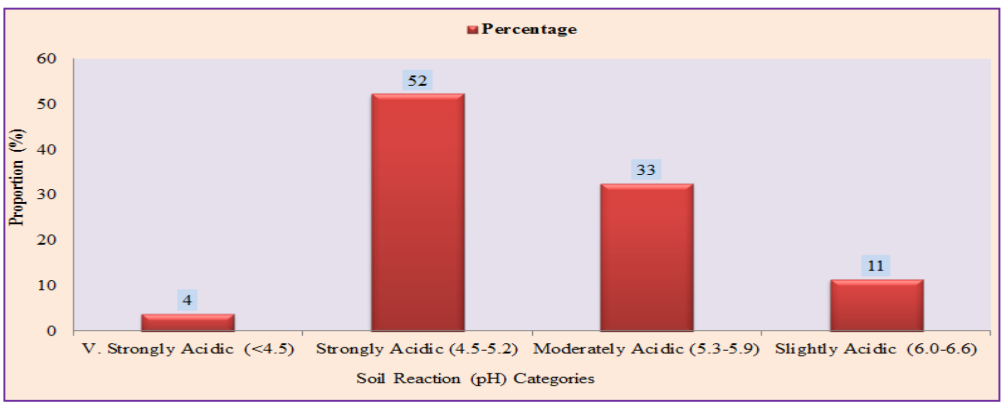


Figure 6. Proportions of pH ratings of soil samples collected from Bedele District.

The exchangeable acidity (Al + H), on the other hand, varied from 0.1 to 5.1 cmolc kg^{-1} for soils with pH values ≤ 5.5 and the mean value was 1.0 cmolc kg^{-1} of soil. Whereas, electrical conductivity (EC) values of the study area varied from 0.0-0.2 dS m^{-1} and in accordance with the EC rating suggested by Scianna *et al*. (2007), the soils of the study area were non-saline (Table 2). Similarly, according to definition set by U.S. Salinity Laboratory Staff (1954) none of the samples were saline and the values were even lower than the suggested cut of point, 4 dS m^{-1}. This is due to rainfall that significantly exceeds evapo-transpiration and results in leaching of soluble ions and prevents accumulation of salt.

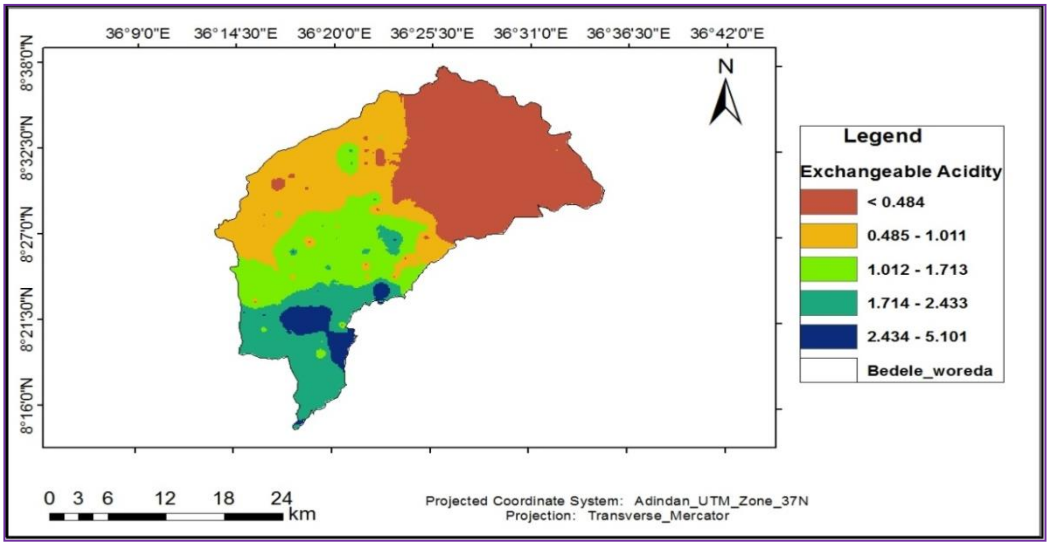


Figure 7. Map of exchangeable acidity of soil samples collected from Bedele District

Soil organic carbon

The organic carbon (OC) content of the soil ranged from 0.3 to 5.6% (Table 2). Based on the rating set by Landon (2014), 59% of the soil samples collected from the district were revealed that low (2-4%), 14% were very low (<2%) and the rest 27 % showed that medium (4-10%) in their OC content (Figure 8).This might be due to complete removal of aboveground biomass (for energy, animal feed, construction) and limitedcrop rotation practice. Besides, the low to medium content of soil OC is also attributed because of the warmer climate, which enhances rapid rate of mineralization (Abayneh, 2005).

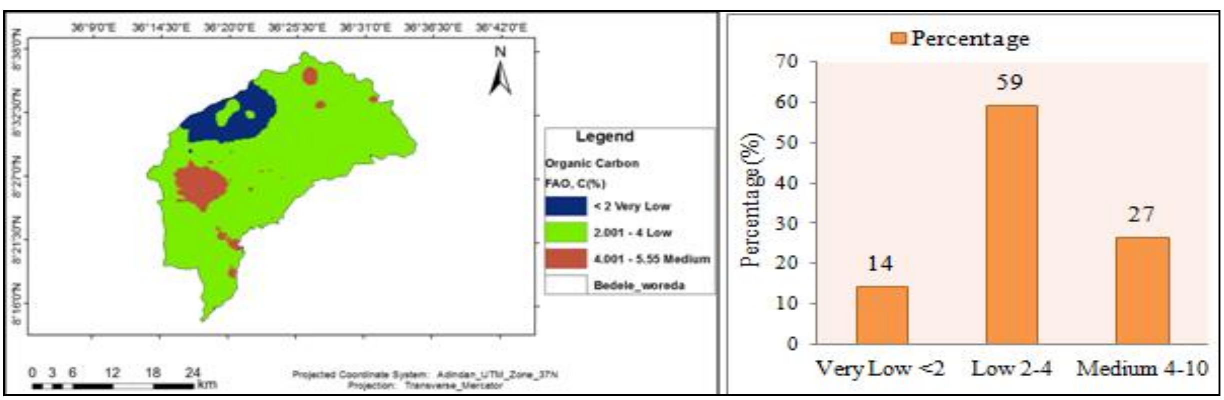


Figure 8. Map showing OC classes and coverage of Bedele district

Available phosphorus

The maximum and minimum values of available P were 38.6 and 0.8 mg kg^{-1}, respectively (Table 2). According to the critical level set by FAO, (2006), from the total samples collected and predicted area, nearly 88% of available phosphorus values falls under very low category and the rest exhibited in medium range (Figure 9). But according to the critical level set recently by EthioSIS (Karltun *et al*., 2013) from the total samples collected and predicted area, nearly about 92% of available phosphorus values falls under very low category (0-15) and the rest exhibit to low and medium (Figure 9).

Generally, the available P status of the soils in the study area was very low, and is among the factors that are highly limiting the productivity of the soils. In agreement with this observation, many researchers including Harrison, (1987); Warren, (1992) and Buehler *et al.*, (2002) have also reported that soil P deficiency is a wide spread phenomenon and it is believed to be the second most important soil fertility problem throughout the world next to N and often the first limiting element in acid tropical soils.

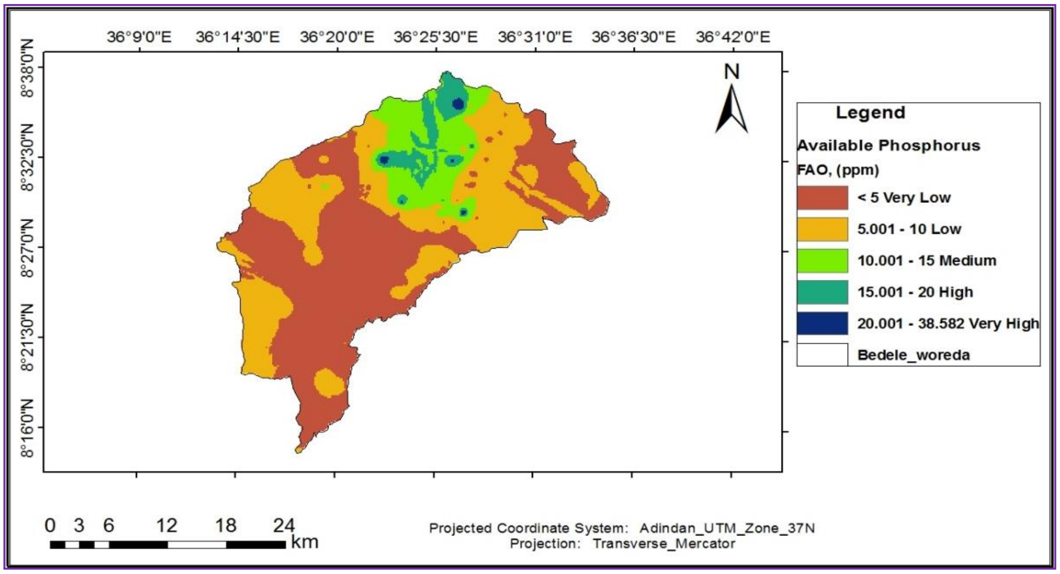


Figure 9. Map showing available P class and status

However, the lower available P in soils of the district may be due to lower SOM status. Most plant nutrients are fixed when the soil pH is less than 5.5. In addition, iron and aluminum ions dominate the exchange sites and become active to react with phosphorus and make it insoluble (Mesfin, 2007). On the other hand most plant nutrients are optimally available at pH value greater than 5.5 and less than 7.5 which is also compatible to plant root growth (Tisdale *et al*., 2003). Result of this study is consistent with that of Achalu *et al*. (2012) who observed that variations in available P contents in soils are related with the intensity of soil disturbance, the degree of P- fixation with Fe and Al ions. Similarly, Tekalign and Haque (1987) and Dawit *et al.* (2002) reported SOM as the main source of available P and the availability of P in most soils of Ethiopia decline by the impacts of fixation, abundant crop harvest and erosion.

Exchangeable bases

Generally, the maximum value of total exchangeable bases (K, Na, Mg and Ca) was 6.5cmol$_c$kg^{-1} and the minimum value was 1.3cmol$_c$kg^{-1} (Figure 10 and Table 3). Potassium is an important plant nutrient and a great deal of study has been made of the amounts believed necessary for adequate plant growth. The maximum and minimum values of exchangeable K were 4.5 and 0.3cmol$_c$kg^{-1} respectively, an exchangeable calcium value of greater than 5cmol$_c$ kg^{-1} soil is considered to be adequate for the nutrition of most crops. The maximum and minimum values of Exchangeable Ca were 3.2 and 0.3cmolckg^{-1} respectively. Exchangeable magnesium which is greater than 1cmol$_c$kg^{-1} soil is believed to be adequate for plant nutrition (Metson, 1961). The amount of exchangeable magnesium reported for the soils of the study area varied from 0.2 to 2.2 $cmol_c$ kg^{-1} soils.

Although sodium (Na) may, in particular circumstances, be utilized by some plants as a partial substitute for K, it is not an essential plant nutrient. Its absence, or presence in very small quantities, is therefore not usually detrimental to plants but if it is high in proportion to other cations it will have an adverse effect not only on crops but also on physical condition of the soil. Accordingly, the value of the measured exchangeable Na falls in the range of 0.0 to 1.5 $cmol_c kg^{-1}$ of soil, indicating lower Na content of the soil and have no any adverse effect on growth of crops and physical properties of soil (Table 3). Based on the ratings set by (FAO, 2006) 9, 27 and 64% of the total area were medium, high and very high in exchangeable K content respectively (Figure 19 and Table 3). According to Hazelton and Murphy (2007), the mean soil exchangeable potassium is rated as moderate to very high. Even though the highest value of exchangeable K were medium, there could be an increasing loss of all exchangeable cations in the study area due to continuous removal by crops without replenishment and vertical movement or leaching.

However, Manbir *et al.*, (2015) reported that, soil test K alone may not be adequate to predict K response. Plants produce higher yields at a certain Ca: Mg ratio and K: Mg ratio on acidic soils which are 10:1 and 0.7:1, respectively (Loide, 2004). Noting that, for potash fertilizer application, K: Mg ratio of 0.7:1 was used as a critical point, since the amount of K was low compared to Mg in many areas, especially in the study area was accounted about ranged from 0.2:1 to 10.9:1 (Table 3), which indicated magnesium induced K deficiency using the rating of Loide (2004).This can be corrected by potassium fertilizer application to bring the potassium to magnesium ratio closer to 0.7:1.

Table 3. Exchangeable bases (CEC), PSP, ESP, SAR, Ca: Mg ratio and K: Mg ratio of Bedele District

Range	Soil chemical property (n = 132)										
	Exchangeable bases ($cmol_c kg^{-1}$)					**PBS**	**ESP**	**SAR Ratio**	**CEC ($cmol_c kg^{-1}$)**	**Ca:Mg Ratio**	**K:Mg Ratio**
	Na^+	**K^+**	**Ca^{++}**	**Mg^{++}**	**TEB**	**(%)**					
Min.	0.0	0.3	0.3	0.2	1.3	9.7	0.0	0.0	2.6	0.3	0.2
Max.	1.5	4.5	3.2	2.2	6.5	51.6	30.4	1.0	35.3	3.4	10.9

Where, Min = minimum, max = maximum

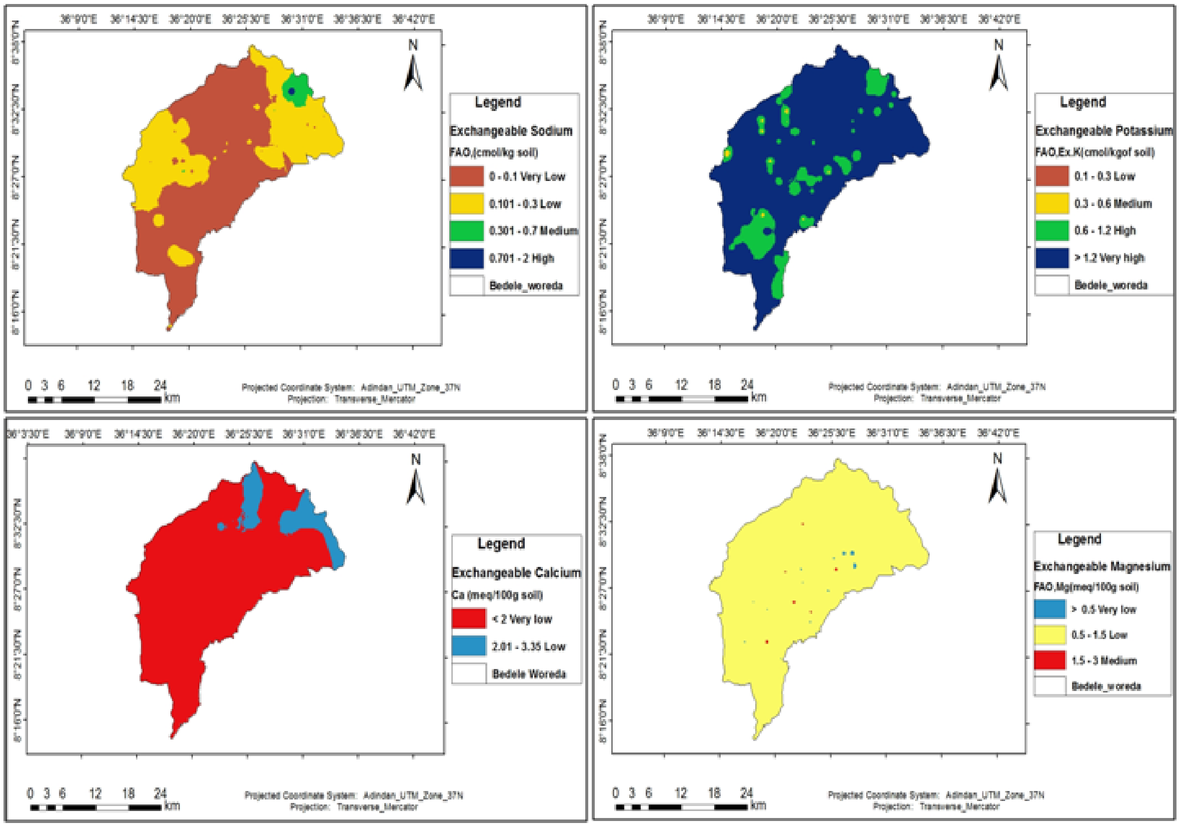


Figure 10. Exchangeable bases (K, Na, Mg and Ca) of Bedele District

From total soil samples collected from the district about 10% and 90% were low, and very low, respectively in exchangeable Ca content, which was ranged from 0.3-3.2$cmol_c kg^{-1}$ (Figure 10 and Table 3). According to sated standard by Hazelton and Murphy (2007), analyzed value of exchangeable calcium is categorized or rated from low to very low. This might be attributed to removal of this exchangeable basic cation by erosion and leaching from higher topography and their subsequent accumulation in the lower elevations. This indicates that more calcium is required as production input and the response to calcium application in form of fertilizer more likely increase productivity.

The analytical values of exchangeable bases indicated that exchangeable Ca and K were dominant cations in the exchange complex (Table 3). Total exchangeable bases of soil samples collected from Bedele district ranged from 1.3 to 6.5$cmol_c Kg^{-1}$. The minimum, maximum and mean of the total exchangeable bases (TEB) of the district was 1.3, 6.5 and 3.6cmolc Kg^{-1}, respectively. Eckert, (1987) also suggested that Ca: Mg ratio is an index appropriate to indicate the level of calcium and magnesium from crop nutrition point of view. According to authors of Eckert (1987), the total soil samples collected from the district, the minimum and maximum values of Ca: Mg ratios were 0.3 and 3.4, respectively.

Cation exchange capacity and base saturation

The maximum value of CEC was recorded at small part of Dhidhessa valley plain at the east margin of the study area (Figure 10). This could be due to high accumulation of clays and organic matter at that location (Figure 7). In addition, most areas of the district contained CEC value at medium level for crop production. The cation exchange capacity (CEC) of the soils ranged from 2.6-35.3cmol$_c$kg^{-1} (Figure 11 and Table 3).

As per rating set by FAO (2006), the CEC value of the district can be classified as 63, 30, 4, and 3% was fallen in the range of moderate, low, high and very low, respectively (Figure 12). This result indicates that the CEC values of the district were ranged from very low to high. The relatively medium CEC values recorded may be attributed to the fact that soils with medium accumulation percent OC. Soils with low CEC are more likely to develop deficiencies

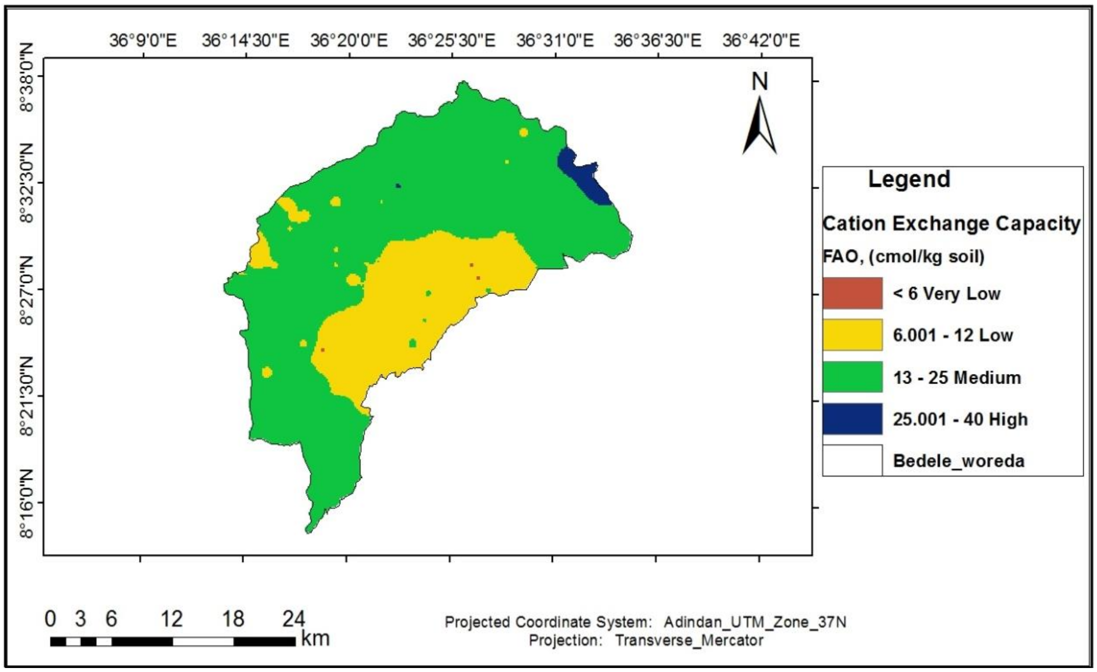


Figure 11. CEC classes and its status in soils collected from Bedele District

in potassium (K^+), magnesium (Mg^{2+}) and other cations which were susceptible to leaching while high CEC soils are less susceptible to leaching of these cations (CUCE, 2007). Generally, the soils of the study area had moderate nutrient retention and buffering capacity due to medium status of CEC. The minimum and maximum values of percent base saturation (PBS) of the district were 9.7 and 51.5% respectively.

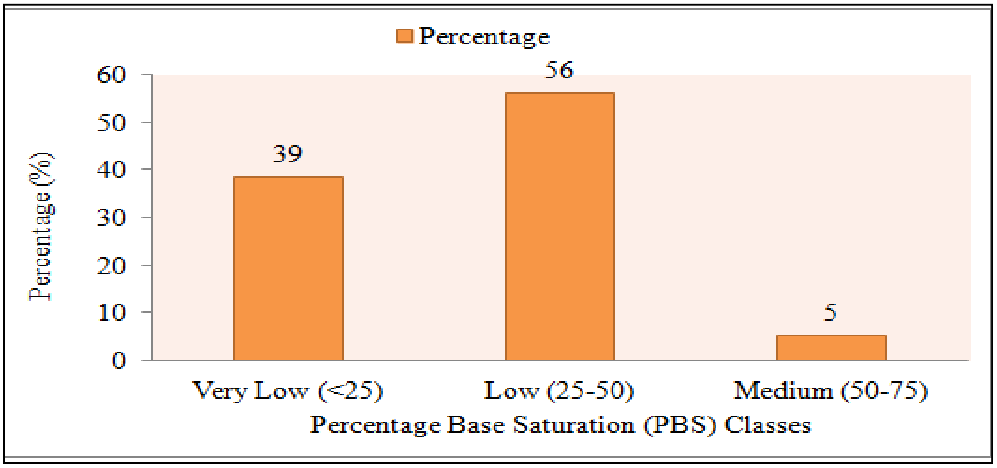


Figure 12. PBS classes and its status in soils collected from Bedele District

According to the rating set by FAO (2006), out of the total collected composite soil samples percent base saturation (PBS) of 39, 56, and 5% were in the range of very low, low, and moderate, respectively (Figure 12). These indicate that 95% of soils samples collected from the district was below the threshold levels. According to FAO (2006), soils having greater than 50% PBS are rated as fertile and potentially productive soils.

Conclusion and Recommendations

Soil fertility map shows plant nutrient status and is useful for decision making for professionals and farmers on fertilizer type and rate, and agricultural liming materials. According to the results of this soil assessment, some required soil chemical, physical, and biological properties were varied extensively within the fields in the study area. Accordingly about 69% of the study area was strongly acidic (pH ≤ 5.5), about 73% of the district cultivated areas were low in soil organic carbon (<4%), nearly 88% of available phosphorus was below critical range (<10ppm). Calcium status of all soil samples was low ranging from 0.3-3.2cmol$_c$kg^{-1}. Finally, based on the findings of this study, the following recommendation is forwarded for decision makers, researchers and stakeholders that this soil map can be used as important information source for soil fertility status in the district. Since agricultural land of the district is affected by depletion of organic matter and plant nutrients, integrated soil fertility management should be a priority focus for researchers, agricultural experts, development agents and other relevant stakeholders. Further correlation and calibration of soil test data with crop response is recommended for soil test crop response based fertilizer recommendation with appropriate fertilizer types and rates.

Acknowledgment

The authors would like to acknowledge Oromia Agricultural Research Institute (IQQO) for financial, logistic and material support during the whole activity; provide special thanks to all researchers, laboratory technicians and support staff of Bedele Soil Research Center for providing the necessary attention and follow up to carry out this soil fertility assessment successfully; appreciate surveyors who participated during soil sample collection and also extend especial gratitude to Mr. Getachew Haile, GIS researcher, for his valuable support during soil fertility map development.

References

Amare H, Priess J, Veldkamp E, Teketay D, Lesschen JP, *et al*., (2005). Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances. Agriculture, Ecosystem and Environment 108(1): 1-16.

Bationo A, Hartemink A, Lungu O, Naimi M, Okoth P, *et al*. (2006). African Soils: Their productivity and profitability of fertilizer use. Background paper prepared for the African fertilizer summit Nigeria.

Bellete T. (2014). Fertility mapping of soils of Abay-Chomen District, Western Oromia, Ethiopia.MSc Thesis, Haramaya University, Ethiopia.

Burrough PA, Rachael A, McDonnell (1998). Principles of Geographical Information Systems. Oxford University Press, New York, USA.

Cao SK, Chena KL, Cao GC, Zhang L, Ma J, *et al*., 2011. The Analysis of Characteristic and Spatial Variability for Soil Organic Matter and Organic Carbon around Qinghai Lake. Procedia Environmental Sciences 10(A): 678 -684.

EthioSIS (Ethiopia Soil Information System), 2014.Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia. Ethiopia. http://www.ata.gov.et/ highlighted-deliverables/ethiopian-soil-information-systemethiosis.

Flower M, Weisz R, White G., 2005. Yield-based management zones and grid sampling strategies: Describing soil test and nutrient variability. Agronomy Journal 97(3): 968-982.

Giday O, Gibrekidan H, Tareke B., 2015. Soil Fertility Characterization in Vertisols of Southern Tigray, Ethiopia, Adv plants agric res 2(1): 00034.

Habtamu A, Heluf G, Bobe B, Enyew A., 2014. Fertility Status of Soils under Different Land uses at Wujiraba Watershed, North-Western Highlands.

Habte M, Gebrekidan H, Wasie H., 2013. Decompostion and nutrient release of selected green manure species at different stages of growth on Alisols at Areke, Sorthern Ethiopia. International Journal of Natural Sciences Research (5): 30-42.

Huang B, Sun W.X, Zhao Y.C, Zhu J, Yang R.Q, *et al*., 2007. Temporal and spatial variability of soil organic matter and total nitrogen in an agricultural ecosystem as affected by farming practices. Geoderma 139(3-4): 336-345.

John D.T.K, Waddington S.R, Snapp S.S, Jones R.B, Blackie M, *et al*., (1995). Soil Fertility Management Research for the Smallholder Maize-Based Cropping Systems of Southern Africa: A Review. Network Research Working Paper Number Soil Fertility Network for Maize-Based Cropping Systems in Countries of Southern Africa. CIMMYT Maize Programme. Zimbabwe: CIMMYT.

Laekemariam F, (2015). Soil spatial variability analysis, fertility mapping and soil plant nutrient relations in Wolaita zone, Southern Ethiopia. Haramaya University Ethiopia.

Lin J.S, Shi X.Z, Lu X.X, Yu D.S, Wang H.J, *et al*., (2009). Storage and spatial variation of phosphorus in paddy soils of China. Pedosphere 19(6): 790-798.

Liu Z.P, Shao M.A, Wang Y.Q (2013). Spatial patterns of soil total nitrogen and soil total phosphorus across the entire Loess Plateau region of China. Geoderma 197-198: 67-78.

Li X.G, Li F.M, Zed R, Zhan Z.Y, Singh B, *et al*., (2007). Soil physical properties and their relations to organic carbon pools as affected by land use in an alpine pastureland. Geoderma 139(1-2): 98-105.

Maccarthy, D.S., Agyare, W.A., Vlek, P.L.G. and Adiku, S.G.K., 2013. Spatial variability of some soil chemical and physical properties of an agricultural landscape. *West African Journals Appl Ecol*, *21*, pp.47-61.

Olsen, S.R., C.V. Cole, F.S. Watanable, L.A. Dean .1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular. 939:119.

Rowell, D. L. 1994. Soil science: Methods and applications. Addison Wesley Longman Limited. England. 350.
Roy R.N, Misra R.V, Lesschen J.P, Smaling E.M., 2003. Assessment of Soil Nutrient Balance: Approaches and Methodologies. FAO Fertilizer and Plant Nutrition Bulletin 14 Rome.
Samira I, Ahmed D, Lhoussaine M., 2014. Soil Fertility Mapping: Comparison of Three Spatial Interpolation Techniques. International Journal of Engineering Research and Technology 3(11): 134-143.
Sanchez P.A, Jama B.A, Niang A.I, Palm CA, 2000. Soil fertility, small farm intensification and the environment in Africa. In Lee DR & Barrett CB (Eds.), Tradeoffs or Synergies, CAB International, Wallingford, UK, pp. 327-346.
Santra P, Chropra UK, Chakraborty D., 2008. Spatial variability of soil properties and its application in predicting surface map of hydraulic parameters in an agricultural farm. 95 (7): 937-945.
Song G, Zhang L, Wang K, Fang M., 2013. Spatial simulation of soil attribute based on principle of soil science. IEEE.
Tesfahunegn G.B, Tamene L, Vlek P.L.G. 2011.Catchment-scale spatial variability of soil properties and implications on site-specific soil management in northern Ethiopia.Soil and Tillage Research 117: 124-139.
Tilahun G (2007). Soil fertility status as influenced by different land uses in Maybar areas of South Wello Zone, North Ethiopia. Haramaya University, Ethiopia.
Walkley, A., and C. A., Black, 1934. An examination of different methods for determining Soil organic matter and the proposed modification by the chromic acid titration method. Soil Sci. J. 37: 29-38.
Weindorf D.C, Zhu Y., 2010. Spatial variability of soil properties at Capulin Volcano, Mew Mexico, USA: implications for sampling strategy. Pedosphere 20(2): 185-197.
Wondwosen Tene, Sheleme Beyene, 2011. Identification of growth limiting nutrient(s) in Alfisols: soil physico-chemical properties, Nutrient Concentration and Biomass Yield of Maize. American Journal of plant nutrient and fertilizer technology 1(1): 23-35.
Verma V.K, Patel L.B, Toor G.S., 2005.Spatial distribution of macronutrients in soils of arid tract of Punjab, India. International Journal of Agriculture and Biology 7(2): 295-297.

Soil Fertility Assessment and Mapping of Chora District, Buno Bedele Zone, Southwest Oromia, Ethiopia

Gedefa Sori*, Abdulmalik Mohammed and Dechassa Mengistu

Bedele Soil Research Center, P.O.Box 167, Bedele, Ethiopia

*Corresponding author: sorigedefa45@gmail.com

Abstract

Soil fertility assessment mapping shows plant nutrient status at required scale and is useful for decision making in fertilizer advisory services for farmers and policy makers. The objective of this study was to assess and map soil fertility status of the study area. A total of 109 soil samples were collected from different locations in Chora District at 1.5 km grid interval from a depth of 0-20 cm from cultivated lands. Soil texture, soil orcanic carbon (SOC), soil reaction (pH), electrical conductivity (EC), exchangeable acidity (EA), available P, exchangeable bases and cation exchange capacity (CEC) were analyzed by standard laboratory methods at Bedele Soil Research Center laboratory. To predict values for not sampled locations the Ordinary Kriging interpolation was used by ArcGIS10.2 software. Clay soils constitute more than 86% of the total soil samples of the District. Soil reaction (pH) ranged from 4.3-6.0, i.e., 90% of the soils of the study area were under strongly acidic conditions (pH ≤ 5.5). Soil organic carbon (SOC) ranged from 1.8-5.4%; 87% of the soil samples collected from the district was low (<4%), while the rest showed medium range. Available phosphorus was ranged from 0.5-11.5ppm[1]. The predicted available phosphorus of the study area which was almost all soil samples collected revealed below required range (<10ppm). Exchangeable potassium and magnesium were ranged from sufficient to very high contents, while exchangeable calcium was mostly revealed difficient (88%) in the study area. To manage these deficient nutrients fertilizers containing P and agricultural lime materials are suggested for increasing crop production in the study area. Site-specific critical levels for each of these deficient nutrients and surveillance of each nutrient status to prevent toxicity are recommended to obtain optimum crop yield in the study area. Further integrated soil fertility management (ISFM) intervention technologies will be needed for sustainable soil resource management practices for food and nutrition security of the study area.

Keywords: *Soil fertility mapping, Ordinary Kriging, ArcGIS*

Introduction

Most of sub-Saharan Africa (SSA) soils are naturally less fertile than soils of North America, Europe, and Asia. They are typically low in available nitrogen (N), CEC, soil organic matter (SOM) and commonly deficient in phosphorus (P), sulphur (S) and magnesium (Mg) (John *et al*., 1995). Soil fertility is one of the primary constraints to agricultural production particularly in densely populated and hilly countries of the Rift Valley areas such as Ethiopia, Kenya, Rwanda and Malawi (Roy *et al.,* 2003; Bationo *et al*., 2006). It comprises not only in supply of nutrient, but also indicates their nutrient supplying capability; moreover fertility of soil is subject to man's control (Deshmukh, 2012).

Ethiopia has potentially rich land resources but agricultural productivity has been below optimum yield mainly due to a range of factors including soil erosion, acidity and nutrient depletion, lack of soil fertility replenishment, nutrient mining and lack of balanced fertilization (Tesfahunegn, *et al*., 2011; Wondwosen *et al*., 2011). Therefore, soil fertility constraints to crop production in region are recognized as the major impediments to food security (Chillot and Hassan, 2010). The proper rates of plant nutrients can be determined by knowledge about the nutrient requirement of the crop and supplying power of the soil (Tilahun, 2007). However, Ethiopian farmers used to apply only chemical fertilizers di-ammonium phosphate (DAP) and urea to increase crop yields for about five decades and this did not consider soil fertility status and crop requirement. For instance, in southern Ethiopia, farmers apply 100/50 kg ha^{-1} DAP/Urea for maize irrespective of the heterogeneity of the farm areas. In contrast to this, Flowe *et al*.; 2005: Santr *et al*.; 2008: Tegbaru, 2014; Fanuel, 2015; & Okubay *et al*., 2015 reported that agricultural fields are not homogenous and soil macro nutrient status is highly variable.

Describing the spatial variability across a field was difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced. GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data (Burrough, 1998). GIS can be used in producing soil fertility map of an area that helps to understand the status of soil fertility spatially and temporally, which will help in formulating site-specific balanced fertilizer recommendation. These technologies allow mapping fields accurately and computing complex spatial relationships between soil fertility factors. Numerous studies have been conducted based on geo-statistical analysis to characterize the spatial variability of different soil properties (Burrough *et al*., 2010; Liuet *al*., 2013; and Wang *et al*., 2009). Thus, information on spatial variability of soil nutrients is important for sustainable management of soil fertility. Among many Geo-statistical methods, ordinary krining is widely used to map spatial variation of soil fertility. According Ismaili *et al.*, (2014), the ordinary kriging (using either exponential or spherical models) is more accurate for predicting the spatial patterns of the soil properties pH, OM, P, and K than the two other methods (IDW and splines), because it provides a higher level of prediction accuracy (Song, 2013).

Soil testing provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for optimizing crop yields. Soil fertility maps are meant for highlighting the nutrient needs, based on fertility status of soils and adverse soil conditions which need improvement to realize good crop yields (Verma, 2005). Knowledge about an up-to-date status of soil macronutrients at different landscapes and mapping their spatial distribution play a vital role in site-specific fertilizer recommendation to enhance production and productivity of the agricultural sector on sustainable basis. However, information on the status and spatial distribution of soil macronutrients are limited specifically for study area. Therefore, as part of the institutional initiative, this study was conducted with specific objectives to identify, classify and mapping soil nutrient status of the study area and to avail information on fertilizer application of the study area.

Materials and Methods

Description of the study area

Chora is one of the Districts in the Buno Bedele Zone, Oromia regional state, Southwest Ethiopia. The district is bordered on the south by Setema, on the west by Yayo and Dorani, on the north by Dega, and on the east by Bedele. The administrative center of this district is Kumbabe. The district is located 519 km away from the capital city of the country and 36 km away from Bedele Town in Buno Bedele Zone. The district is located at an average elevation 2000 masl and located at 8°23'N, 36°07'E. It is generally characterized by warm climate with a mean annual maximum temperature of 25.5°C and a mean annual minimum temperature of 12.5°C. The driest season lasts between December and January, while the coldest month being December. The annual rainfall ranges from 1440 mm. The soil of the area is characterized as an old soil called Nitisol (CHDAO, 2018).

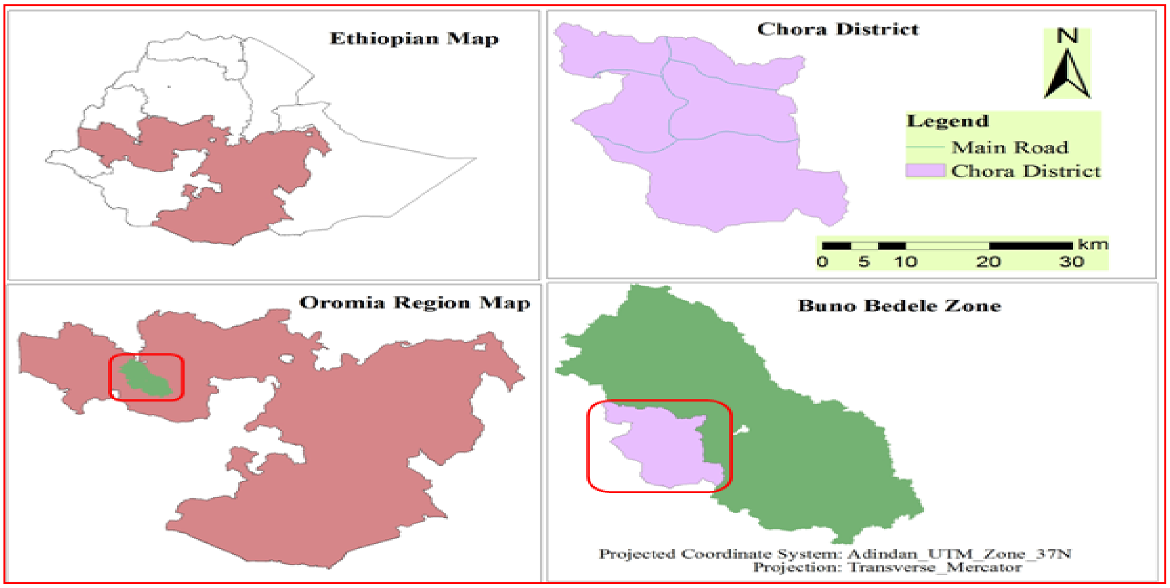


Figure 1. Map of the study area

Site selection and soil sample collection

The tentative sampling points were distributed at 1.5 km grid intervals throughout the district by the use of ArcGIS version 10.1 and the area of interest for soil sampling was prepared to establish the pre-defined sampling points (Figure 2). The region of interest for soil sampling location was prepared by stratifying the non- agricultural land from the country's land use/land cover map by using a Google Earth map displayed. The tentative sampling points that fall out of agricultural land were excluded and the predefined sampling points that fall on agricultural land were surveyed.

Surface (0-20cm) soil samples were collected during the off season of 2015/ using systematic sampling technique. During sampling, the predefined sampling points were navigated by using Garmin GPS_78 and letting the GPS average the location for 3-5 minutes to increase accuracy. At the plot level, basic site characteristics were described and recorded on the standard description sheet provided for each sampling

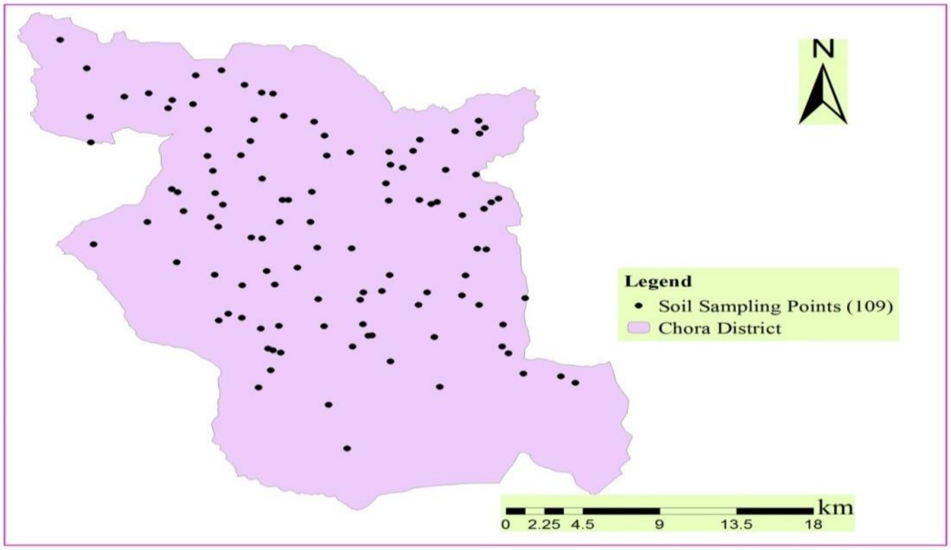


Figure 2. Sampling locations of Chora District

After locating the center of sampling point by GPS, soil samples were collected from 15-24 subplots by using auger to the depth of 20 cm and mixed to make a composite sample. The sub-samples taken from each subplot were pooled into one bucket and thoroughly mixed and homogenized after which a representative sample of approximately 1.0 kg was taken and placed in a properly labeled sample bag to represent one composite sample and transported to the laboratory properly (Bedele Soil Research Center, soil Laboratory). A total of 109 composite soil samples were collected from agricultural land of the entire district (Figure 2).

Soil sample preparation and soil laboratory analysis

Soil samples preparation was conducted at Bedele Soil Research Center, Soil Laboratory. The samples were air dried and crushed using mortar and pestle and sieved through a 2mm mesh sieve size. Soil samples preparation and analysis was conducted at Bedele Soil Research Center, Soil laboratory. The samples were air dried and crushed using mortar and pestle and sieved through a 2mm mesh sieve size. Organic Carbon was determined using the wet oxidation method (Walkley and Black, 1934). Available Phosphorus was extracted by Olsen method (Olsen *et al*., 1954). The pH was measured potentiometrically using a digital pH-meter in the supernatant suspension of 1:2.5 soils to water ratio. electrical conductivity, exchangeable acidity, Exchangeable Basic Cation (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+},) was analyzed using atomic absorption spectrophotometer following an ammonium acetate extraction method and measured by using flame photometer (Rowell, 1994). Similarly, CEC was measured after leaching the NH_4OAc extracted soil samples with 10% NaCl solution and particle size was analyzed by the hydrometer method.

Soil fertility mapping

Based on soil analysis results, soil fertility indices were generated and ratings made (FAO, 2006). Accordingly, the soils were classified into different fertility categories, i.e., very low, low, medium, high and very high on the basis of the content of each selected soil parameters. Fertility maps of the study area for required soil parameters were developed through ArcGIS 10.1 software by using ordinary Kriging method. For each fertility class, different symbol, colors, and patterns were selected from symbol selector of ArcMap. Finally, the fertility status of the land units was mapped by using the respective legend symbols.

Results and Discussion

Soil particle size distribution

The soil textural class of the district constituted more of clay particles than sand and silt (Table 2 and Figure 3). Three different textural classes were identified in the study area, namely: clay, clay loam and sandy clay loam textural classes, which accounted 86, 12 and 2% of the total collected samples, respectively. The maximum clay, silt and sand of samples collected from Chora district were 80, 45 and 48% respectively whereas the minimum values were 30, 6, and 4% respectively (Table 2). Soils with high clay content have sufficient particle-to-particle contact points to form strong bonds when the soil dries which can lead to the formation of a strong crust (FAO, 2006). According to Buol *et al*. (2003), high clay content is an indication of complete alteration of weatherable minerals into secondary clays and oxides. Similarly, frequent cultivation might have enhanced weathering of primary particles and contributed for the high clay fraction. On the other hand, the contents of sand in the soils were very low compared to clay and silt separates.

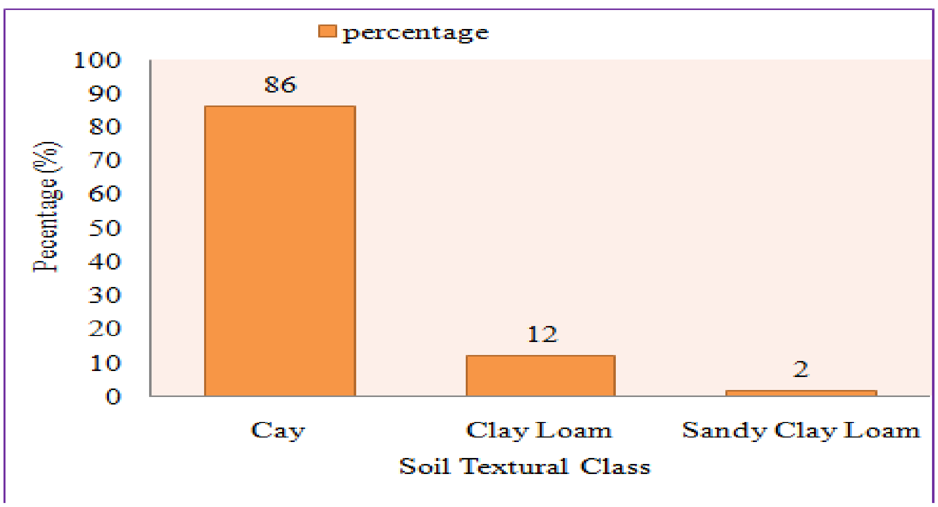


Figure 3. Soil textural classes and percentage in Chora District

Table 2. Particle size distribution of soils in Chora District

		Particle size range (%)	
Texture	**Observations (No.)**	**Minimum**	**Maximum**
Clay	109	30	80
Silt	109	6	45
Sand	109	4	48

Soil reaction, exchangeable acidity and electrical conductivity

The results revealed that the soil reaction, pH (H_2O) of the surface soil of the district ranged from 4.3 to 6.0 (Table 3). Based on soil acidity range established by FAO, (2006), the study area ranged from very strongly acidic to slightly acidic. The minimum value of soil pH was observed in the higher altitude of the study area which was intensively cultivated, while the maximum value was observed in the lower altitude. Accordingly, very strongly acidic, strongly acidic, moderately acidic were accounted as 7%, 59% and 34% of the total area of Chora District (Figures 4 and 5).

Table 3**.** Soil reaction (pH), electrical conductivity (EC), exchangeable acidity, organic carbon (OC) and available phosphorus (Av.P) of soils in Chora District

Soil property	**Observations (No.)**	**Range**	
		Minimum	**Maximum**
pH (H_2O)	109	4.3	6
EC(dS/m)	109	0.03	0.13
EA ($cmol_c kg^{-1}$)	109	0.0	3.5
OC (%)	109	1.8	5.4
Av. P (ppm)	109	0.5	11.5

Considering the optimum pH for many plant species to be 5.5 to 6.8 (Amacher *et al.*, 2007) and absence of free exchangeable Al in this range, only about 10% of the pH of the soils in the study area could be considered as suitable for most crop production (Figure 6). While according to critical levels adopted by EthioSIS and Tekalign (1991) at pH (1:2.5), 90% of the soils of the study area were under strongly acid soils ($pH \leq 5.5$), where the solubility of essential nutrients needed for plant growth reduced. This could be due to high rainfall received by the area that caused leaching of bases and clay particles.

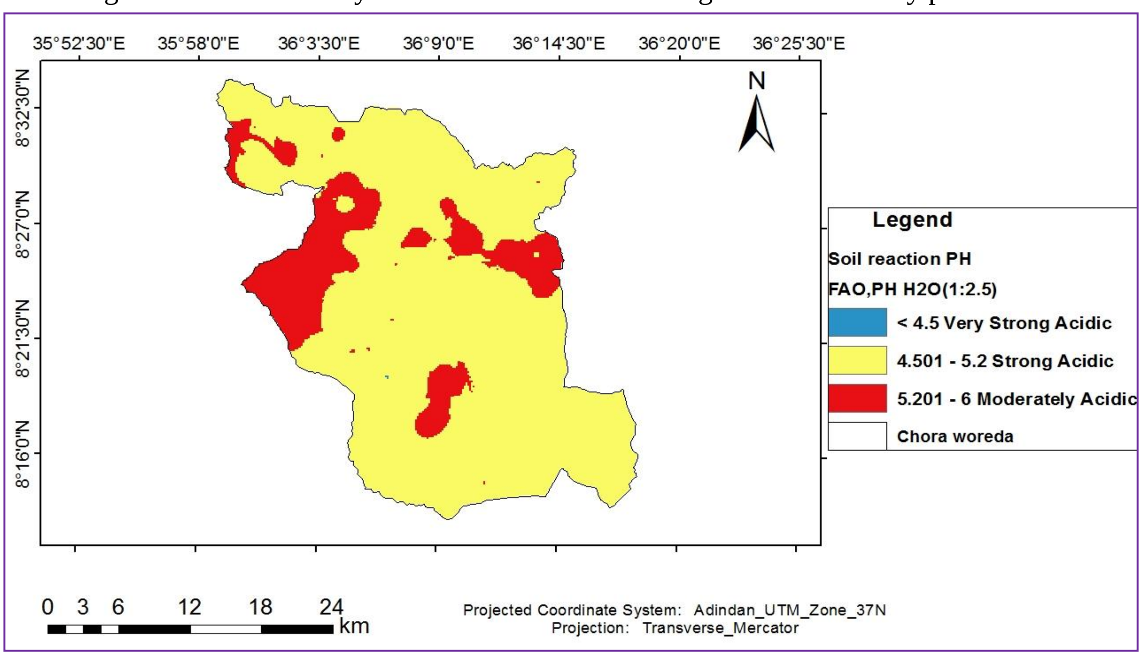


Figure 4. Map showing surface soil pH classes and status of Chora District

As a result this condition also usually leads to Al and Mn toxicity plus deficiency in N, P, K, Mg, Ca and various micronutrients. This has multiple implications for plant growth and other soil fertility issues including reduced response to ammonium phosphate and urea fertilizers, stunted root and plant growth due to nutrient deficiency (yields frequently reduced), increased incidence of disease, and toxicity (e.g. for Mn: black spots and streaks on leaves). The exchangeable acidity (Al+H), on the other hand, varied from 0.0 to 3.5cmolckg^{-1} for soils with pH ≤5.5.

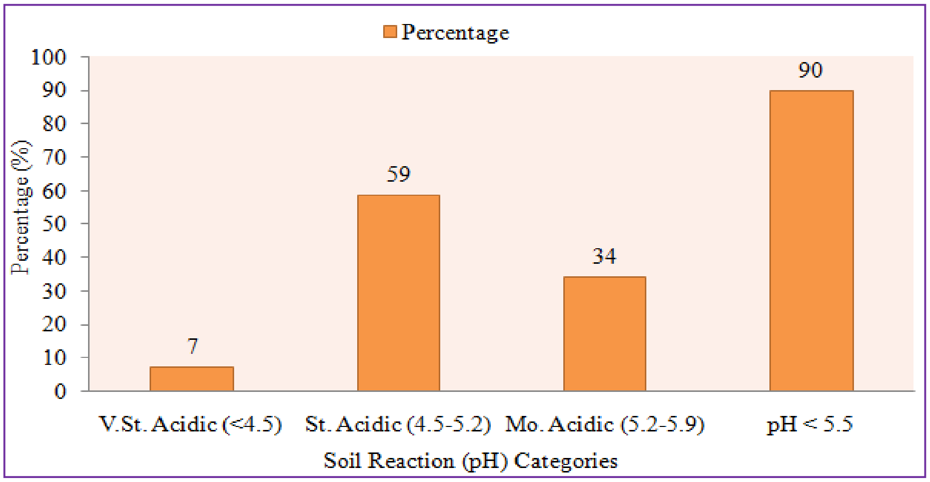


Figure 5. Proportions of pH ratings of soil samples collected from Chora District

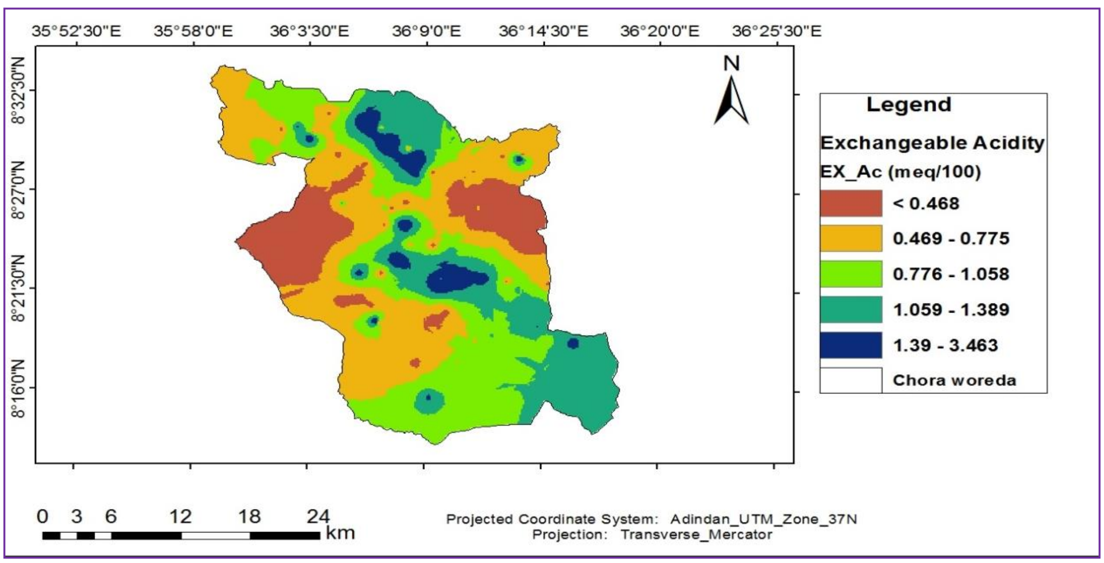


Figure 6. Map of exchangeable acidity (EA) of soil samples collected from Chora District

Wheras electrical conductivity (EC) values of the study area varied from 0.03-0.13 dS m^{-1} and in accordance with the EC rating suggested by Scianna *et al*. (2007), the soils of the study area were non-saline (Table 3). Similarly, according to definition set by U.S. Salinity Laboratory Staff (1954) none of the samples were saline and the values were even lower than the suggested cut of point, 4dSm^{-1}. This is due to rainfall that significantly exceeds evapotranspiration and results in leaching of soluble ions and prevents accumulation of salt. Plants growing in these study areas do not have the problem of absorbing water because of the lower osmotic effect of dissolved salt contents.

Soil organic carbon

The organic carbon (OC) content of the soil ranged from 1.8-5.4% (Table 3). Based on the rating set by Landon (2014), 87% of the soil samples collected from the district was revealed that low (2-4%), while the rest 13% showed that medium (4-10%) in their SOC content (Figure 8). This might be due to complete removal of aboveground biomass (for energy, animal feed, construct) and limited crop rotation practice. Furthermore, the low to medium content of soil organic carbon is also attributed because of the warmer climate, which enhances rapid rate of mineralization (Abayneh, 2005).

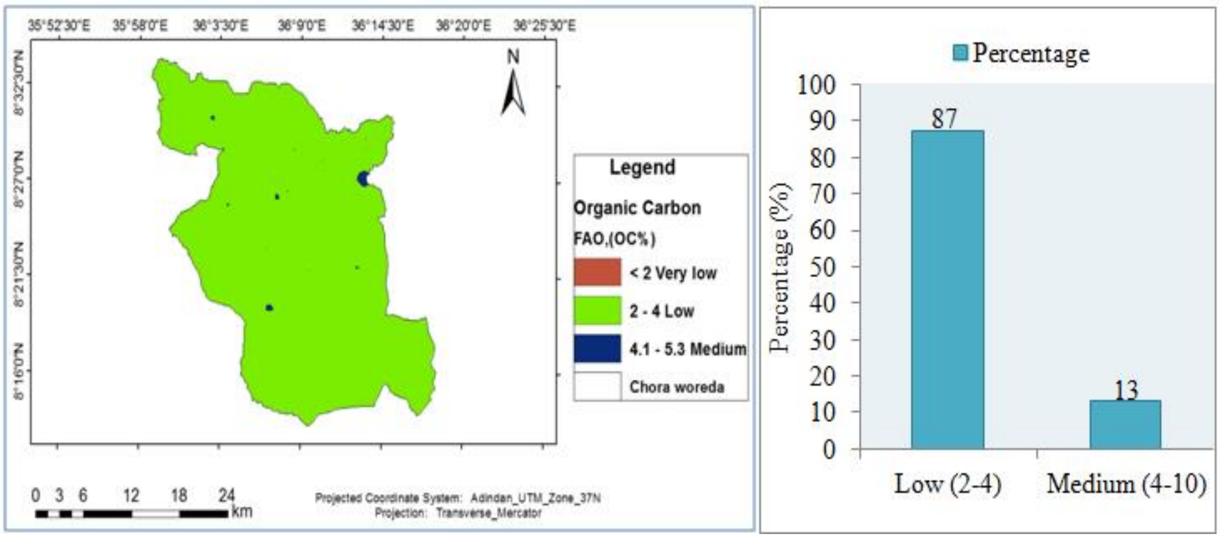


Figure 7. Map showing SOC classes and its coverage of Chora District

Available phosphorus

The maximum and minimum values of available phosphorus were 11.5 and 0.5ppm, respectively (Table 3). From the total samples collected and predicted area almost all samples revealed that nearly 97% of available phosphorus falls under very low (<5ppm) According to the critical level set by FAO, (2006), from the total samples collected and predicted area, nearly 97% of available phosphorus value falls under very low category (<5ppm) and the rest exhibited in low (Figure 8). But according to the critical level set recently by EthioSIS (Karltun *et al*., 2013) total samples collected and predicted area available phosphorus values were under very low category (0-15ppm).

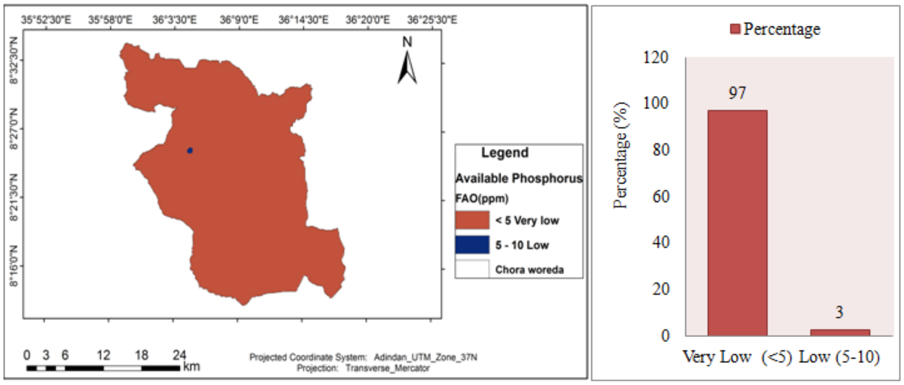


Figure 8. Map showing available P class and its coverage in Chora District

Generally, the available P status of the soils in the study area was very low, and is among the factors that are highly limiting the productivity of the soils. In agreement with this observation, many researchers Warren, 1992; Buehler *et al.*, 2002) have also reported that soil P deficiency is a wide spread phenomenon and it is believed to be the second most important soil fertility problem throughout the world next to N and often the first limiting element in acid tropical soils.

However, the lower available P in soils of the district may be due to lower SOM status and most plant nutrients are fixed when the soil pH is less than 5.5. In addition, iron and aluminium ions dominate the exchange sites and become active to react with phosphorus and make it insoluble (Mesfin, 2007). On the other hand most plant nutrients are optimally available at pH value greater than 5.5 and less than 7.5 which is also compatible to plant root growth (Tisdale *et al*., 2003). Result of this study was consistent with that of Achalu *et al*. (2012) who observed that variations in available P contents in soils are related with the intensity of soil disturbance, the degree of P- fixation with Fe and Al ions. Similarly, Tekalign and Haque (1987) and Dawit *et al.* (2002) reported SOM as the main source of available P and the availability of P in most soils of Ethiopia decline by the impacts of fixation, abundant crop harvest and erosion.

Exchangeable bases

Generally, the maximum value of total exchangeable bases (K, Na, Mg and Ca) was 16.5$cmol_c kg^{-1}$ and the minimum value was 1.5$cmol_c kg^{-1}$ (Table 4). Potassium is an important plant nutrient and a great deal of study has been made of the amounts believed necessary for adequate plant growth. The maximum and minimum values of exchangeable K were 4.8 and 0.2$cmol_c kg^{-1}$ respectively (Table 4). An exchangeable calcium value of greater than 5$cmol_c$ kg^{-1} soil is considered to be adequate for the nutrition of most crops. The maximum and minimum values of Exchangeable Ca were 8.3 and 0.4cmolc kg^{-1} (Table 4). Exchangeable magnesium which is greater than 1$cmol_c$ kg^{-1} soil is believed to be adequate for plant nutrition (Metson, 1961). The amount of exchangeable magnesium reported for the soils of the study area varied from 0.1-6.0$cmol_c$ kg^{-1} (Table 4).

Table 4. Exchangeable bases (CEC), PSP, ESP, SAR, Ca: Mg Ratio and K: Mg ratio of Chora District

Soil Chemical Properties (n = 109)											
	Exchangeable bases ($cmol_c kg^{-1}$)					PBS	ESP	SAR	CEC	Ca:Mg	K:Mg
Range	Na^+	K^+	Ca^{++}	Mg^{++}	TEB	(%)		ratio	($cmol_c kg^{-1}$)	ratio	ratio
Min.	0.0	0.2	0.4	0.1	1.5	8	0	0.0	5.3	0.3	0.1
Max.	0.7	4.8	8.3	6.0	16.2	100	22	0.5	24.5	19.4	22.0

Where Min = minimum, max = maximum

Although sodium (Na) may, in particular circumstances be utilized by some plants as a partial substitute for K, it is not an essential plant nutrient. Its absence, or presence in very small quantities, is therefore not usually detrimental to plants but if it is high in proportion to other cations it will have an adverse effect not only on crops but also on physical condition of the soil. The value of the measured exchangeable Na was in the range of 0.0 -0.7 $cmol_c kg^{-1}$ of soil, indicating lower Na content of the soil and have no any adverse effect on growth of crops and physical properties of soil (Table 4).

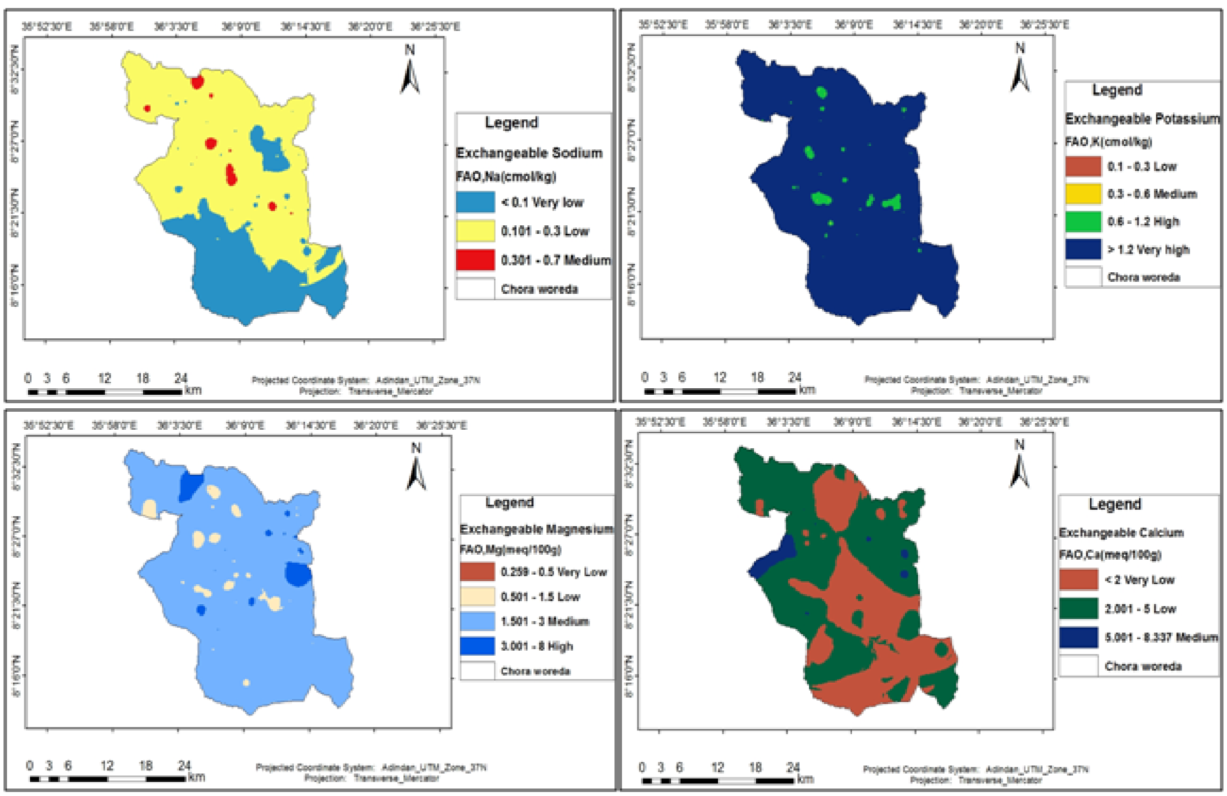


Figure 9. Exchangeable bases (Na, K, Mg and Ca) of Chora District

Based on the ratings set by FAO (2006) 8, 20 and 67% of the total area were medium, high and very high in exchangeable K content, respectively (Figure 11 and Table 4). According to Hazelton and Murphy (2007), the mean soil exchangeable potassium is rated as moderate to very high. Even though highest, there could be an increasing loss of all exchangeable cations in the study area due to continuous removal by crops without replenishment and vertical movement or leaching.

However, Manbir *et al.,* (2015) reported that, soil test K alone may not be adequate to predict K response. Plants produce higher yields at a certain Ca: Mg ratio and K: Mg ratio on acidic soils which are 10:1 and 0.7:1, respectively (Loide, 2004); noting that, for potash fertilizer application, K: Mg ratio of 0.7:1 was used as a critical point, since the amount of K was low compared to Mg in many areas, especially in the study area it was ranged from 0.2:1 to 22.1:1 (Table 4), which indicated that Mg induced K deficiency using the rating of Loide (2004). This can be corrected by potassium fertilizer application to bring the potassium to magnesium ratio closer to 0.7:1.

From a total soil samples collected from the district was about 43, 45 and 12% was low, very low and medium ranges in exchangeable Ca, which was ranged from 0.4-8.3cmol$_c$kg^{-1} (Figure 9 and Table 4). According to sated standard by Hazelton and Murphy (2007), the analyzed value of exchangeable calcium is categorized from low to very low. This might be attributed to removal of this exchangeable basic cation by erosion and leaching from higher topography and their subsequent accumulation in the lower elevations. This indicates that more calcium is required as production input and the response to calcium application in form of fertilizer and lime more likely increase productivity in the study area.

The analytical values of exchangeable bases indicated that exchangeable Ca and K were dominant cations in the exchange complex (Table 4). Total exchangeable bases of soil samples collected from Chora district ranges from 1.5-16.2cmol$_c$Kg^{-1} (Table 4). The minimum, maximum and mean of the total exchangeable bases of the district was 1.5, 16.2 and 6.9cmolc Kg^{-1}, respectively.

Cation exchange capacity and base saturation percentage

The maximum value of cation exchange capacity (CEC) was recorded at small part of plateau plain of the study area (Figure 10). This could be due to high accumulation of clays and organic matter at that location. In addition, most areas of the district contained CEC value at medium level for crop production. The CEC of the soils ranged from 5.3-24.5 cmol$_c$kg^{-1} with mean and standard deviation values of 14.8 and 3.8cmol$_c$kg^{-1} respectively (Figure 10 and Table 4).

As per rating set by FAO (2006), the CEC value of all agricultural land of the district can be classified as moderate (74%) and low (26%) status (Figure 10). This result indicates that the CEC values of the district were ranged from low to medium. The relatively medium CEC values recorded might be attributed to the fact that soils with medium accumulation percent of SOC. Soils with low CEC are more likely to develop deficiencies in potassium (K^+), magnesium (Ca^{2+}) and other cations which was susceptible to leaching while high CEC soils are less susceptible to leaching of these cations (CUCE, 2007).

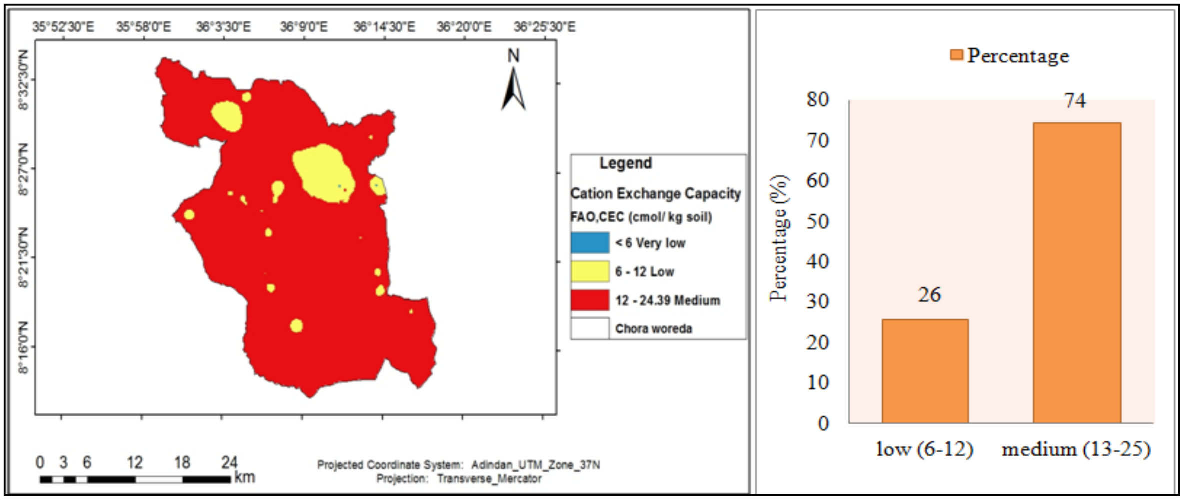


Figure 10. CEC classes and its coverage in Chora District

Generally, the soils of the study area had moderate nutrient retention and buffering capacity due to the medium status of CEC. The minimum and maximum values of percent base saturation (PBS) of the district were 8 and 100% respectively. According to the rating seted by FAO (2006), out of the total collected composite soil samples percent base saturation 34, 11, and 25% was categorized in the range of very low, low, and moderate respectively (Figure 11). These indicate that majority soils of the district were below the threshold levels. According to FAO (2006), soils having greater than 55% base saturation are rated as fertile and potentially productive soils.

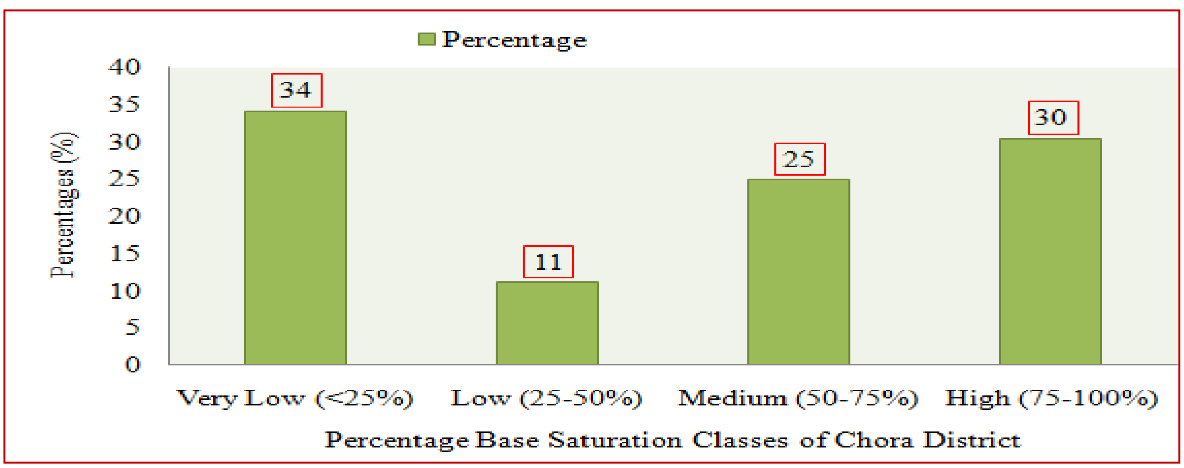


Figure 11. PBS classes and its coverage in Chora District

Conclusion and Recommendations

Soil fertility map shows plant nutrient status and is useful for decision making for professionals and farmers on fertilizer type and rate, agricultural liming materials and others. The results of soil fertility assessment showed that some required soil chemical, physical, and biological properties were varied extensively within the fields in the study area. Accordingly about 90% of the study area was strongly acidic (pH ≤ 5.5), about 87% of the district was low in soil organic carbon (<4%), totally 100% of the district available phosphorus was below critical range (<10ppm), and calcium status of all samples was low ranging from 0.4-8.3$cmol_c kg^{-1}$. Finally, based on these results, the following recommendation is given for decision makers, researchers, and stakeholders that this soil fertility map can be used as information source for soil fertility management in the district. Agricultural land of the district is highly depleted in soil organic content and plant nutrients then integrated soil fertility management should get priority attention by researchers, agricultural experts, development agents, and other stakeholders in creasing crop productivity and production of the district.

Acknowledgment

The authors would like to acknowledge Oromia Agricultural Research Institute (IQQO) for financial, logistic and material support during soil fertility assessment. Special thanks to all researchers, laboratory technicians and supportive staff of Bedele Soil Research Center for providing the necessary attention and follow up during the assessment. Appreciation also for surveyors participated in soil sample collection and Mr. Getachew Haile for his valuable support during soil fertility map development.

References

Amare H, Priess J, Veldkamp E, Teketay D, Lesschen JP, *et al*., (2005). Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances. Agriculture, Ecosystem and Environment 108(1): 1-16.

Bationo A, Hartemink A, Lungu O, Naimi M, Okoth P, *et al*. (2006). African Soils: Their productivity and profitability of fertilizer use. Background paper prepared for the African fertilizer summit Nigeria.

Bellete T (2014). Fertility mapping of soils of Abay-Chomen District, Western Oromia, Ethiopia. MSc Thesis, Haramaya University, Ethiopia.

Burrough PA, Rachael A, McDonnell (1998). Principles of Geographical Information Systems. Oxford University Press, New York, USA.

Cao SK, Chena KL, Cao GC, Zhang L, Ma J, *et al.,* (2011). The Analysis of Characteristic and Spatial Variability for Soil Organic Matter and Organic Carbon around Qinghai Lake. Procedia Environmental Sciences 10(A): 678 -684.

EthioSIS (Ethiopia Soil Information System), (2014). Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia. Ethiopia. http://www.ata.gov.et/highlighted-deliverables/Ethiopian-soil-information-system EthioSIS.

Flower M, Weisz R, White G (2005). Yield-based management zones and grid sampling strategies: Describing soil test and nutrient variability. Agr/. Journal 97(3): 968-982.

Giday O, Gibrekidan H, Tareke B (2015). Soil Fertility Characterization in Vertisols of Southern Tigray, Ethiopia, Adv plants agric res 2(1): 00034.

Habtamu A, Heluf G, Bobe B, Enyew A (2014). Fertility Status of Soils under Different Land uses at Wujiraba Watershed, North-Western Highlands.

Habte M, Gebrekidan H, Wasie H (2013). Decompostion and nutrient release of selected green manure species at different stages of growth on Alisols at Areke, Sorthern Ethiopia. International Journal of Natural Sciences Research (5): 30-42.

Huang B, Sun W.X, Zhao Y.C, Zhu J, Yang R.Q, *et al*. (2007). Temporal and spatial variability of soil organic matter and total nitrogen in an agricultural ecosystem as affected by farming practices. Geoderma 139(3-4): 336-345.

Hurni H, Bruno M (1990). Degradation and conservation of the soil resources in the Ethiopian highlands. African Mountains and Highlands: Problems and Perspectives, USA, pp. 51-64.

John D.T.K, Waddington S.R, Snapp S.S, Jones R.B, Blackie M, *et al*., (1995). Soil Fertility Management Research for the Smallholder Maize-Based Cropping Systems of Southern Africa: A Review. Network Research Working Paper Number Soil Fertility Network for Maize-Based Cropping Systems in Countries of Southern Africa. CIMMYT Maize Programme. Zimbabwe: CIMMYT.

Laekemariam F, (2015). Soil spatial variability analysis, fertility mapping and soil plant nutrient relations in Wolaita zone, Southern Ethiopia. Haramaya University Ethiopia.

Lin J.S, Shi X.Z, Lu X.X, Yu D.S, Wang H.J, *et al*., (2009). Storage and spatial variation of phosphorus in paddy soils of China. Pedosphere 19(6): 790-798.

Liu Z.P, Shao M.A, Wang Y.Q (2013). Spatial patterns of soil total nitrogen and soil total phosphorus across the entire Loess Plateau region of China. Geoderma 197-198: 67-78.

Li X.G, Li F.M, Zed R, Zhan Z.Y, Singh B, *et al*., (2007). Soil physical properties and their relations to organic carbon pools as affected by land use in an alpine pastureland. Geoderma 139(1-2): 98-105.

Maccarthy, D.S., Agyare, W.A., Vlek, P.L.G. and Adiku, S.G.K., 2013. Spatial variability of some soil chemical and physical properties of an agricultural landscape. *West African Journals Appl Ecol*, *21*, pp.47-61.

Olsen, S.R., C.V. Cole, F.S. Watanable, L.A. Dean .1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular. 939:119.

Roy R.N, Misra R.V, Lesschen J.P, Smaling E.M (2003). Assessment of Soil Nutrient Balance: Approaches and Methodologies. FAO Fertilizer and Plant Nutrition Bulletin 14 Rome.

Rowell, D. L. 1994. Soil science: Methods and applications. Addison Wesley Longman Limited. England. 350.

Samira I, Ahmed D, Lhoussaine M (2014). Soil Fertility Mapping: Comparison of Three Spatial Interpolation Techniques. International Journal of Engineering Research and Technology 3(11): 134-143.

Sanchez P.A, Jama B.A, Niang A.I, Palm CA (2000). Soil fertility, small farm intensification and the environment in Africa. In Lee DR & Barrett CB (Eds.), Tradeoffs or Synergies, CAB International, Wallingford, UK, pp. 327-346.

Santra P, Chropra UK, Chakraborty D (2008). Spatial variability of soil properties and its application in predicting surface map of hydraulic parameters in an agricultural farm. 95 (7): 937-945.

Song G, Zhang L, Wang K, Fang M (2013). Spatial simulation of soil attribute based on principle of soil science. IEEE.

Tesfahunegn G.B, Tamene L, Vlek P.L.G (2011). Catchment-scale spatial variability of soil properties and implications on site-specific soil management in northern Ethiopia. Soil and Tillage Research 117: 124-139.

Tilahun G (2007). Soil fertility status as influenced by different land uses in Maybar areas of South Wello Zone, North Ethiopia. Haramaya University, Ethiopia.

Walkley, A., and C. A., Black, 1934. An examination of different methods for determining Soil organic matter and the proposed modification by the chromic acid titration method. Soil Sci. J. 37: 29-38.

Weindorf D.C, Zhu Y (2010). Spatial variability of soil properties at Capulin Volcano, Mew Mexico, USA: implications for sampling strategy. Pedosphere 20(2): 185-197.

Wondwosen Tene, Sheleme Beyene (2011). Identification of growth limiting nutrient(s) in Alfisols: soil physico-chemical properties, Nutrient Concentration and Biomass Yield of Maize. American Journal of plant nutrient and fertilizer technology 1(1): 23-35.

Verma V.K, Patel L.B, Toor G.S (2005). Spatial distribution of macronutrients in soils of arid tract of Punjab, India. International Journal of Agriculture and Biology 7(2): 295-297.

Soil Fertility Assessment and Mapping of Mana District, Jimma Zone, Southwest Oromia, Ethiopia

Gedefa Sori*, Abdulmalik Mohammed, Dechassa Mengistu and Getachew Haile[1]

Bedele soil Research Center, P.O.Box 167, Bedele, Ethiopia

[1]Oromia Agricultural Research Institute, P.O.Box 81265, Finfinne, Ethiopia

*Corresponding author: sorigedefa45@gmail.com

Abstract

Soil fertility mapping shows plant nutrient status at required scale and is useful for decision making in fertilizer advisory services for farmers. The objectives of this study were to assess the fertility status of the soils and mapping of the study area. A total of 125 soil samples were collected across Bedele District at 1.5 km grid interval from the depth of 0-20 cm. Soil texture, soil orcanic carbon (SOC), soil reaction (pH), electrical conductivity (EC), exchangeable acidity (EA), available phosphorus (P), exchangeable bases and cation excheange capacity (CEC) were analyzed following standard laboratory methods at Bedele Soil Research Center soil laboratory. To predict values for not sampled locations the Ordinary Kriging interpolation was used by ArcGIS10.2 software. Clay soils constitute 98% of the total soil samples of the district. Soil organic carbon (SOC) range was from 1.0-5.8% indicating 70% of the soil samples collected from the district were low (<4%), while the rest 30% was in medium range. Soil reaction (pH) ranged from 4.1-6.2, i.e., 75% of the soils of the study area were under strongly acidic (pH<5.5). Available phosphorus was ranged from 0.6-21.8ppm, where *nearly 87% of analyzed soil samples values was under low category (<10ppm). Exchangeable potassium and magnisium were ranged from sufficient to very high range, while values of most exchangeable calcium showed difficient range in the study area. To address these nutrient deficiencies fertilizers containing of P and agricultural lime materials were suggested for optimum crop production in the district. Setting soil test based critical levels for each of these deficient nutrients and surveillance of each nutrient status to prevent toxicity are recommended to obtain optimum crop yield in the study area. Further ISFM intervention technologies will be needed for sustainable soil resource management practices for food and nutrition security of farmers in the study area. Generally, the soil fertility map developed for pH, OC, available P, CEC, Ca, Mg, K, and Na clearly indicates areas of the district where these soil properties are adequate and deficient for increasing crop productivity and production in the district.*

Keywords: *Soil fertility mapping, Ordinary Kriging, ArcGIS and lime materials*

Introduction

Most of sub-Saharan Africa (SSA) soils are naturally less fertile than soils of North America, Europe, and Asia; they are typically low in available nitrogen (N), CEC, soil organic matter (SOM) and commonly deficient in phosphorus (P), sulphur (S) and magnesium (Mg) (John *et al*., 1995). Soil fertility is one of the primary constraints to agricultural production particularly in densely populated and countries characterized by hilly and Rift Valley areas such as Ethiopia, Kenya, Rwanda and Malawi (Roy *et al*., 2003; Bationo *et al*., 2006). The challenge comprises not only in supply of nutrient, but also indicates their nutrient supplying capability; moreover fertility of soil is subject to man's control (Deshmukh, 2012).

Ethiopia has potentially rich land resources but agricultural productivity has been below optimum yield mainly due to a range of factors including soil erosion, acidity and nutrient depletion, lack of soil fertility replenishment, nutrient mining and lack of balanced fertilization (Tesfahunegn, *et al*., 2011; Wondwosen *et al*., 2011).Therefore, soil fertility constraints to crop production in region are recognized as the major impediments to food security (Chillot and Hassan, 2010).

The proper rates of plant nutrients can be determined by knowledge about the nutrient requirement of the crop and supplying power of the soil (Tilahun, 2007). However, Ethiopian farmers used to apply only chemical fertilizers di-ammonium phosphate (DAP) and urea to increase crop yields for about five decades and this did not consider soil fertility status and crop requirement. For instance, in southern Ethiopia, farmers apply 100/50 kg ha^{-1} DAP/Urea for maize irrespective of the heterogeneity of the farm areas. In contrast to this, Flowe *et al*. (2005); Santr *et al*. (2008); Tegbaru (2014); Fanuel (2015); and Okubay *et al*. (2015) reported that agricultural fields are not homogenous and soil macro-nutrient status is highly variable.

Describing the spatial variability across a field was difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced. GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data (Burrough, 1998). GIS can be used in producing soil fertility map of an area that helps to understand the status of soil fertility spatially and temporally, which will help in formulating site-specific balanced fertilizer recommendation. These technologies allow mapping fields accurately and computing complex spatial relationships between soil fertility factors. Numerous studies have been conducted based on geo-statistical analysis to characterize the spatial variability of different soil properties (Burrough *et al*., 2010; Liuet *al*., 2013; and Wang *et al*., 2009). Thus, information on spatial variability of soil nutrients is important for sustainable management of soil fertility. Among many Geo-statistical methods, ordinary krining is widely used to map spatial variation of soil fertility. According Ismaili et al., (2014), the ordinary kriging (using either exponential or spherical models) is more accurate for predicting the spatial patterns of the soil properties pH, OM, P, and K than the two other methods (IDW and splines), because it provides a higher level of prediction accuracy (Song, 2013).

Soil testing provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for optimizing crop yields. Soil fertility maps are meant for highlighting the nutrient needs, based on fertility status of soils and adverse soil conditions which need improvement to realize good crop yields (Verma, 2005). Knowledge about an up-to-date status of soil macronutrients at different landscapes and mapping their spatial distribution play a vital role in site-specific fertilizer recommendation to enhance production and productivity of the agricultural sector on sustainable basis. However, information on the status and spatial distribution of soil macronutrients are limited specifically for study area. Therefore, as part of the institutional initiative, this study was conducted with specific objectives to identify, classify and mapping soil nutrient status of the study area and to avail information on fertilizer application of the study area.

Materials and Methods

Description of the study area

Mana District is one of the districts in Jimma Zone, Oromia, Southwest Ethiopia. It is bordered in the south by Seka Chekorsa District, in the west by Gomma, in the north by Limmu Kosa, and in the east by Kersa District. The administrative center of this district is Yebu. The district is located 382 km away from the capital city of the country and 32 km away from Jimma Town in Jimma Zone. The district is located at an elevation ranged between 1400-2610masl and located at 7°67'N, 37°07'E. It is generally characterized by warm climate with a mean annual maximum temperature of 25°C and a mean annual minimum temperature of 18°C. The driest season lasts between December and January, while the coldest month being December. The annual rainfall ranges from 1,138 to 1,690 mm. The soil of the area is characterized as a old soil called Nitisol (Misgana *et al.*, 2018).

The landscape of Mana District includes mountains, high forests and plain divided by valleys. Mountains include Weshi and Bebella. Rivers include Aniso, Doha, Wanja, Yebu and Sogibo. A survey of the land in this district shows that 89.1% is arable or cultivable (86.1% was under annual crops), 2.7% pasture, 2.8% forest, and the remaining 5.4% is considered swampy, degraded or otherwise unusable. Khat and Coffee is an important cash crop for this district (Misgana *et al.*, 2018).

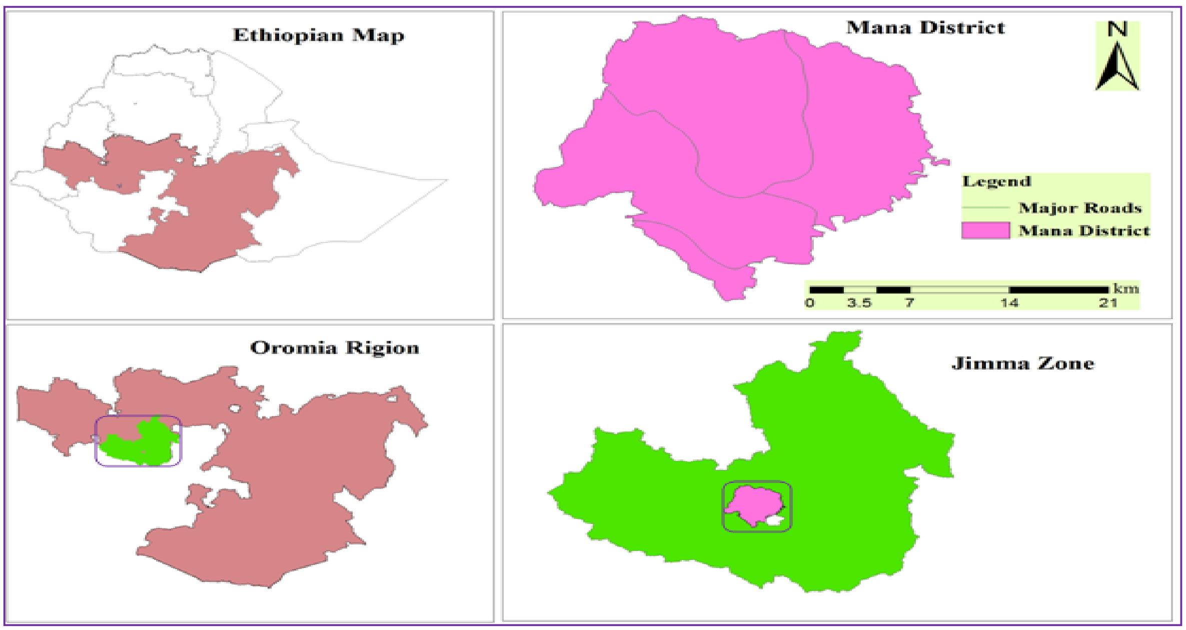


Figure 1. Map of the study area

Site selection and soil sample collection

The tentative sampling points were distributed at 1.5 km grid intervals throughout the District by the use of ArcGIS version 10.1 and the area of interest for soil sampling was prepared to establish the pre-defined sampling points (Figure 2). The region of interest for soil sampling location was prepared by stratifying the non- agricultural land from the country's land use/land cover map by using a Google Earth map displayed. The tentative sampling points that fall out of agricultural land were excluded and the predefined sampling points that fall on agricultural land were surveyed.

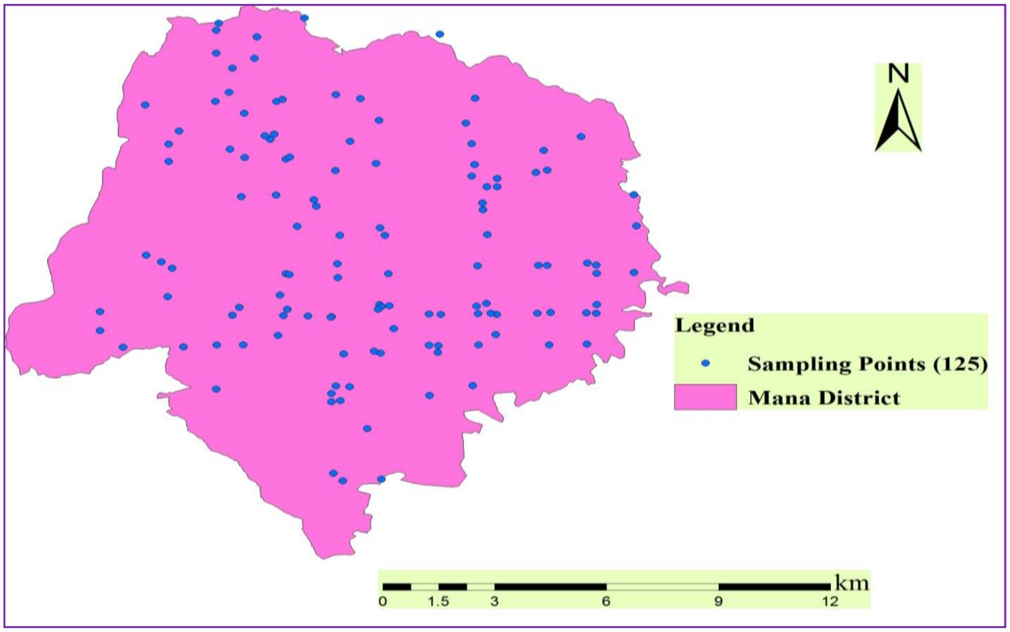


Figure 2. Sampling locations of Mana District

Surface (0-20cm) soil samples were collected during the off season of 2016/2017 using systematic sampling technique. During sampling, the predefined sampling points were navigated by using Garmin GPS_78 and letting the GPS average the location for 3-5 minutes to increase accuracy. At the plot level, basic site characteristics were described and recorded on the standard description sheet provided for each sampling plot. After locating the center of sampling point by GPS, soil samples were collected from 15-20 subplots by using auger to the depth of 20 cm and mixed to make a composite sample. The sub-samples taken from each subplot were pooled into one bucket and thoroughly mixed and homogenized after which a representative sample of approximately 1.0 kg was taken and placed in a properly labeled sample bag to represent one composite sample and transported to the laboratory properly (Bedele Soil Research Center, soil Laboratory). A total of 125 composite soil samples were collected from agricultural land of the entire district (Figure 2).

Soil sample preparation and soil laboratory analysis

Soil samples preparation was conducted at Bedele Soil Research Center, soil laboratory. The samples were air dried and crushed using mortar and pestle and sieved through a 2mm mesh sieve. Organic Carbon was determined using the wet oxidation method (Walkley and Black, 1934). Available Phosphorus was extracted by Olsen method (Olsen *et al*., 1954). The pH was measured potentiometrically using a digital pH-meter in the supernatant suspension of 1:2.5 soil to water ratio. electrical conductivity, exchangeable acidity, Exchangeable Basic Cation (Ca^{2+}, Mg^{2+}, K^{+}, and Na^{+},) was analyzed using atomic absorption spectrophotometer following an ammonium acetate extraction method and measured by using flame photometer (Rowell, 1994). Similarly, CEC was measured after leaching the NH_4OAc extracted soil samples with 10% NaCl solution and particle size was analyzed by the hydrometer method.

Soil fertility mapping

Finally, based on soil analysis results interpretation (FAO, 2006), fertility map of the study area for required soil parameter were developed through ArcGIS 10.1 software by using ordinary Kriging method. The district was categorized as sufficient or deficient in respective plant nutrients and the extent was shown on a map. The deficient plant nutrients were combined appropriately and recommended.

Results and Discussion

Soil particle size distribution

The soil textural class of the district constituted more of clay particles than sand and silt (Table 2 and Figure 3). Three different textural classes were identified in the study area, namely: clay and clay loam textural classes, which accounted 98 and 2% of the total collected samples, respectively. The maximum clay, silt and sand of samples collected from Mana district were 69, 35 and 43%, respectively whereas the minimum values were 30, 9, and 12% respectively (Table 2). Soils with high clay content have sufficient particle-to-particle contact points to form strong bonds when the soil dries which can lead to the formation of a strong crust (FAO, 2006).

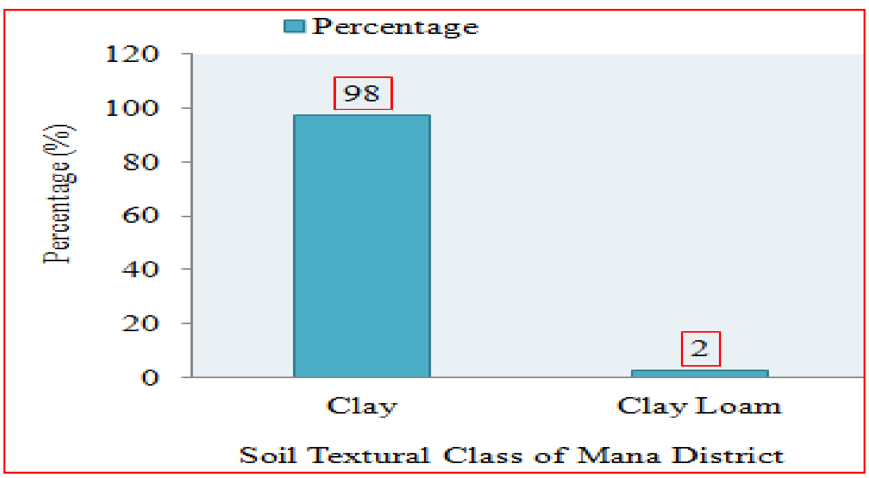


Figure 3. Soil textural classes and percentage of Mana District.

Table 2. Particle size distribution of the soils in Mana District

Texture	Observations (No.)	Particle size range (%)	
		Minimum	Maximum
Clay	125	30	69
Silt	125	9	35
Sand	125	12	43

According to Buol *et al*. (2003), high clay content is an indication of complete alteration of weatherable minerals into secondary clays and oxides. Similarly, frequent cultivation might have enhanced weathering of primary particles and contributed for the high clay fraction. On the other hand, the contents of sand in the soils were very low compared to clay and silt separates.

Soil reaction, exchangeable acidity and electrical conductivity

The results revealed that the soil reaction, pH (H_2O) of the surface soil of the district ranged from 4.1-6.2 (Table 3). Based on acidity class established by FAO (2006) the soil acidity of the study area ranged from very strongly acidic to moderately acidic. The minimum value of soil pH was observed in the higher altitude of the study area which was intensively cultivated, while the maximum value was observed in the lower altitude. Accordingly, very strongly acidic, strongly acidic, moderately acidic and slightly acidic soils were accounted for about 10, 55, 30 and 5% of the total area of the district (Figures 4 and 5).

Considering the optimum pH for many plant species to be 5.5-6.8 (Amacher *et al.*, 2007) and absence of free exchangeable Al in this range, only about 25% of the pH of the soils in the study area could be considered as suitable for most crop production (Figure 5); whereas according to critical levels adopted by EthioSIS and Tekalign (1991) at pH (1:2.5), 75% of the soils of the study area were under strongly acidic (pH $\leq$ 5.5),where the solubility of essential nutrients needed for plant growth is reduced.This could be due to high rainfall received by the area that caused leaching of bases and clay particles.Moreover, the acidic nature with low soil pH might be obtained from the entire district could be attributed to the fact that soils were derived from weathering of acidic igneous granites and leaching of basic cations such as K, Ca and Mg from the surface soil (Frossard *et al.*, 2000).

Table 3. Soil reaction (pH), electrical conductivity (EC), exchangeable acidity, organic carbon (OC) and available phosphorus (Av.P) of soils in Manna District

		Range	
Parameter	**Observations (No.)**	**Minimum**	**Maximum**
pH (H_2O)	125	4.1	6.2
EC (dS/m)	125	0.02	0.13
EA ($cmol_c kg^{-1}$)	125	0.0	3.6
OC (%)	125	1.0	5.8
Av. P (ppm)	125	0.6	21.8

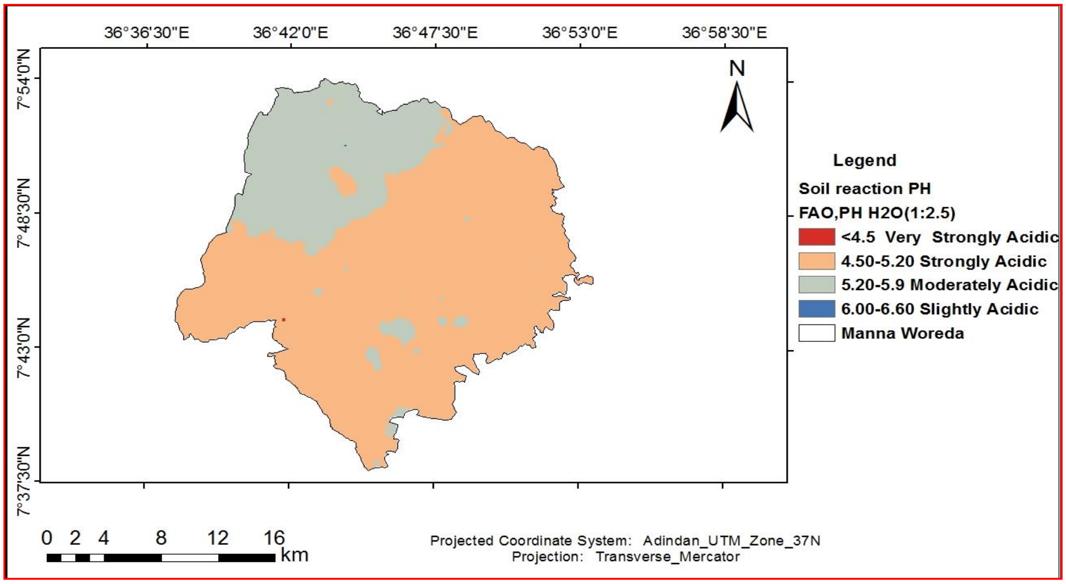


Figure 4. Map showing surface soil pH classes and status of Mana District

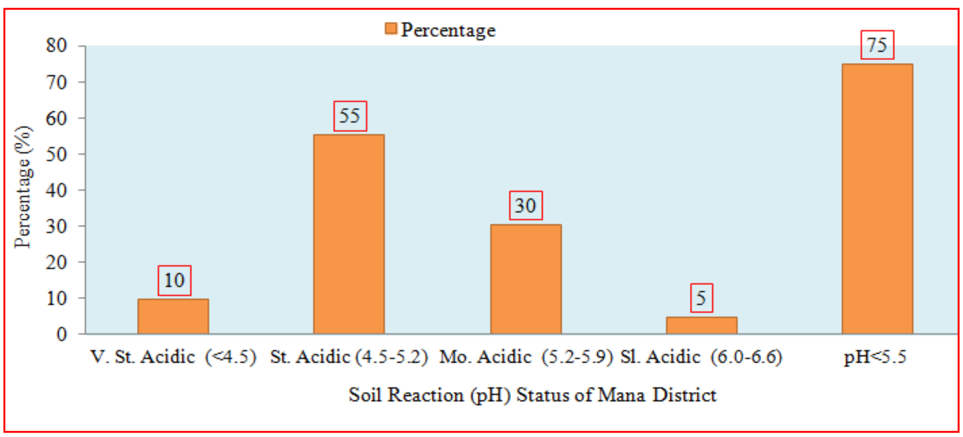


Figure 5. Proportions of soil reaction (pH) rating of Mana District

As a result this condition also usually leads to Al and Mn toxicity plus deficiency in N, P, K, Mg, Ca and various micronutrients. This has multiple implications for plant growth and other soil fertility issues including reduced response to ammonium phosphate and urea fertilizers, stunted root and plant growth due to nutrient deficiency (yields frequently reduced), increased incidence of disease, and toxicity (e.g. for Mn: black spots and streaks on leaves).

The exchangeable acidity (Al+H), on the other hand, varied from 0.0 to 3.6cmolckg^{-1} for soils with pH<5.5 and the mean value was 0.7cmolckg^{-1} of soil (Table 3 and Figure 6). Whereas, electrical conductivity (EC) values of the study area varied from 0.02 to 0.13dSm^{-1} and in accordance with the EC rating suggested by Scianna *et al*. (2007), the soils of the study area were non-saline (Table 3). Similarly, according to definition set by U.S. Salinity Laboratory Staff (1954) none of the samples were saline and the values were even lower than the suggested cut of point, 4dSm^{-1}. This is due to rainfall that significantly exceeds evapotranspiration and results in leaching of soluble ions and prevents accumulation of salt. Plants growing in these study areas do not have the problem of absorbing water because of the lower osmotic effect of dissolved salt contents.

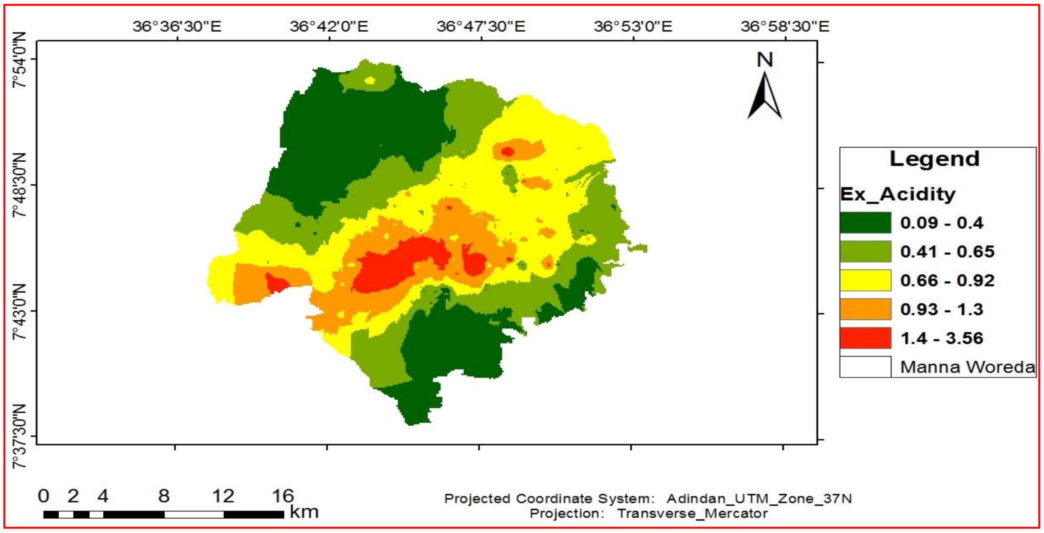


Figure 6. Map of Exchangeable Acidity (EA) of soil samples collected from Mana District

Soil organic carbon

The organic carbon (OC) content of the soil ranged from 1.0-5.8% (Table 3). Based on the rating set by Landon (2014), 4 and 66% of the soil samples collected from the district was revealed that very low (<2%) and low (2-4%) respectively, while the rest 30% showed that medium (4-10%) in their SOC contents (Figure 7). This might be due to complete removal of aboveground biomass (for energy, animal feed, construction) and limited crop rotation practice. Besides, the low to medium content of soil OC is also attributed because of the warmer climate, which enhances rapid rate of mineralization (Abayneh, 2005).

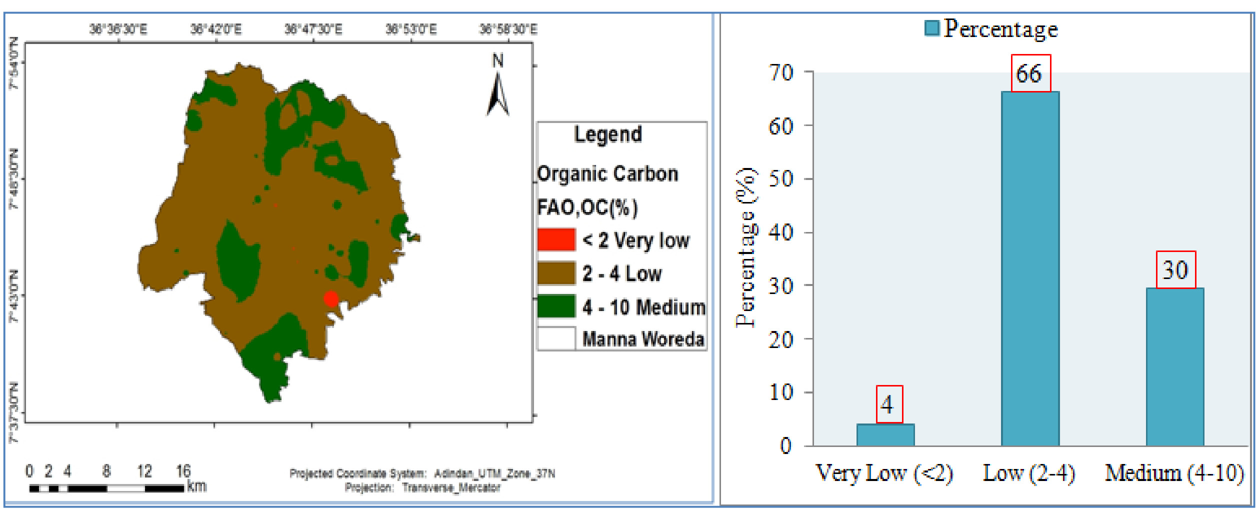


Figure 7. Map of SOC rating and proportions of Mana District

Available phosphorus

The maximum and minimum values of available P were 21.8 and 0.6ppm respectively (Table 3). According to the critical level set by FAO, (2006), from the total samples collected and predicted area, nearly 61% of available phosphorus values falls under very low (<5 $mgkg^{-1}$ whereas, the rest results showed that 26, 9 and 4% exhibited to low, medium and high rating ranges respectively (Figure 8). But according to the critical level set recently by EthioSIS (Karltun *et al.*, 2013) almost all samples collected and predicted area, available phosphorus values falls under very low category (0-15 $mgkg^{-1}$) which acounted about 96%.

Generally, the available P status of the soils in the study area was very low, and is among the factors that are highly limiting the productivity of the soils. In agreement with this observation, many researchers including (Warren, 1992; Buehler *et al.*, 2002) have also reported that soil P deficiency is a wide spread phenomenon and it is believed to be the second most important soil fertility problem throughout the world next to N and often the first limiting element in acid tropical soils.

However, the lower available P in soils of the district may be due to lower SOM status. Most plant nutrients are fixed when the soil pH is less than 5.5. In addition, iron and aluminium ions dominate the exchange sites and become active to react with phosphorus and make it insoluble

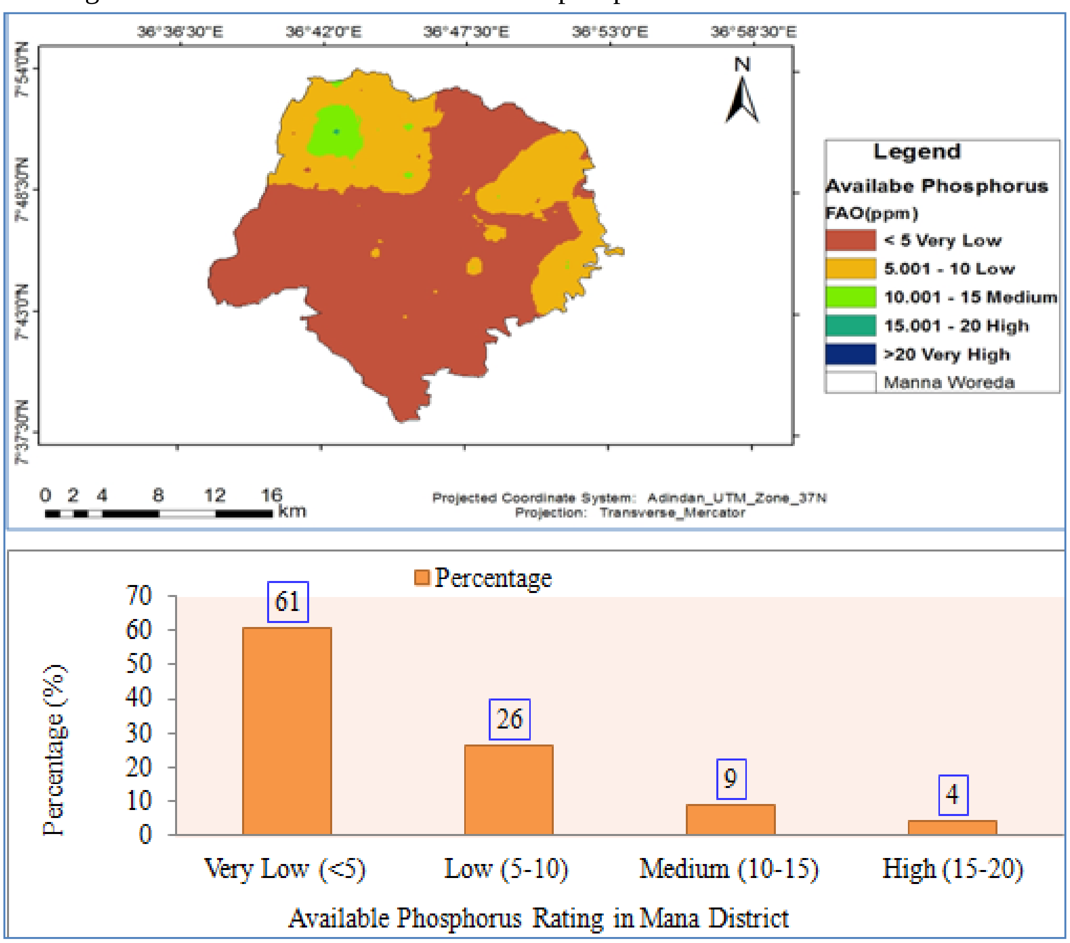


Figure 8. Map showing available P class and status by percentage in Mana District (Mesfin, 2007)

On the other hand most plant nutrients are optimally available at pH value greater than 5.5 and less than 7.5 which is also compatible to plant root growth (Tisdale *et al*., 2003). Result of this study was also consistent with that of Achalu *et al*. (2012) who observed that variations in available P contents in soils are related with the intensity of soil disturbance, the degree of P- fixation with Fe and Al ions. Similarly, Tekalign and Haque (1987) and Dawit *et al.* (2002) reported SOM as the main source of available P and the availability of P in most soils of Ethiopia decline by the impacts of fixation, abundant crop harvest and erosion.

Exchangeable bases

Generally, the maximum value of total exchangeable bases (K, Na, Mg and Ca) was 7.6cmol$_c$kg^{-1} and the minimum was 2.6cmol$_c$kg^{-1} (Table 4). Potassium is an important plant nutrient and a great deal of study has been made of the amounts believed necessary for adequate plant growth. The maximum and minimum values of exchangeable K were 3.3 and 0.1cmol$_c$kg^{-1} respectively (Table 4). The value of the measured exchangeable Na ranged of 0.0 to 2.9cmol$_c$kg^{-1} of soilindicating lower Na content of the soil and have no any adverse effect on growth of crops and physical properties of soil (Table 4). Therefore, the soil of the study area was non-saline, no soil problems with Na^+ ion consentrations (Figure 9).

Table 4. Exchangeable bases (CEC), PBS, ESP, SAR, Ca:Mg Ratio and K: Mg Ratio of Mana District

	Soil chemical properties (n = 125)										
	Exchangeable bases (cmol$_c$kg^{-1})					**PBS**	**ESP**	**SAR**	**CEC**	**Ca:Mg**	**K:Mg**
Range	**Na^+**	**K^+**	**Ca^{++}**	**Mg^{++}**	**TEB**	**(%)**		**ratio**	**(cmol$_c$kg^{-1})**	**ratio**	**ratio**
Min.	0.0	0.1	0.3	0.1	2.6	20.3	0.0	0.0	7.4	0.1	0.1
Max.	2.9	3.3	1.9	4.7	7.6	75.9	50.5	1.7	23.9	35.8	48.0

Where min = minimum, max = maximum

Exchangeable calcium (Ca^{++}) value of greater than 5cmol$_c$ kg^{-1} soil is considered to be adequate for the nutrition of most crops. The maximum and minimum values of Exchangeable Ca were 1.9 and 0.3cmolc kg^{-1} respectively (Table 4). Exchangeable magnesium which is greater than 1cmol$_c$kg^{-1} soil is believed to be adequate for plant nutrition (Metson, 1961). The amount of exchangeable magnesium reported for the soils of the study area ranged from 0.1 to 4.7cmol$_c$kg^{-1} (Table 4).

Based on the ratings seted by (FAO, 2006) 15, 21 and 59% of the total area were medium, high and very high in exchangeable K content respectively (Figure 9) whereas, about 5% of the total soil sample collected was showed that bellow medium range. According to Hazelton and Murphy (2007), the mean soil exchangeable potassium is rated as moderate to very high. Even though the highest mean value of exchangeable K were medium, there could be an increasing loss of all exchangeable cations in the study area due to continuous removal by crops without replenishment and vertical movement or leaching. However, Manbir *et al.,* (2015) reported that, soil test K alone may not be adequate to predict K response. Plants produce higher yields at a certain Ca:Mg ratio and K:Mg ratio on acidic soils which are 10:1 and 0.7:1, respectively (Loide, 2004). Noting that, for potash fertilizer application, K:Mg ratio of 0.7:1 was used as a critical point, since the amount of K was low compared to Mg in many areas, especially in the study area it was ranged from 0.1:1 to 48.0:1 (Table 4), which indicated that Mg induced K deficiency using the rating of Loide (2004). Accordingly, in the history, farmers of the area did not use K fertilizer.

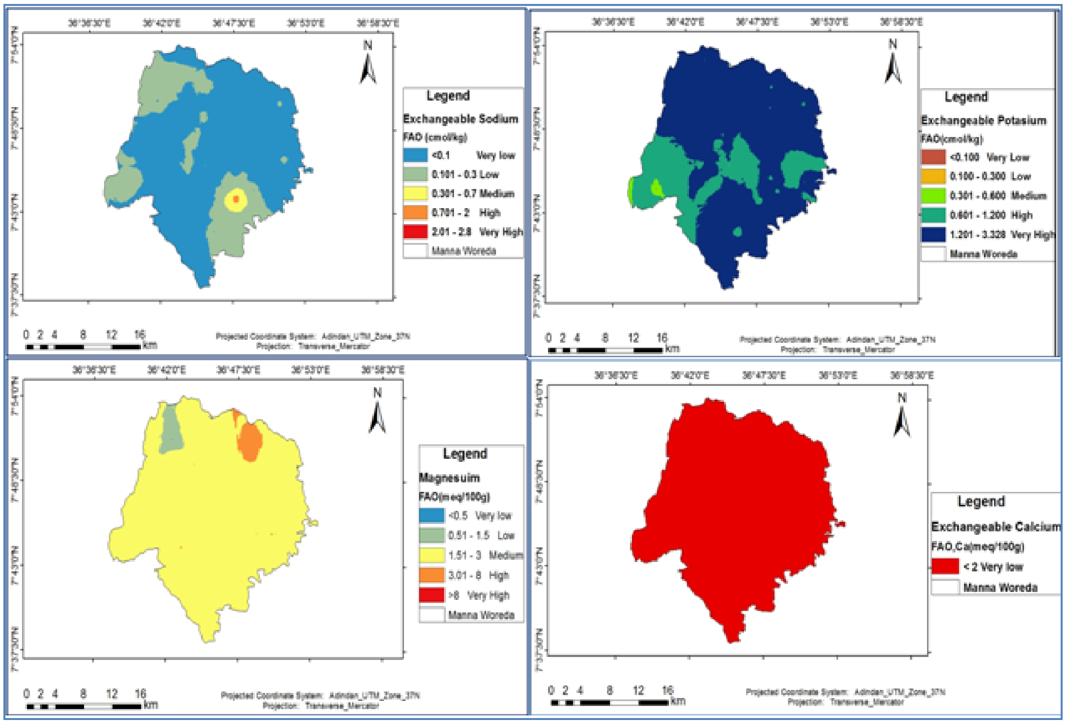


Figure 9. Map of exchangeable bases (Na, K, Mg and Ca) of Mana District

From total soil samples collected from the district showed in very low rage (<2 $cmol_c kg^{-1}$) in exchangeable Ca, which was ranged from 0.3 to 1.9$cmol_c kg^{-1}$ (Figure 9 and Table 4). According to sated standard by Hazelton and Murphy (2007), analyzed value of exchangeable calcium was rated as very low. This might be attributed to removal of this exchangeable basic cation by erosion and leaching from higher topography and their subsequent accumulation in the lower elevations.This indicates that more calcium is required as production input and the response to calcium application in form of fertilizer and lime more likely increase productivity in the study area.

The analytical values of exchangeable bases indicated that exchangeable Ca and K were dominant cations in the exchange complex (Table 4). Eckert (1987) also suggested that Ca:Mg ratio is an index appropriate to indicate the level of calcium and magnesium from crop nutrition point of view. As a rate was set up by Eckert (1987), for the whole soil samples collected from the district the minimum and maximum value of Ca:Mg ratio were 0.1 and 35.8 respectively (Table 4). From the total samples collected from the study area, nearly about 47% were deficient in Ca^{++} whereas the rest 53% fall under the low ratio between calcium and magnesium (Table 4).

Cation exchange capacity and base saturation

The maximum value of cation exchange capacity (CEC) was recorded at small part of plateau plain of the study area (Figure 10). This could be due to high accumulation of clays and organic matter at that location. In addition, most areas of the District contained CEC value at medium level for crop production. The CEC of the soils ranged from 7.4-23.9$cmol_c kg^{-1}$ in the study area respectively (Figure 10 and Table

4). As per rating by FAO (2006), the CEC value of all agricultural land of the district can be classified as moderate (61%) and low (39%) status (Figure 10).

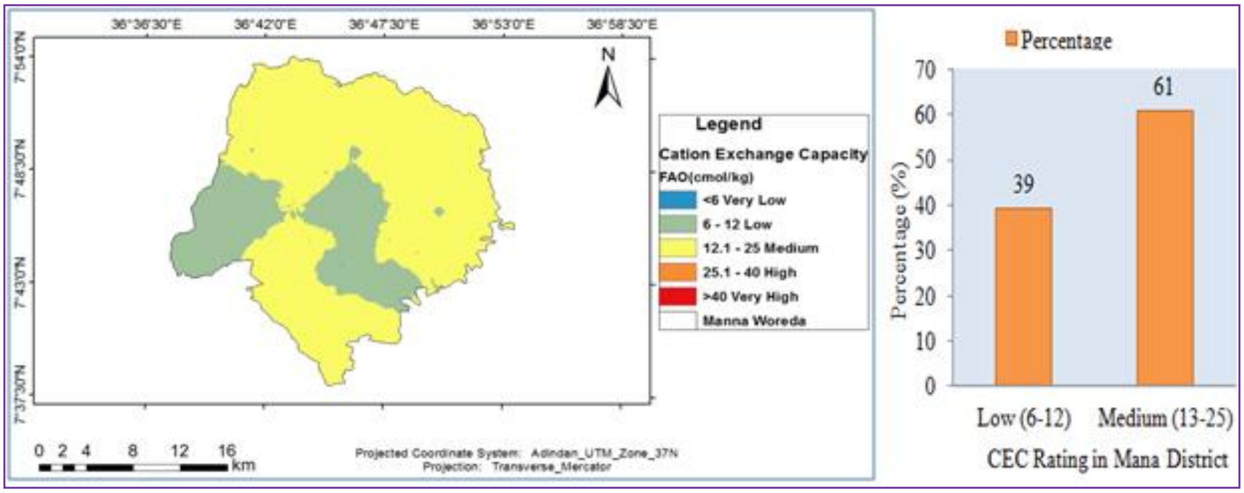


Figure 10. CEC classes and its status in soils collected from Mana District.

This result indicates that the CEC values of the district were ranged from low to medium. The relatively medium CEC values recorded may be attributed to the fact that soils with medium accumulation percent of OC. Soils with low CEC are more likely to develop deficiencies in potassium (K^{+}), magnesium (Mg^{2+}) and other cations which was susceptible to leaching while high CEC soils are less susceptible to leaching of these cations (CUCE, 2007). Generally, the soils of the study area had moderate nutrient retention and buffering capacity due to the mediumstatus of CEC.

The minimum and maximum values of percent base saturation (PBS) of the district were 8 and 100% respectively. According to the rating seted by FAO (2006), out of the total collected composite soil samples percent base saturation 34, 11, and 25% of the was categorized as very low, low, and moderate respctivily (Figure 11). These indicate that majority soils of the district were below the threshold levels which was. According to FAO (2006), soils having greater than 50% base saturation are rated as fertile and potentially productive soils.

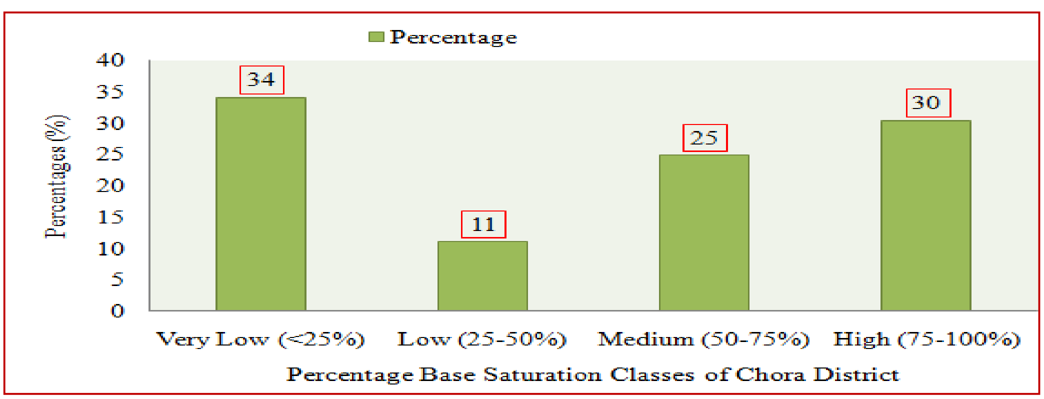


Figure 11. PBS classes and status in soils collected from Chora District

Conclusion and Recommendations

Soil fertility assessment mapping shows plant nutrient status and is useful for decision making for professionals, farmers and other stockholders on fertilizer type and rate, and agricultural liming materials. According to the results of this assessment, some required soil chemical, physical, and biological properties were varied widely within the fields in the district. About 75% of the study area was strongly acidic (pH ≤ 5.5), about 70% low in soil organic carbon (<4%), nearly 87% of the district available phosphorus was below critical level (<10ppm), and Calcium status of all soil samples was low ranging from 0.3-3.2$cmol_c kg^{-1}$. Based on these results, recommendations for decision makers, researchers, agricultural experts, and other stakeholders are to use these soil fertility maps as reference for soil information source in the district. Agricultural lands of the district are highly affected by depletion of organic carbon and plant nutrients, soil fertility improvement should be priority area for researchers, experts and development agents, and others in increasing crop productivity and production. Further ISFM intervention technologies are critically needed for sustainable soil resource management and sustrainable food and nutrition security of people in the study area.

Acknowledgment

The authors acknowledge Oromia Agricultural Research Institute (IQQO) for financial, logistic and material support during the soil fertility assessment; thank all researchers, laboratory technicians and supportive staff of Bedele Soil Research Center for providing the necessary attention and follow up during the assessment; appreciate surveyors participated during soil samples collection.

References

Amare H, Priess J, Veldkamp E, Teketay D, Lesschen JP, *et al.*, (2005). Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances. Agriculture, Ecosystem and Environment, 108(1): 1-16.

Bationo A, Hartemink A, Lungu O, Naimi M, Okoth P, *et al*. (2006). African Soils: Their productivity and profitability of fertilizer use. Background paper prepared for the African fertilizer summit Nigeria.

Bellete T (2014). Fertility mapping of soils of Abay-Chomen District, Western Oromia, Ethiopia. MSc Thesis, Haramaya University, Ethiopia.

Burrough PA, Rachael A, McDonnell (1998). Principles of Geographical Information Systems. Oxford University Press, New York, USA.

Cao SK, Chena KL, Cao GC, Zhang L, Ma J, *et al.*, (2011). The Analysis of Characteristic and Spatial Variability for Soil Organic Matter and Organic Carbon around Qinghai Lake. Procedia Environmental Sciences 10(A): 678 -684.

EthioSIS (Ethiopia Soil Information System), (2014). Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia. Ethiopia. http://www.ata.gov.et/ highlighted-deliverables/ethiopian-soil-information-systemethiosis

Flower M, Weisz R, White G (2005). Yield-based management zones and grid sampling strategies: Describing soil test and nutrient variability. Agronomy Journal 97(3): 968-982.

Giday O, Gibrekidan H, Tareke B (2015). Soil Fertility Characterization in Vertisols of Southern Tigray, Ethiopia, Adv plants agric res 2(1): 00034.

Habtamu A, Heluf G, Bobe B, Enyew A (2014). Fertility Status of Soils under Different Land uses at Wujiraba Watershed, North-Western Highlands.

Habte M, Gebrekidan H, Wasie H (2013). Decompostion and nutrient release of selected green manure species at different stages of growth on Alisols at Areke, Sorthern Ethiopia. International Journal of Natural Sciences Research (5): 30-42.

Huang B, Sun W.X, Zhao Y.C, Zhu J, Yang R.Q, *et al*. (2007). Temporal and spatial variability of soil organic matter and total nitrogen in an agricultural ecosystem as affected by farming practices. Geoderma 139(3-4): 336-345.

Hurni H, Bruno M (1990). Degradation and conservation of the soil resources in the Ethiopian highlands. African Mountains and Highlands: Problems and Perspectives, USA, pp. 51-64.

John D.T.K, Waddington S.R, Snapp S.S, Jones R.B, Blackie M, *et al*., (1995). Soil Fertility Management Research for the Smallholder Maize-Based Cropping Systems of Southern Africa: A Review. Network Research Working Paper Number Soil Fertility Network for Maize-Based Cropping Systems in Countries of Southern Africa. CIMMYT Maize Programme. Zimbabwe: CIMMYT.

Laekemariam F, (2015). Soil spatial variability analysis, fertility mapping and soil plant nutrient relations in Wolaita zone, Southern Ethiopia. Haramaya University Ethiopia.

Lin J.S, Shi X.Z, Lu X.X, Yu D.S, Wang H.J, *et al*., (2009). Storage and spatial variation of phosphorus in paddy soils of China. Pedosphere 19(6): 790-798.

Liu Z.P, Shao M.A, Wang Y.Q (2013). Spatial patterns of soil total nitrogen and soil total phosphorus across the entire Loess Plateau region of China. Geoderma 197-198: 67-78.

Li X.G, Li F.M, Zed R, Zhan Z.Y, Singh B, *et al*., (2007). Soil physical properties and their relations to organic carbon pools as affected by land use in an alpine pastureland. Geoderma 139(1-2): 98-105.

Maccarthy, D.S., Agyare, W.A., Vlek, P.L.G. and Adiku, S.G.K., 2013. Spatial variability of some soil chemical and physical properties of an agricultural landscape. *West African Journals Appl Ecol*, *21*, pp.47-61.

Olsen, S.R., C.V. Cole, F.S. Watanable, L.A. Dean .1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. USDA Circular. 939:119.

Roy R.N, Misra R.V, Lesschen J.P, Smaling E.M (2003). Assessment of Soil Nutrient Balance: Approaches and Methodologies. FAO Fertilizer and Plant Nutrition Bulletin 14 Rome.

Rowell, D. L. 1994. Soil science: Methods and applications. Addison Wesley Longman Limited. England. 350.

Samira I, Ahmed D, Lhoussaine M (2014). Soil Fertility Mapping: Comparison of Three Spatial Interpolation Techniques. International Journal of Engineering Research and Technology 3(11): 134-143.

Sanchez P.A, Jama B.A, Niang A.I, Palm CA (2000). Soil fertility, small farm intensification and the environment in Africa. In Lee DR & Barrett CB (Eds.), Tradeoffs or Synergies, CAB International, Wallingford, UK, pp. 327-346.

Santra P, Chropra UK, Chakraborty D (2008). Spatial variability of soil properties and its application in predicting surface map of hydraulic parameters in an agricultural farm. 95 (7): 937-945.

Song G, Zhang L, Wang K, Fang M (2013). Spatial simulation of soil attribute based on principle of soil science. IEEE.

Tesfahunegn G.B, Tamene L, Vlek P.L.G (2011). Catchment-scale spatial variability of soil properties and implications on site-specific soil management in northern Ethiopia. Soil and Tillage Research 117: 124-139.

Tilahun G (2007). Soil fertility status as influenced by different land uses in Maybar areas of South Wello Zone, North Ethiopia. Haramaya University, Ethiopia.

Walkley, A., and C. A., Black, 1934.An examination of different methods for determining Soil organic matter and the proposed modification by the chromic acid titration method. Soil Sci. J. 37: 29-38.

Weindorf D.C, Zhu Y (2010). Spatial variability of soil properties at Capulin Volcano, Mew Mexico, USA: implications for sampling strategy. Pedosphere 20(2): 185-197.

Wondwosen Tene, Sheleme Beyene (2011). Identification of growth limiting nutrient(s) in Alfisols: soil physico-chemical properties, Nutrient Concentration and Biomass Yield of Maize. American Journal of plant nutrient and fertilizer technology 1(1): 23-35.

Verma V.K, Patel L.B, Toor G.S (2005). Spatial distribution of macronutrients in soils of arid tract of Punjab, India. International Journal of Agriculture and Biology 7(2): 295-297

Soil Fertility Management Research

Soil Test Crop Response Based Phosphorous Calibration Study on Maize in Chora District, West Oromia, Ethiopia

Dagne Chimdessa and Bati Dube
Bedele Soil Research Center, P.O.Box 167, Bedele, Ethiopia

Corresponding author: dagnechim@gmail.com

Abstract

Sustainability of agricultural soils is essential to enhancing crop production on sustainable basis. On-farm phosphorus calibration study was conducted in Chora District of Buno Bedele Zone of Oromia during the main cropping seasons 2014-2016. The objectives were to determine phosphorus critical level and P-requirement factor for maize using hybrid variety BH-661. Factorial combination of four levels of N (0, 46, 92 and 138 kg N/ha) and four levels of P (0, 20, 40 and 60 kg P/ha) were arranged in the first year to determine N rate. Thenafter seven levels of P (0, 10, 20, 30, 40, 50 and 60 kg P/ha), and 92 kg N /ha in the second and third years were tested to determine phosphorus critical level and requirement factor and laid out in RCBD with three replications. Maize grain yield was analyzed using SAS software. Composite surface soil samples (0-20 cm depth) were collected from each experimental site before planting for laboratory analysis of selected soil chemical properties. Similarly, after 21 days of planting intensive composite soil samples were collected from each experimental plot to analyze available P. The results of the study revealed that soil reaction pH (H_2O) values were strongly acidic ranged from 4.25-5.06, very low available P from 0.78-4.60 ppm. The highest grain yield (7449 kg ha^{-1}) was obtained from 138 kg N ha^{-1}, while the lowest (1366 kg ha^{-1}) was from the control (without fertilizer). However, fertilizer rates of 138 kg N ha^{-1} and 92 kg N ha^{-1} showed no significant difference in grain yield. Therefore, the result showed that nitrogen rate 92 kg N ha^{-1}, P-critical level (8.5 ppm) and P-requirement factors (6.64) were determined for maize production in Chora District. Thus, maize producers are advised to use soil test crop response based phosphorus recommendation to increase maize productivity and production in the district.

Keywords: *Maize variety BH-661, nitrogen, phosphorus, P critical and requirement*

Introduction

In countries with a capacity for excess food production, maintenance of soil fertility is a requirement for both economic and environmental viability of their farming system, People are dependent on soils and, conversely, good soils are dependent on people and the uses they make of the land (Brady and Weil, 2002). Crop yields in the developed world are high and agricultural soils have high fertility status due to intensive use of fertilizers (Mengel and Kirkby, 1996). This implies that using chemical fertilizer plays significant role in increasing food production to meet the demand of the growing world population. On the other hand, sub Saharan Africa is characterized by diverse agricultural systems that are typically low input based subsistence farming systems (Bekunda *et al*., 1997). These soils have been sustaining agricultural production for centuries; as a result, their native fertility has been extremely low (Wong *et al.*, 1991). Soil fertility replenishment has, therefore, been singled out as the necessary, but not sufficient condition for sustainable development in Africa (Sanchez and Leakey, 1997)

Soil fertility depletion presents a major challenge to bring about increased and sustainable productivity in order to feed the ever increasing population of the country. The loss of soil fertility from continual nutrient mining by crop removal without adequate replenishment, combined with imbalanced plant nutrition practices, has posed a serious threat to agricultural production (FAO, 2006). The secret of ensuring food security for the ever increasing world population is strongly linked to the productivity of soils (Wakene, 2001). Quinenes *et al.* (1992) also stated that unless something is done to restore soil fertility first, other efforts to increase crop production would end up with little success. Kelsa *et al. (*1992) reported that using chemical fertilizers can increase yield in Ethiopia.

In Ethiopia, maize is first in productivity and second in area coverage after *teff* (CSA, 2010). Research results in high potential maize growing areas are high. However, yield levels obtained by small scale farmers remained stagnant despite the availability of improved varieties even in high maize growing potential areas of western Oromia (Benti, 1993). One of the main causes for this discrepancy is low use of external inputs, leading to negative balances for N, P and K (Rhodes *et al.*, 1996).

Information on soil fertility status and plant nutrients requirement of a given area has vital role in enhancing crop production and productivity on sustainable basis. Nevertheless, little information is available in Oromia in general and Buno Bedele Zone in particular on essential plant nutrients requirement for maize production. The prevailing blanket fertilizer rate recommendation throughout the country on all soil types and agro ecological zone justifies the existence of little information on the fertility status of soils. This calls for assessment of both agronomic and determination of nutrient rate application to increase maize productivity to feed the rapidly growing population. Therefore the objectives of the study were to assess and determine P critical level and requirement factor; and give guidelines and phosphorus recommendations for maize production in Chora district.

Materials and Methods

Description of the study area

The trial was conducted on-farm in Chora District, Buno Bedele Zone of West Oromia, located 536 km west of Addis Abeba along the main road from Bedele to Metu at $08^{0}21'$ to $08^{0}31'$ N latitude and $036^{0}05'$ to $036^{0}13'$ E longitude. The mean annual rainfall and temperatures of the district ranged from 1000-1500 mm, 15-31^{o}C, respectively. Altitude ranged from 1000-2060masl and soil type of the district is dominated by Nitisols. The economy of the area is based on mixed crop-livestock farming system. Dominant crops are cereals, teff, maize, sorghum and wheat, horticultural crops, coffee, avocado and spices, and others.

Soil sampling and analysis

Twenty sites were selected and Composite surface soil samples (0-20 cm depth) were collected from each experimental sites before planting to determine soil pH (H_2O) with 1:2.5 soil to water ratio, and available P (Olsen method). Similarly, after 21 days of planting, intensive composite soil samples were collected from each experimental plot to analyze available P, which serves as to determine P critical level and requirement factor

Treatments, experimental designs and procedures

On-farm study was conducted in the district during the main cropping seasons of 2014-2016 to determine P-critical level and requirement factor for phosphorus recommendation of hybrid maize variety BH-661 for Chora district. Factorial combination of four levels of N (0, 46, 92 and 138 kg N/ha) and four levels of P (0, 20, 40 and 60 kg P/ha) were laid out in RCBD with three replications in the first year to determine N rate. Moreover, single factor of seven levels of P (0, 10, 20, 30, 40, 50 and 60 kg P/ha) and 92 kg N/ha in the second and third years to determine Phosphorus critical level and requirement factor were laid out in RCBD with three replications. Maize population per hectare was 50,000. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times.

The gross plot size was (5m x6.4 m) with (5m x 4.8 m.) net plot area. DAP and TSP was applied at planting. Nitrogen was applied at 30 days after emergency in the form of urea. During the different growth stages of the crop, all the necessary field management practices were carried out as per the practices followed by the farming community. Grain yield was analyzed using SAS computer package version 9.1 and LSD was used for mean separation

Determination of phosphorus critical level

Phosphorus critical level was determined following the Cate-Nelson graphical method where soil P values were put on the X-axis and the relative yield values on the Y-axis (yield x 100/maximum yield). The Cate-Nelson graphical method is based on dividing the Y-X scatter diagram into four quadrants and maximizing the number of points in the positive quadrants. The positions of the lines on the overlay with respect to the axes of the graph were transferred to the graph by making marks on the edges of the graph. The two intersecting lines were then drawn lightly on the graph. The point where the vertical line crosses the X-axis is defined as 'critical soil test level'

Determination of phosphorus requirement factor

Phosphorus requirement factor was calculated using available P values in soil samples collected and analyzed from each unfertilized and fertilized experimental plots, after that the relation between each fertilizer rate and averaged corresponding soil test P value for each fertilizer rates was calculated..

Results and Discussion

Soil reaction (pH) and available phosphorus

The pH (H_2O) values of the soil samples collected before planting were ranged from (4.25-5.06) (Table 1). Accordingly, the soils were strongly acidic in reaction (FAO, 2008). Continuous cultivation and long-term application of inorganic fertilizers lower soil pH and aggravate the losses of basic cations from highly weathered soils (Mokwunye *et al*. 1996). The result showed that soil pH affects maize production which is less than the maize requirement proposed (FAO, 2006). Available Phosphorus (Olsen method) collected before planting were ranged from (0.78 *to* 4.60) ppm (Table 1). The available P contents of the soil were very low (Olsen *et al.*, 1954). The low contents of available P observed in the soil of the study areas are in agreement with the results reported by (Mesfin, 1998).

Table 1. Soil pH and initial available phosphorus status in soils before planting in Chora District

Site	pH (H_2O)	Available P (ppm)
1	4.71	1.938
2	4.42	2.878
3	4.36	1.468
4	4.88	0.888
5	4.33	1.316
6	4.75	1.988
7	4.90	2.671
8	4.88	0.784
9	4.91	4.206
10	5.06	1.205
11	4.68	2.773
12	4.45	1.647
13	4.25	1.374
14	4.40	2.178
15	4.76	2.714
16	4.45	3.030
17	4.25	3.491
18	4.77	4.601
19	4.35	1.927
20	4.45	1.055
Average		**2.21**

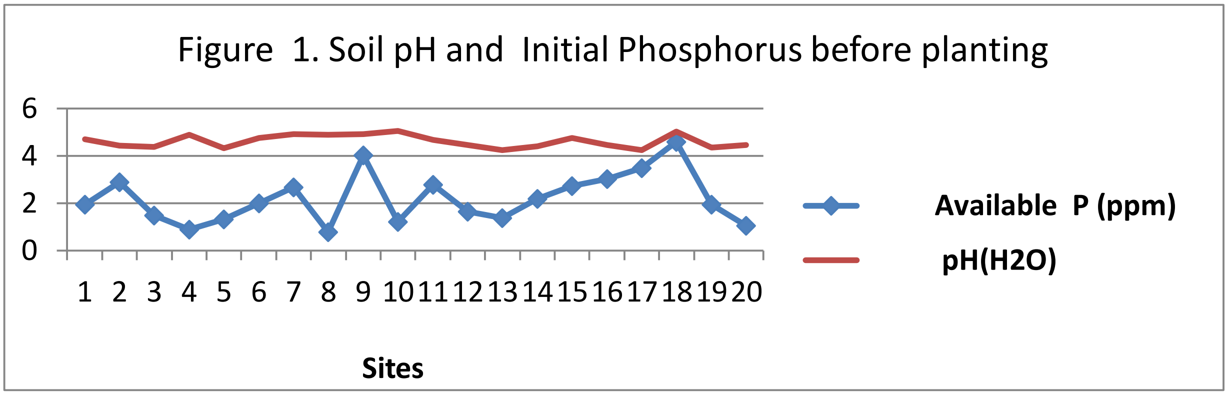


Figure 1. Soil pH and Initial Phosphorus before planting

In general, while available P values were oscillated between one and three, soil pH values were between four and five (figure 1). This indicated that at low soil pH (acidic media) phosphorus is not available to plants. Ethiopian agricultural soils particularly the Nitisols and other acid soils have low available P content due to their inherently low P content, high P fixation capacity, crop harvest and soil erosion (Yihenew, 2002; Dagne, 2012).

Nitrogen fertilizer determination

The interaction effect of N and P fertilizers was significant ($P \leq 0.05$) on maize grain yield. These results agree with (Orkaido, 2004). The highest grain yield (7449 kg ha^{-1}) was obtained from applicationof 138 kg N ha^{-1} and 60 kg P ha^{-1} , whereas the lowest (1366 kg ha^{-1}) was from the control plot (without fertilizer) (Table 2). However, rates of 138 kg N ha^{-1} and 60 kg P ha^{-1}, 138 kg N ha^{-1} and 40 kg P ha^{-1}), and 92 kg N ha^{-1} and 40 kg P ha^{-1} were not significantly different (Table 2). The level of N was changed from 138 kg N ha^{-1} to 92 kg N ha^{-1} wthout significant yield difference among maize grain yield. Therefore, 92 kg N ha^{-1} was recommended for maize production in Chora District. Nitrogen status of soil has a major role in maintaining highest maize grain yield (Akmal *et al*., 2010). N plays an important role in crop life. It is one of the most important nutrients needed by plants in large quantities. Its availability in sufficient quantity throughout the growing season is essential for optimum maize yield. It also mediates the utilization of phosphorus, potassium and other elements in plants (Brady and Weil, 2002). The optimal amounts of these elements in the soil cannot be utilized efficiently if nitrogen is deficient in plants.

Table 2. Interaction effect of N and P fertilizers on maize variety BH-661 grain yield (kg ha^{-1}) in Chora District in 2014 cropping season

	P rate (kg ha^{-1})				
N rate (kg ha^{-1})	0	20	40	60	**Mean**
0	1366^{i}	2519^{fgh}	3005^{fg}	3412^{f}	2575
46	2361^{gh}	5134^{e}	5764^{de}	6264^{cd}	4881
92	1884^{hi}	5917^{cde}	6759^{abc}	6398^{bcd}	5240
138	16481^{hi}	6218^{cd}	7301^{ab}	7449^{a}	5654
Mean	1815	4947	5707	5881	
LSD			968		
CV (%)			32.1		

Note: Means with the same letter are not significantly different at $P < 0.05$

Phosphorus critical level and requirement factor

The study result showed that determined P-critical level and P-requirement factor for maize in Chora District was 8.5 ppm (Figure 2) and 6.64(Table 1), respectively.

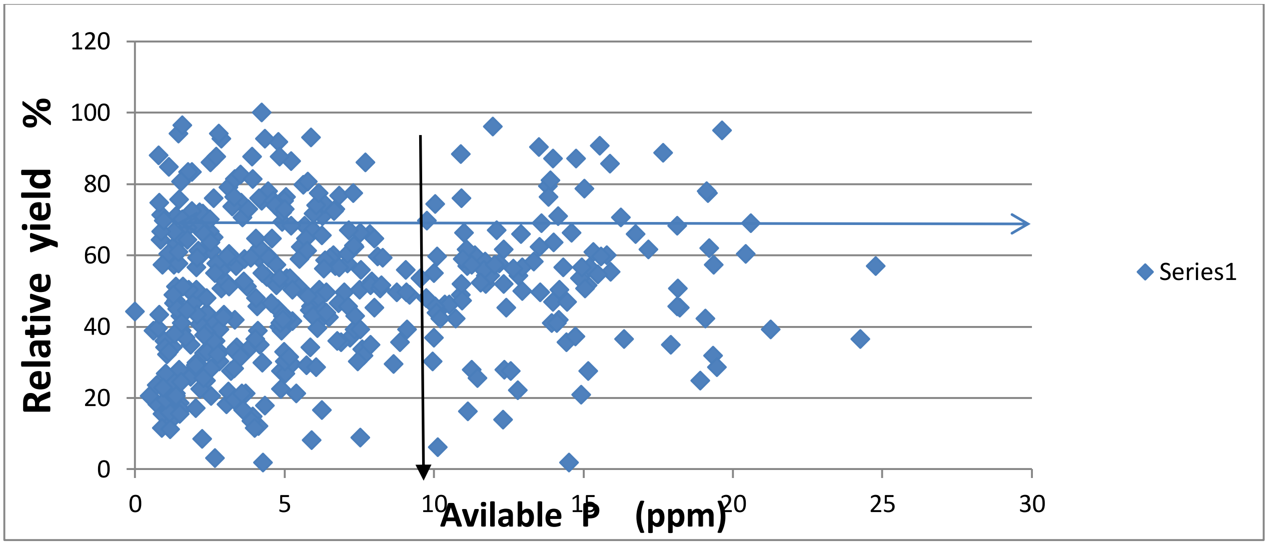


Figure 2. Phosphorus critical level for maize in Chora District

Table. 3. Phosphorus requirement factor for maize in Chora District

Fertilizer P applied (kg P/ha)	Olsen P (ppm)	P- increase over the control	P- requirement factor (Pr)*
0	2.21		
10	4.18	1.97	5.08
20	5.16	2.95	6.78
30	7.17	4.96	6.05
40	8.27	6.06	6.60
50	8.66	6.45	7.75
60	10.13	7.92	7.58
Average			**6.64**

Conclusion and Recommendations

The soil reaction pH (H_2O) of the study area was strongly acidic and very low available phosphorus in the soils. The highest mean grain yield was resulted from application of nitrogen rate (138 kg N ha^{-1}), but no significant yield difference with 92 kg N ha^{-1}. Hence phosphorus critical level (8.5 ppm), P-requirement factor (6.64) and nitrogen rate (92 kg N ha^{-1}) were recommended for maize production in Chora District. Therefore awareness creation and promotion of soil test crop response based P recommendation should be made for adoption of the technology by farmers through verification and demonstration. Moreover, to improve the current soil fertility status of the study area, integrated soil fertility management including soil amendment with lime, crop rotation and others are advised to be used to improve the current depletion of soil fertility condition in the district.

Acknowledgment

The authors would like to thank Oromia Agricultural Research Institute for finance support and Bedele Soil Research Center for provision of facility for the research work.

References

Akmal, M., H.-Ur-Rehman, Farhatullah, M. Asim and H. Akbar, 2010. Response of Maize Varieties to Nitrogen Application for Leaf Area Profile, Crop Growth, Yield and Yield Components. *Pakistan Journal of Botany*, 42(3): 1941-1947.

Bekunda, M.A., A. Bationo and H. Ssali, 1997. Soil fertility management in Africa: Areview of selected research trials. pp. 63-79. In: Buresh, R.J., P.A. Sanchez and F. Calhoun Replenishing soil fertility in Africa. SSSA. Special publication No. 51. Madison, WI: SSSA.

Benti Tolessa, 1993.The need and objective of the 1st National Maize Workshop. *In: Proceed ings of the 1st National Maize Workshop of Ethiopia*. 5-7 May, 1992, IAR and IMWIC, Addis Ababa, Ethiopia.

Brady, N. C. and R. R. Weil, 2002. The Nature and Properties of soils (13thed). Pearson Education, Asia. 960p.

CIMMYT ,1988. From Agronomic Data to Farmer Recommendation: An Economics Training Manual .Completely Revised edition. Mexico , DF.

CSA (Central Statistical Agency), 2010.Agricultural Sample Survey for the 2009/2010 crop season.Volume II Report on Area and production of Crops for Private Peasant Holdings (Meher Season) Statistical Bulletin 446.FDRE/CSA, Addis Ababa, Ethiopia.

Dagne Chimdessa, 2012, Soil Characterization and Evaluation of Blended Fertilizers with and without Copper and Zinc for Maize (*Zea mays L.*) Production on Nitisols of Gobu Seyo District of East Wollega Zone, Ethiopia. MSc Thesis. Haramaya University, Ethiopia. 93p.

FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16. FAO, Rome.

FAO, 2008.Efficiency of soil and fertilizer phosphorus use Reconciling changing concepts of soil phosphorus behavior with agronomic information. Bulletin 18

Kelsa Kena, Tadesse Yoannes and Tesfa Bogale, 1992. Influence of fertilizer and its management practices on maize grain yields in major maize producing areas of Ethiopia. *In: proceedings of the first national maize work shop of Ethiopia*. IAR (Institute of Agricultural Research), Ethiopia.

Mengel, K. and E. A. Kirkby, 1996. Principles of plant nutrition. Panimo published corporation, New Delhi, India.520p.

Mesfin Abebe, 1998. Nature and management of Ethiopian soils. Alemaya University, Ethiopia. 272p.

Mokwunye, A.U., A. de Jager and E.M.. Smailing, 1996. Restoring and maintaining the productivity of West Africa Soils: Key to sustainable development. International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama. 94p.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available pho sphorous in soils by extraction with sodium bicarbonate. *USA Circular J.* 939: 1-19.

Orkaido Olte,2004. Effects of nitrogen and phosphorus fertilizers on yield and yield Components of maize (*Zea mays* L.) On black soil of regede konso. Msc. Thesis, the School of Graduate Studies Alemaya University

Quinenes, M., A. Foster, D. Akibo and N.P. Siclima, 1992. Methodology used by SG 2000 Project in Africa for transfer of improved production technologies to small scale farmer. pp. 149-153.*In: Proceeding of the First National Maize Workshop of* Ethiopia, Addis Ababa.

Rhodes, E., A. Bationoa, E A.. Smaling and A. Viskerc, 1996. Nutrient stocks and flows in West African soils. Pp: 22-32. In: AU MokWuange,A.de Jager and E. M. A. Smaling (eds). *Key to sustainable development*.

Sanchez, A. P. and R.B. Leakey, 1997. Land use transformation in Africa: three determinants for balancing food security with natural resource utilization. *Agron J.* 7: 15-23.

Wakene Negassa, 2001. Assessment of Important Physico-Chemical Properties of District Udalf (District Nitosols) Under Different Management Systems in Bako Area,Western Ethiopia. MSc Thesis. Alemaya University, Ethiopia. 93p.

Wong, M.T., A.Wild and A.V.Mokwunye, 1991. Overcoming soil nutrient constraints to crop production in west Africa: importance of fertilizers and priorities in soil fertility research. *Fert. Res. J.* 29:45-54.

Yihenew Gebreselssie, 20002. Selected chemical and physical characteristics of soils of Adet Research Center and its testing sites in Northwestern Ethiopian. Society of Soil Science. *Ethiopian J, Natura. Resource.* 4: 199-215.

Soil Test Crop Response Based Phosphorous Calibration Study on Bread Wheat in Chora District of Buno Bedele Zone, West Oromia, Ethiopia

Dagne Chimdessa and Alemayehu Abdeta

Bedele Soil Research Center, P.O.Box 167, Bedele, Ethiopia

Corresponding author: dagnechim@gmail.com

Abstract

Phosphorus calibration study was conducted in Chora District of Buno Bedele Zone of Oromia during the main cropping seasons, 2014-2016. The aims of the study were to determine phosphorus critical level and P-requirement factor for phosphorus recommendation of bread wheat using Digalu variety. Factorial combination of four levels of N (0, 46, 92 and 138 kg N/ha) and four levels of P (0, 20, 40 and 60 kg P/ha) were used in the first year to determine N rate. Seven levels of P (0, 10, 20, 30, 40, 50 and 60 kg P/ha) and 138 kg N /ha in the second and third years were used for P calibration to determine P-critical level and P-requirement factor in RCBD with three replications. Wheat grain yield was analyzed with SAS software. Composite surface soil samples (0-20 cm) were collected from each trial site before planting for laboratory analysis of selected soil chemical properties. After 21 days of planting intensive composite soil samples were collected from each plot to analysis available P content in the soil. The results of the study revealed that the soil reaction pH (H_2O) values were strongly acidic ranged from 4.20-5.27; very low available P from 0.62-3.01 ppm. The highest grain yield (3083 kg ha^{-1}) was from the application of 138 kg N ha^{-1}, while the lowest yield (931kg ha^{-1}) was from the control (without fertilizer). The results showed that nitrogen rate (138 kg N ha^{-1}), P-critical level (3.8 ppm) and P-requirement factor (30.28) were determined for bread wheat production in Chora District. Therefore, producers in the district are advised to use soil test crop response based phosphorus recommendation to increase productivity and production of bread wheat in the district.

Keywords: *Bread wheat, nitrogen, phosphorus, P critical and P-requirement factor*

Introduction

Wheat is the leading grain and most important food crop. Its importance derives from the properties of wheat gluten, a cohsive network of touch endosperm proteins that stretch with the expansion of fermenting dough, yet coagulates and holds together when heated to produce a "risen" loaf of bread (Poehlman and Sleper, 1995). Wheat is produced across a wide range of soil conditions, although it is best adapted to the fertile well drained silt and clay loam soils (Onwueme and Sinha, 1999). It is one of the most important small cereal crops in Ethiopia widely cultivated in wide range of altitudes.

Soil degradation and depletion of soil nutrients are among the major factors threatening sustainable cereal production in the Ethiopian highlands. Wheat production in the country is adversely affected by low soil fertility and suboptimal use of mineral fertilizers in addition to diseases, weeds, erratic rainfall distribution in lower altitude zones, and water-logging in the Vertisol areas (Amanuel *et al*., 2002).

Soil fertility depletion presents a major challenge to bring about increased and sustainable productivity in order to feed the ever increasing population of the country. The loss of soil fertility from continual nutrient mining by crop removal without adequate replenishment, combined with imbalanced plant nutrition practices, has posed a serious threat to agricultural production (FAO, 2006). The secret of ensuring food security for the ever increasing world population is strongly linked to the productivity of soils (Wakene, 2001). Quinenes *et al.* (1992) also stated that unless something is done to restore soil fertility first, other efforts to increase crop production would end up with little success. Kelsa *et al. (*1992) reported that using chemical fertilizers can increase yield under Ethiopian.

Soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops. It is widely believed that economic optimum fertilizer application can only be achieved by developing appropriate fertilizer recommendation that takes into consideration the nutrient status of individual field. Currently there are no site-specific fertilizer recommendations for the different soil-crop climatic conditions. Understanding soil fertility status and plant nutrients requirement of a given area has vital role in enhancing crop production and productivity on sustainable basis. Nevertheless, little information is available in Oromia in general and Buno Bedele Zone in particular on essential plant nutrients requirement for wheat production. The prevailing blanket fertilizer rate recommendation throughout the country on all soil types and agro ecological zone justifies the existence of little information on the fertility status of Ethiopia's soils. This situation calls for assessment of both agronomic and nutrient rate determination is very important to increase crop productivity and production to feed the rapidly growing population. Therefore the objectives of the study were to assess and determine P critical level and P-requirement factor; and give recommendations and guidelines of phosphorus fertilizer for bread wheat production in Chora District.

Materials and Methods

Description of the study area

The trial was conducted on-farm in Chora District, Buno Bedele Zone, West Oromia, located 536 km west of Addis Abeba along the main road from Bedele to Metu between $08^0 21'$ to $08^0 31'$ N latitude and $036^0 05'$ to $036^0 13'$ E longitude. The mean annual rainfall and temperatures of the district ranged from 1000-1500 mm, and 15-31ºC, respectively. Altitude range is from 1000-2060masl and soil type of the district is dominated by Nitisols. The economy of the area is based on mixed cropping system and livestock raring agricultural productions system among, which dominant crops (teff, maize, sorghum and wheat), horticultural crops (coffee, avocado and spices).

Soil sampling and analysis

The trial was conducted on farmers' fields in the district. Twenty sites were selected and composite surface soil samples (0-20 cm) were collected from each site before planting to determine soil pH (H_2O) with 1:2.5 soil to water ratio, and available P (Olsen method). Similarly, after 21 days of planting, intensive composite soil samples were collected from each plot to analyze available P content in the soils, which serves to determine P critical level and P-requirement factor.

Treatments, experimental designs and procedures

On-farm trial was conducted in the district during the main cropping seasons, 2014-2016 to determine P-critical level and P-requirement factor for P rate recommendation for bread wheat using Digalu variety. Factorial combination of four levels of N (0, 46, 92 and 138 kg N/ha) and four levels of P (0, 20, 40 and 60 kg P/ha) were arranged in RCBD with three replications in the first year to determine N rate. Seven levels of P (0, 10, 20, 30, 40, 50 and 60 kg P/ha) and 138 kg N/ha were applied in the second and third years to determine P critical level and P-requirement factor. The experimental fields were prepared by using oxen plow in accordance with conventional farming practices followed by the farming community in the area where, the fields were plowed four times. The gross plot size was 5m x4.8 m with 5m x 3.2 m. net plot. DAP and TSP was applied at planting. Nitrogen was applied at 30 days after emergency in the form of urea. During the different growth stages of the crop, all the necessary field management practices were carried out as per the practices followed by the farming community. Grain yield was analyzed using SAS computer package version 9.1.

Determination of phosphorus critical level and P-requirement factor

Phosphorus critical level was determined following the Cate-Nelson graphical method where soil P values were put on the X-axis and the relative yield values on the Y-axis (yield x 100/maximum yield). The Cate-Nelson graphical method is based on dividing the Y-X scatter diagram into four quadrants and maximizing the number of points in the positive quadrants. The positions of the lines on the overlay with respect to the axes of the graph were transferred to the graph by making marks on the edges of the graph. The two intersecting lines were then drawn lightly on the graph. The point where the vertical line crosses the X-axis is defined as 'critical soil test level'.

Phosphorus requirement factor was calculated using available P values in soil samples collected and analyzed from each unfertilized and fertilized experimental plot, after that the relation between each fertilizer rate and averaged corresponding soil test P value for each fertilizer rate was calculated.

Results and Discussion

Soil reaction (pH) and available phosphorus

The pH (H_2O) values of the soil samples collected before planting were ranged from 4.20 -5.27 (Table 1). Accordingly, the soils were strongly acidic in reaction (FAO, 2008). Continuous cultivation and long-term application of inorganic fertilizers lower soil pH and aggravate the losses of basic cations from highly weathered soils (Mokwunye *et al*. 1996). The result showed that soil pH affects wheat production which is less than pH of the wheat requirement. Available P contents of the soils were very low ranged from 0.62-3.01 ppm (Table 1), similar with reports of Olsen *et al. (*1954). The low contents of available P observed in the soil of the study areas are in agreement with the results reported by Mesfin (1998).

Table 1. Initial soil pH and available phosphorus content before planting in Chora District

Site	pH (H_2O)	Available P(ppm)
1	5.27	2.07
2	4.66	1.16
3	4.65	1.31
4	4.67	2.23
5	4.84	1.50
6	4.88	1.23
7	4.62	1.16
8	4.50	0.62
9	4.42	3.01
10	4.25	1.53
11	4.75	1.10
12	4.20	0.79
13	4.55	1.59
14	4.38	0.63
15	4.27	1.68
16	4.58	2.46
17	4.44	0.79
18	4.84	2.87
19	4.56	0.80
20	4.32	1.03
Average		**1.48**

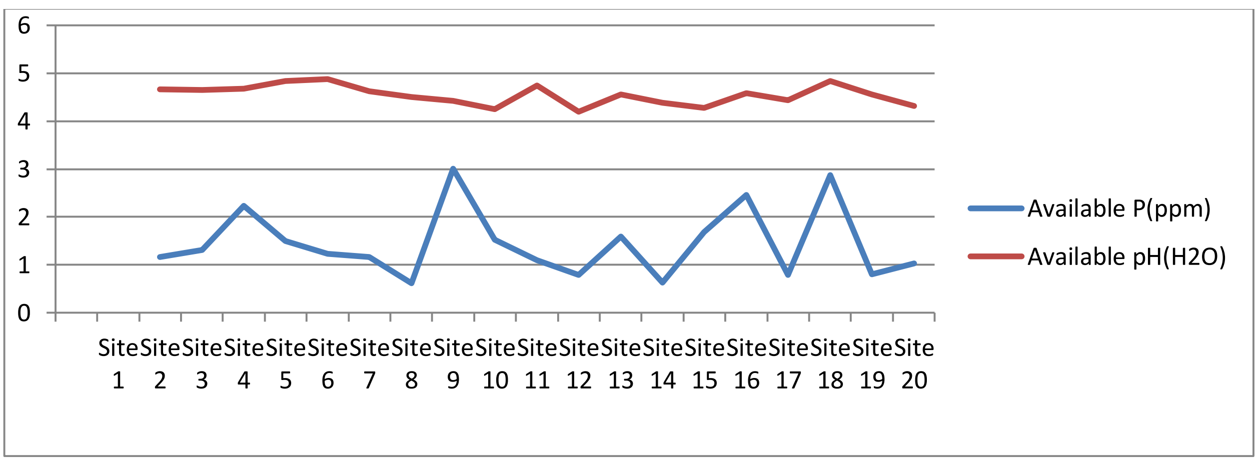


Figure 1. Soil pH and initial Phosphorus status in sites of Chora District

In general, while available P values were oscillated between one and three, soil pH were between four and five (figure 1). This indicated that at low soil pH (acidic media) phosphorus is not available to plants. Ethiopian agricultural soils particularly the Nitisols and other acid soils have low available P content due to their inherently low P content, high P fixation capacity, crop harvest and soil erosion (Yihenew, 2002; Dagne, 2012)

Nitrogen rate determination

The main and interaction effects of both N and P fertilizers were significant ($P \leq 0.05$) for bread wheat grain yield. The highest grain yield (3083 kg ha^{-1}) was at NP combination rates of 138 kg N ha^{-1} and 60 kg P ha^{-1} , while the lowest yield (931 kg ha^{-1}) was from the control plot (without fertilizer) (Table 2). However, NP combination rates of 138 kg N ha^{-1} and 60 kg P ha^{-1}, and 138 kg N ha^{-1} and 40 kg P ha^{-1} were not significantly different (Table 2). As levels of P was changed the levels of N was not changed. Therefore, 138 kg N ha^{-1} was N rate recommended for bread wheat production in Chora District.

It is essential to know the best level of nitrogen application to getting higher crop yield so that better benefits could be achieved (Arif *et al*., 2010). N plays an important role in crop life. It is one of the most important nutrients needed by plants in large quantities. Its availability in sufficient quantity throughout the growing season is essential for optimum crop growth. It also mediates the utilization of phosphorus, potassium and other elements in plants (Brady and Weil, 2002).

Table 2. Interaction effect of N and P rates on grain yield of bread wheat variety Digalu (kg ha^{-1}) in 2014 cropping season, Chora District

	P rate (kg ha^{-1})				
N rate (kg ha^{-1})	0	20	40	60	**Mean**
0	931^{f}	1245^{ef}	1280^{ef}	1569^{e}	1256
46	1225^{ef}	2032^{d}	2181^{cd}	2153^{cd}	1898
92	1403^{e}	2380^{bcd}	2440^{bc}	2590^{b}	2203
138	1435^{e}	2669^{b}	2776^{ab}	3083^{a}	2491
Mean	1248	2082	2169	2349	
LSD			401		
CV (%)			31.1		

Note: Means with the same letters are not significantly different at $P < 0.05$

Phosphorus critical level and P-requirement factor

The results showed that for bread wheat production in Chora district, determined P-critical level was 3.8 ppm (Figure 1) and P-requirement factor was 30.28 (Table 2**)**.

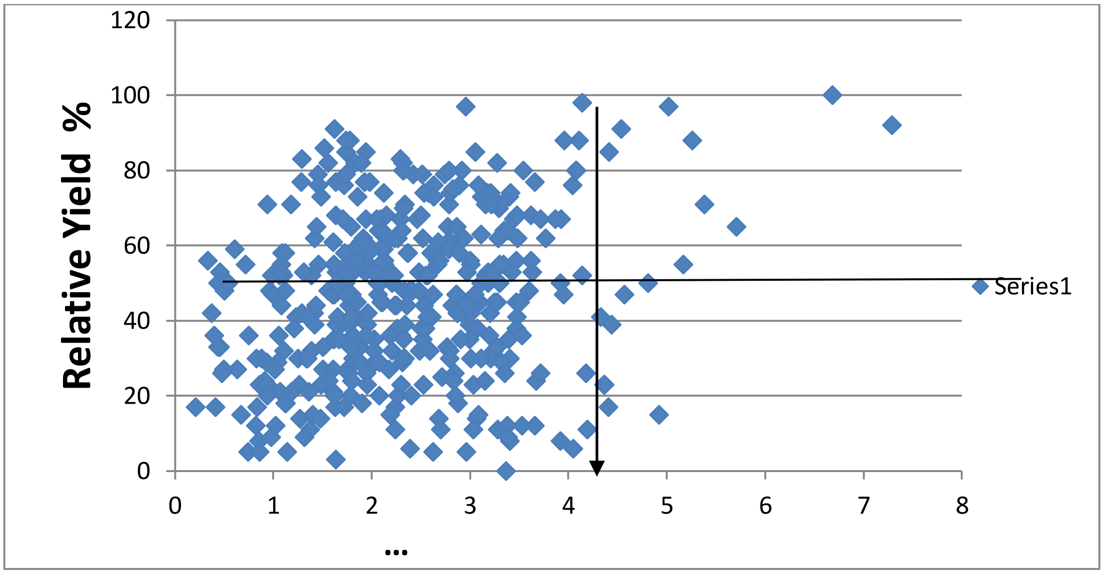


Figure 2. Phosphorus critical level for bread wheat in Chora District

Table. 3. Phosphorus requirement factor for bread wheat in Chora District

Fertilizer P applied (kg P/ha)	Olsen P (ppm)	P- increase over control	P- requirement factor (Pr)*
0	1.48	-	-
10	2.26	0.78	12.82
20	2.30	0.82	24.39
30	2.46	0.98	30.61
40	2.63	1.15	34.78
50	2.85	1.37	36.50
60	2.89	1.41	42.55
			30.28

Conclusion and Recommendations

The soil reaction pH (H_2O) values of the study area were strongly acidic; and very low available phosphorus content in the soils. The highest grain yield was obtained from nitrogen rate (138 kg N ha^{-1}). Hence this N rate, phosphorus critical level (3.8 ppm) and P-requirement factor (30.28) were recommended for bread wheat production in Chora District. Therefore awareness creation should be b for farmers through verification and demonstration to adopt P critical level based P rate recommendation. To sustain the current soil fertility status, integrated soil fertility management, soil amendment with lime, crop rotation, and other practices can improve the current soil fertility situation of the district.

Acknowledgment

The authors would like to thank Oromia Agricultural Research Institute for finance support and Bedele Soil Research Center for provision of facilities for the research work.

References

Amanuel Gorfu., R.F. Kuhne,. D.G. Tanner and. P.L.G. Vlek, 2002. Recovery of 15- N labeled urea applied to wheat in the Ethiopian Highlands as affected by P fertilization. *J. Agron* and *Crop Scie.* 189:.30-38.

Arif, M., I. Amin, M. T. Jan, I. Munir3, K. Nawab, N. U. Khan, and K. B. Marwat, 2010. Effect of Plant Population And Nitrogen Levels And Methods of Application on Ear Characters and Yield of Maize. *Pakistan Journal of Bot*any, 42(3): 1959-1967.

CIMMYT ,1988. From Agronomic Data to Farmer Recommendation: An Economics Training Manual. Completely Revised edition. Mexico , DF.

Dagne Chimdessa, 2012, Soil Characterization and Evaluation of Blended Fertilizers with and without Copper and Zinc for Maize (*Zea mays L.*) Production on Nitisols of Gobu Seyo District of East Wollega Zone, Ethiopia. MSc Thesis. Haramaya University, Ethiopia. 93p.

FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16. FAO, Rome.

FAO, 2008.Efficiency of soil and fertilizer phosphorus use Reconciling changing concepts of soil phosphorus behavior with agronomic information. Bulletin 18

Kelsa Kena, Tadesse Yoannes and Tesfa Bogale, 1992. Influence of fertilizer and its management practices on maize grain yields in major maize producing areas of Ethiopia. *In: proceedings of the first national maize work shop of Ethiopia*.IAR (Institute of Agricultural Research), Ethiopia.

Mesfin Abebe, 1998. Nature and management of Ethiopian soils. Alemaya University, Ethiopia. 272p.

Mokwunye, A.U., A. de Jager and E.M.. Smailing, 1996. Restoring and maintaining the productivity of West Africa Soils: Key to sustainable development. International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama. 94p.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available pho sphorous in soils by extraction with sodium bicarbonate. *USA Circular J.* 939: 1-19.

Onwueme, I. C. and T. D. Sinha. 1999. Field crop production in tropical Africa, CTA Wageningen, Nether lands.

Orkaido Olte,2004. Effects of nitrogen and phosphorus fertilizers on yield and yield Components of maize (*Zea mays* L.) On black soil of regede konso. Msc. Thesis, the School of Graduate Studies Alemaya University

Poehlman, J. and Sleper, A., 1995. Breeding field crops. 4th edition, Lowa State university Press Corporation, USA.

Quinenes, M., A. Foster, D. Akibo and N.P. Siclima, 1992. Methodology used by SG 2000 Project in Africa for transfer of improved production technologies to small scale farmer. pp.149-153. *In: Proceeding of the First National Maize Workshop of* Ethiopia, Addis Ababa.

Wakene Negassa, 2001. Assessment of Important Physico-Chemical Properties of District Udalf (District Nitosols) Under Different Management Systems in Bako Area, Western Ethiopia. MSc Thesis. Alemaya University, Ethiopia. 93p.

Yihenew Gebreselssie, 20002. Selected chemical and physical characteristics of soils of Adet Research Center and its testing sites in Northwestern Ethiopian. Society of Soil Science. *Ethiopian J, Natura. Resource.* 4:199-215.

Soil Test Crop Response Based Phosphorus Calibration Study on Bread Wheat in Wuchale District of North Shewa Zone, Oromia, Ethiopia

Abera Donis and Abreham Feyisa

Fitche Soil Research Center, P.O.Box 109, Fitche, Ethiopia

Corresponding author: aberadonis2006@gmail.com

Abstract

Soil test crop response based phosphorous calibration study was conducted on bread wheat during 2014-2016 cropping seasons in Wuchale District. The objectives were to determine phosphorus critical concentration (Pc) and phosphorus requirement factor (Pf) and economical N fertilizer level for bread wheat in suitable growing areas of the district. The treatments were factorial combination of four levels of N (0, 46, 92and 138 kg N ha^{-1}) and four levels of P (0, 23, 46 and 92 kg P_2O_5 ha^{-1}) in the first year to determine nitrogen rate. Six levels of P (0, 23, 46, 69, 92and 115 kg P_2O_5 ha^{-1}) and 92 kg N ha^{-1} treatments combinations were used in P-calibration trial in the second and third year to determine P-critical level and P-requirement factor. The trial was laid out in randomized complete block design (RCBD) in three replications. Intensive composite soil samples were collected after 21days of planting from each treatment plot and the collected samples were analyzed for available P using Olsen method for the correlation purpose. Economic nitrogen level was 92 kg N/ha. Accordingly, the determined P critical level and P requirement factor for bread wheat in Wuchale district were 9.5 ppm and 14.25, respectively.

Keywords: *Calibration, P Critical, P requirement factor, bread wheat*

Introduction

Wheat (*Triticum spp.)* is one of the major cereal crops grown in the highlands of Ethiopia and this region is regarded as the largest wheat producer in Sub-Saharan Africa (Efrem et al., 2000). In Ethiopia wheat has become one of the most important cereal crops which ranking 4^{th} in total grain production (3.92 million tons, 15.6%) and 4^{th} in area coverage (1.61 million hectare) next to teff, maize and sorghum (CSA, 2014). However, the country is forced to import wheat every year since its productivity is minimal due to depletion of nutrients and poor management practices (Gebreselassie, 2002). Despite the long history of wheat cultivation and its importance to the Ethiopian agriculture, its average yield is still very low, not exceeding 2.4 t ha^{-1} (CSA, 2014) as compared to the world average 3.0 t ha^{-1} (FAOSTAT, 2013).

Fertilization, particularly of the macro-nutrients such as nitrogen, phosphorus and potassium is a major input in wheat production affecting yield and quality (Bacon, 1995). Thus, the choice of fertilizer type and best varieties are one of the best recognized cultivation techniques which have large influence on yield quantity and quality in wheat grain production.

Experimental results from nitrogen (N) and phosphorus (P) fertilizer trials on various field crops showed that grain yields could be substantially improved with the application of N and P fertilizers. In Ethiopia, particularly in the present study areas, low soil fertility is one of the factors limiting the yields of crops, including wheat. It may be caused as a result of removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residues from farmlands, low or absence of fertilizer use and lack of proper crop rotation program (Tamirie, 1982).

The results of several studies conducted on the status of P in Ethiopian soils indicated that most of the soils studied require addition of P fertilizer for optimum growth and profitable production of most crop plants (Sahlemedhin and Ahmed, 1983; Eylachew, 1987; Tekalign and Haque, 1987). The low yield of wheat in Ethiopia (1.84 tons per ha), is primarily due to depleted soil fertility, low levels of chemical fertilizer usage and the unavailability of other modern inputs and crop management practices (CSA, 2011). Thus, managing of soil fertility is crucial for improving agricultural productivity on sustainable basis and assuring food security both at national and household levels in the country. Hence, in order to step up the productivity of wheat crop production, soil test based crop response fertilization is very essential.

Soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops. Therefore, fertilizer application schedules should be based on the magnitude of crop response to applied nutrients at different soil fertility levels (Santhi *et.al*. 2002). As in all other regions of the country, a fertilizer recommendation in Wuchale district is also not based on soil test results. Hence, this study was conducted with the objectives to determine the critical phosphorus concentration (Pc), phosphorus requirement factor (Pf) and economical N fertilizer level for bread wheat on major soils of bread wheat growing area of the district.

Materials and Methods

Description of the study area

The study area, Wuchale district is found in North Shewa Zone of Oromia at about 78 km distance North West from Finfinne (Addis Ababa). It is geographically located between $9^0$18’00” to $9^0$46’ 50” N and 38^0 42’50” to 39^0 07’ 00” E. The district has an altitude ranging from 1800-2809m.a.s.l, and receives an average annual rain fall of 1000mm. The annual average minimum and maximum temperature was about 13 and 25^0C respectively. The soil of the study area is dominantly characterized by vertisols.

Experimental layout and design

The study was conducted in the district during the main cropping season 2014-2016 to determine P-critical value and P-requirement factor for P-fertilizer recommendation of bread wheat for the district. The treatments of the experiment were factorial combination of four level of N (0, 46, 92and 138kg N ha^{-1}) and four level of P (0, 10, 20 and 40 kg P ha^{-1}) in the first year to determine nitrogen rate. Moreover, single factor of six level of P (0, 10, 20, 30, 40 and 50 kg P ha^{-1}) and economic nitrogen level which was determined in the first year (92 kg N ha^{-1}) treatments combinations were used in the P-calibration experiment in the second and third year to determine P-critical value and P-requirement factor. The trial was conducted in randomized complete block design (RCBD) in three replications on plot size 3m*4m =12 m^2. Improved bread wheat variety Danda’a was used for the trial.

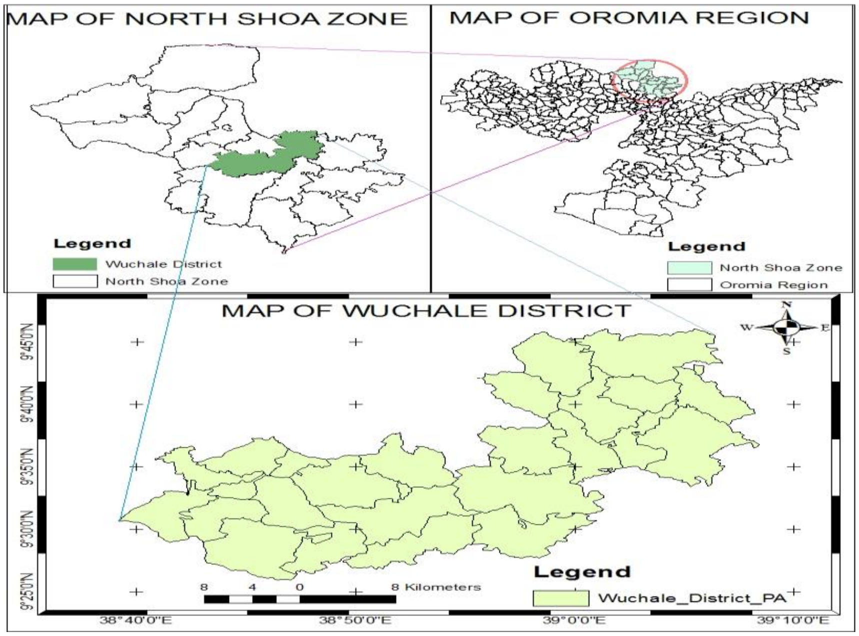


Figure 1. Location map of the study area

Experimental procedures

Composite soil sample were collected from 41 farmers field during two experimental years from the district following the standard procedures. After soil physical and chemical analyses have been completed, twenty one (21) farmers' fields (10 and 11 farmers' for 1st and 2nd year, respectively) for the districts were selected based on initial phosphorus concentration categories (low, medium and high). The trial was laid down in RCBD in three replications. After twenty one days of planting, intensive composite soil samples were collected from each treatment plot by replication and the collected samples were analyzed for available P using Olsen method for the correlation study.

Determination of phosphorus critical and requirement factor

Phosphorus critical value was determined following the Cate-Nelson graphical method where soil P values were put on the X-axis and the relative yield values on the Y-axis. The average yield was adjusted reducing by 10% to minimize over estimation of grain yield while converting yield of small plot to hectare base. The Cate-Nelson graphical method was based on dividing the Y-X scatter diagram into four quadrants and maximizing the number of points in the positive quadrants while minimizing the number of points in the negative quadrants (Nelson and Anderson, 1977).

Phosphorus requirement enables to determine the quantity of P required per hectare to raise the soil test by 1ppm, and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level. It was calculated using available P values in samples collected from unfertilized and fertilized plots. Phosphorus requirement factor is the amount of P in kg needed to raise the soil P by 1ppm, which is equal to

$$Pf = \frac{P\ applied}{change\ in\ soil\ P}$$

Using P requirement factor, P critical level and initial P values rate of p-fertilizer to be applied was calculated as follows.

Rate of P-fertilizer to be applied= (critical P concentration-initial P value) x P requirement factor

Data collection

During field experiment the agronomic data collected were planting date, emergence date, plant height, plant population/m^2, maturity date, grain and biomass yield.All agronomic and soil data collected across locations were subjected to analysis of variance using R software program. Least Significant Difference (LSD) at 5 probability level test was used for mean separation for significant treatments.

Result and Discussion

Determination of nitrogen rate

Optimum yield can be obtained in the presence of all available essential nutrients at balanced and optimum level where phosphorus and nitrogen are the most deficient and essential nutrient in the country. Therefore determination of nitrogen fertilization level during P-fertilizer calibration is the most important procedure. Hence, determination of optimum nitrogen level was done by economic analysis, andh was 92 kg N/ha for bread wheat in Wuchale District.

Determination of P-critical and P-requirement factor

The Cate-Nelson graphical method was employed to determine the P-critical point. The P-critical concentration above which the response of crop to applied P become minimal was 9.5 ppm. Phosphorus requirement factor is the amount of P in kg needed to raise the soil P by 1ppm. Phosphorus requirement enables to determine the quantity of P required per hectare to raise the soil test by 1ppm, and to determine the amount of fertilizer required per hectare to bring the level of available P above the critical level. It was calculated using available P values in samples collected from unfertilized and fertilized plots. Phosphorus requirement factor is the amount of P in kg needed to raise the soil P by 1ppm, which is equal to

$$\boldsymbol{Pf} = \frac{\mathbf{P\ applied}}{\mathbf{change\ in\ soil\ P}}$$

Table 1. Phosphorus requirement factor (Pf) for bread wheat in Wuchale District

P fertilizer applied (kg P ha^{-1})	Available P (ppm) (Olsen method)	P level increase over the control (Olsen method)	P requirement factor (Pf)
0	9.30	-	-
10	10.07	0.77	10/0.77=12.99
20	10.48	1.18	20/1.18=16.95
30	11.85	2.55	30/2.55=11.76
40	11.63	2.33	40/2.33=17.17
50	13.37	4.07	50/4.07=12.29
Mean			**14.23**

Accordingly, the determined P-requirement factor for the district was 14.23.

Conclusion and Recommendations

Soil test crop response based P calibration study in Wuchale District resulted in determination of economical N level, P critical and P-requirement factor (Pf) for the distric. Accordingly, economical nitrogen rate (92 kg N/ha), phosphorus critical level (Pc) (9.5ppm) and phosphorus requirement factor (Pf) (14.23) were determined for bread wheat production in Wuchale district, which could be used for similar agro-ecology in the district. Therefore, verification and demonstration of the determined Pc and Pf recommendation should be prerequisite for awearness creation and farmers' adoption to soil test crop response based fertilizer recommendation to increase bread wheat productivity and production in the district.

Acknowledgment

The authors would like to thank Oromia Agricultural Research Institute for financial support and Fitche Soil Research Center for providing all the necessary facilities required for the research work.

References

Bacon, P. E., 1995. Nitrogen fertilization in the environment. II. Series. Marcel Dekker, Inc. 270 Madison Avenue, New York.

CSA (Central Statistical Authority). 2011. Agricultural Sample Survey 2010/2011. Reports on area under cultivation, yield and production of major crops for 2010/2011 main (Meher) season. Volume I. FDRE/CSA, Addis Ababa, Ethiopia.

CSA (Central statistical agency), 2014. Agricultural sample survey 2013/2014. Vol. I. Report on area and production for major crops (private peasant holdings, meher season). Statistical Bulletin 532, Central Statistical Agency. Addis Ababa, Ethiopia.

Efrem, B., Hirut, K. and Getachew, B.2000.Durum Wheat in Ethiopia: An old crop in an anicient land. Institute of Biodiversity Conservation and Research. Addis Ababa, Ethiopia.68p.

Eylachew Zewdie, 1987.Study on Phosphorus Status of Different Soil Types of Chercher Highland S.E.Ethiopia.Phd, Dissertation, der Justus Universitat Grie Ben.

Eylachew Zewdie, 2001. Study on the physical, chemical and mineralogical characteristics of some Vertisols of Ethiopia. Pp.87-102. In: Wondimagegn Chekol and Engida Mersha (eds.). Proceedings of the 5th Conference of the Ethiopian Society of Soil Science (ESSS*)*, March 30-31, 2000. The ESSS. Addis Ababa.

FAOSTAT (The Food and Agriculture Organization Corporate Statistical Database). 2013. Agricultural production Statistics. (http://www.fao.org/faostat.) (Accesses on 13 January 2014).

Gebreselassie, Y. 2002. Selected chemical and physical characteristics of soils of Adet research center and its testing sites in North-western Ethiopia. Ethiopian Journal of Natural Resources. Retrieved from http://agris.fao.org/aos/records/ET2009000093.

Peterson, C.J., R.A. Graybosch, D.R. Shelton and P.S. Baenziger, 1998. Baking quality of hard red winter wheat: Response of geno-types to environment in the Great Plains. Euphytica, 100:157-162.

Sahlemedhin Sertsu and Ahmed Ali, 1983. Phosphorous sorption characteristics of some Ethiopia soils. Ethiopia Journal of Agricultural Science. 5:1-12.

Santhi R, Natesan R, and G.Seh'akumari, 2002. Soil test based fertilizer recommendation under IPNS for aggregatum onion in Inceptisols of Tamil Nadu.Department of Soil Science and Agricultural Chemistry.Tamil jadu Agricultural University.Coimhatore Ml 003. India. Agrupedolo R.V, 12:141-147.

Tamirie Hawando, 1982. Problems of soils and its implications on crop improvement program in Ethiopia context. Department of plant science, college of Agriculture, Addis Ababa University.

Tekalign Mamo, I. Haque, and C.S. Kamara, 1988. Phosphorus status of Ethiopian Vertisols: Management of Vertisols in Sub-Saharan Africa. pp. 232-252. In: Proceeding of the Conference held at International Livestock Centre for Africa (ILCA), 31 August – 4 September 1987.

Verification of Soil Test Crop Response Based Phosphorus Recommendation for Bread Wheat in Wuchale District of North Shewa Zone, Oromia, Ethiopia

Abera Donis and Abreham Feyisa

Fitche Soil Research Center, P.O.Box 109, Fitche, Ethiopia

Corresponding author: aberadonis2006@gmail.com

Abstract

*On-farm verification trial of soil test crop response based phosphorus recommendation for bread wheat was conducted in Wuchale District of North Shewa Zone in 2017 cropping season using recommended nitrogen rate (92 kg N/ha), P critical (9.5 ppm) and P-requirement factor (14.23).The verification trial was initiated to verify P critical and P-requirement factor for bread wheat. Three treatments were used, control (without fertilizer (T1)), farmers' practices (blanket recommendation) (T2) and soil test crop response based phosphorus recommendation (T3) using improved bread wheat variety Danda'a. The trial was conducted on nine farmers' fields which were used as replications. Plot size was 10m*10m for each treatment. Bread wheat grain yield (kg/ha) was affected by different fertilizer rates used as treatments. The highest grain yield (2729 kg/ha) was resulted with soil test crop response based P recommendation. It was significantly higher than the farmers' practice (1892 kg/ha). Similarly economic analysis for these different treatments indicated that soil test crop response based P recommendation was economically feasible for bread wheat production in the district.*

Keywords: *Soil test based, blanket recommendation, P critical, P-requirement factor, bread wheat*

Introduction

Ethiopia is one of sub-Saharan Africa countries where severe soil nutrient depletion and low agricultural production as well as economic growth are observed even though the country has potentially rich in land resource. Most Ethiopian soils are deficit in nutrients, especially nitrogen and phosphorus and fertilizer application has significantly increased yields of crops (Tekalign *et al*., 2001). However, the amount of this element in available forms in the soil is small, while the quantity withdrawn annually by crops is comparatively large (Brady and Weil, 2002). Nitrogen is the major nutrients affecting wheat yield and quality (Bacon, 1995). Several reports have also indicated that increased usage of N fertilizer is considered a primary means of increasing wheat grain in Ethiopia (Asnakew *et al.*, 1991; Tanner *et al*., 1993; Amsal *et al*., 2000).

Phosphorus (P) has long been known to be an essential element in the nutrition of plants. It plays an essential role in many physiological and biochemical processes (Mathews *et al*., 1998). Phosphorous has a lower mobility than any other nutrients and it does not remain in a free state for long in which it is slowly available to plants (Parnes, 1990). Plant P uptake is influenced by P supply, characteristics of the soil and P requirement of crop plants. There are several reports that signify the role of P application in the enhancement of yield and yield components of wheat. (Daniel *et al*., 1998) reported readily availability of P during early season which saved the plants from early stresses and its higher uptake at higher levels resulted into enhanced number of grains per spike and 1000-grain weight due to its involvement in grain formation and development. Moreover, (Asnakew *et al*., 1991) stated that the effect of P on grain yield was highly significant with a general increase in yield as the level of P_2O_5 increased up to 69 kg ha^{-1}.

The low yield of wheat in Ethiopia (1.84 tons per ha), is primarily due to depleted soil fertility, low levels of chemical fertilizer usage and the unavailability of other modern inputs and crop management practices (CSA, 2011). In Ethiopia, particularly in the present study areas, low soil fertility is one of the factors limiting the yields of crops, including wheat. It may be caused as a result of removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residues from farmlands, low or absence of fertilizer use and lack of proper crop rotation program (Tamirie, 1982).

Managing of soil fertility is crucial for improving agricultural productivity on sustainable basis and assuring food security both at national and household levels in the country. Hence, in order to step up the productivity of wheat crop production, soil test based crop response fertilization is very essential. Soil test based fertilizer recommendation plays a vital role in ensuring balanced nutrition to crops. Therefore, fertilizer application schedules should be based on the magnitude of crop response to applied nutrients at different soil fertility levels (Santhi *et.al*. 2002).

Application of Urea and DAP fertilizers has been adapted through extension program in the Ethiopia. However, the blanket recommendations have been used for long years, regardless of considering physical and chemical properties of the soil as well as does not taken in to account climatic condition and available nutrient present in the soil (Taye Bekele *et al*., 2000). Accordingly, 100 Kg/ha of DAP and 100 Kg/ha of Urea were set by the Ministry of Agriculture and Rural Development. However, for many years no studies have been conducted on site specific fertilizer recommendation rate. As in all other regions of the country, a fertilizer recommendation in Wuchale district is also not based on soil test results.

Accordingly, to give soil test based fertilizer recommendation soil test crop response based phosphorus calibration study was conducted in Wuchale District on bread wheat in 2014-2016 cropping season and optimum nitrogen rate (92 kg N/ha), P critical (9.5ppm) and P-requirement factor (14.23) were determined. Therefore, the objective of this trial was to verify P critical and P-requirement factor for bread wheat comparing with farmers' practices.

Materials and Methods

Description of the study area

The study area, Wuchale District, is found in North Shewa Zone of Oromia at about 78 km distance north west from Finfine (Addis Ababa). It is geographically located between $9^0$18'00" to $9^0$46' 50" N and 38^0 42'50" to 39^0 07' 00" E. The district has an altitude ranging from 1800-2809m.a.s.l, and receives an average annual rain fall of 1000 mm. The annual average minimum and maximum temperature was about 13 and 25^0C respectively. The soil of the study area is dominantly characterized by Vertisols.

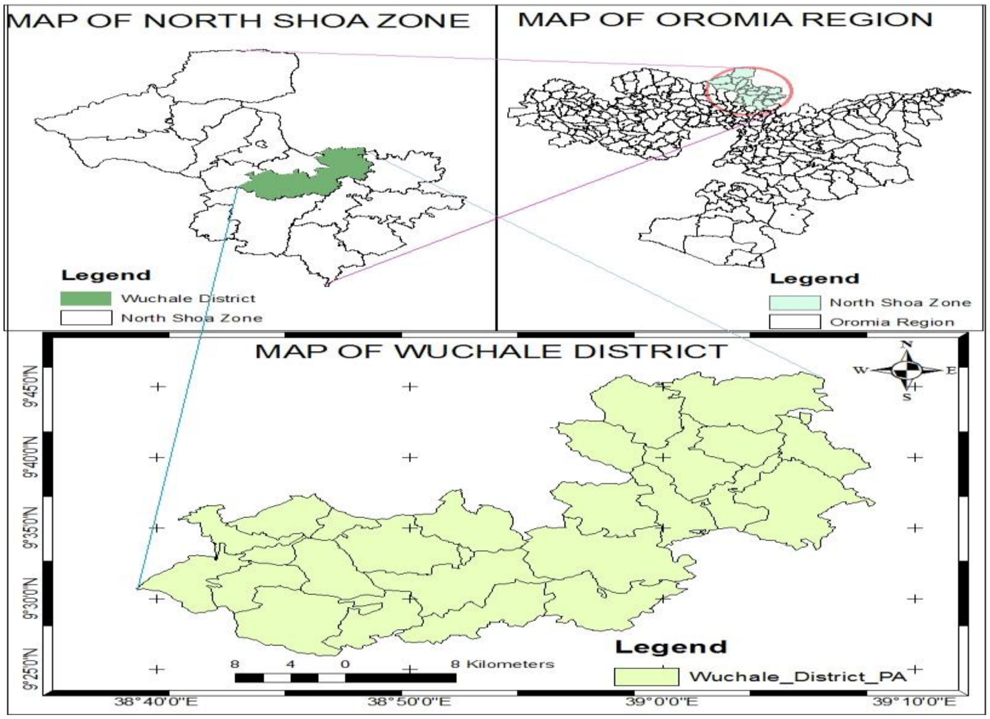


Figure 1. Location map of the study area

Experimental design and layout

The verification trial was conducted in 2017 main cropping season. Three treatments were control (without fertilizer (T1)), farmers' practices (blanket recommendation) (46 kg N and 46 kg P_2O_5 ha^{-1}) (T2)), and soil test crop response based phosphorus recommendation (T3) with recommended nitrogen rate (92 kg N ha^{-1}). The trial was conducted on nine farmers' fields which were used as replications. Sources of fertilizer for N and P were urea and DAP. Improved bread wheat variety Danda'a was used in the trial. Plot size was 10m*10m (100m^2) for each treatments and 150 kg ha^{-1} seed rate was used. All cultural practices were done as per farmer's practices of the area.

Soil sampling and analysis

Prior to planting time, surface composite soil samples were collected from the farmer's field for available P analysis at a depth of 0-20cm. The collected samples were properly labeled, packed and transported to Fitche soil research center's laboratory for analysis. A total of 20 composite soil samples were collected and 9 farmer's field having initial available phosphorus below critical concentration determined for the district were selected to conduct the experiment. Then Phosphorus fertilizer requirement were calculated for each farmer by using the formula:

Phosphorus fertilizer rate (kg/ha) = (Pc-Pi)*Pf;

Where, **Pc**-phosphorus critical level ***9.5 ppm,*** **Pi-** Initial available phosphorus, **Pf-**phosphorus requirement factor ***14.23*** for Wuchale District

Data collection and analysis

During field trial agronomic data collected were planting date, emergence date, plant height, plant population/m^2, maturity date, grain and biomass yield. All agronomic data collected across locations were subjected to analysis of variance using R software program. Least Significant Difference (LSD) at 5 probability level test was used for mean separation for significant treatments.

Economic analysis

Marginal rate of return (MRR) was calculated both for farmers practice and soil test based values by using the formula given blow.

$$\mathbf{MRR} = \frac{\textbf{Net Income From Fertilized Field} - \textbf{Net Income From Unfertilized Field}}{\textbf{Total Variable Cost From Fertilizer Application}}$$

Total variable cost is a cost incurred due to application of P fertilizer (both but in separate of Soil test based P calibration result and farmers' fertilizer rate) with the assumption that the rest of the costs incurred are the same for all treatments. Gross income is obtained by multiplying mean grain yield (kg/ha) of each treatment by the price of one kg of the grain. Net income is calculated by subtracting the total variable cost from the gross income. To use the marginal rate of return (MRR) as basis for fertilizer recommendation, the minimum acceptable rate of return (MARR) was set to 100%.

Results and Discussion

Grain yield

Wheat grain yield was affected by different fertilizer rates as presented in Fig 1**.** According to analysis of variance, the result of the trial conducted in Wuchale District indicated significant difference (p <0.05) among different fertilizer rates. The highest grain yield (2729 kg/ha) was resulted with soil based test P recommendation which was significantly higher than the farmers; practice (1892 kg/ha).

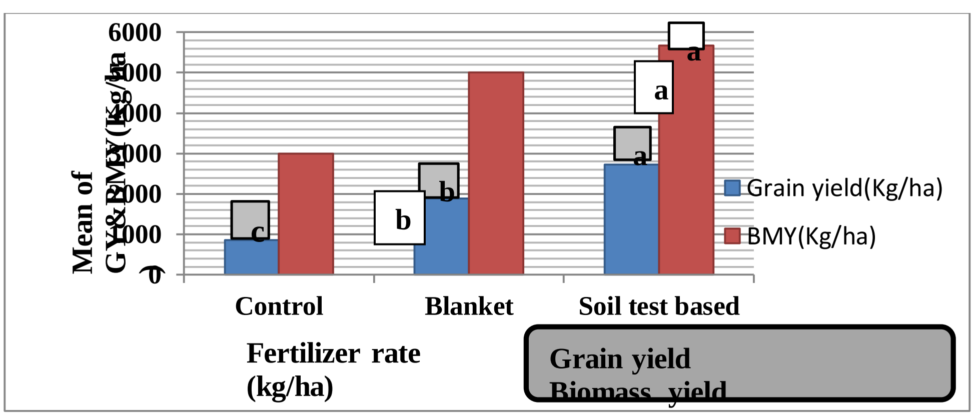


Fig. 1. Bread wheat grain yield (kg/ha) as affected by different fertilizer rates
Bar graphs with the same letters are not significantly different from each other at P<0.05

Economic analysis

To estimate the economic significant of the different fertilizer rates, partial budget analysis (CIMMYT, 1988) was employed to calculate the marginal rate of return (MRR) to investigate the economic feasibility of treatments. Based on actual unit prices during the year 2016 harvesting season (personal observation) farm gate price of 10ETB (Ethiopian Birr) per kg of wheat, 14.5 &10.4 Birr per kg of DAP & Urea, respectively (Table 1) were used to calculate variable cost.

Table 1. Partial budget analysis

No	Fertilizer rate (kg/ha)	Variable Input (kg/ha)		Unit price(ETB)		TVC	Mean Wheat grain yield (kg/ha)	Unit price (Birr)	Gross Income	Net Income	MRR (%)
		DAP	Urea	DAP	Urea						
1	Control	0	0	14.5	10.4	0	854.2	10	8542	8542	-
2	Farmer practice	100	100	14.5	10.4	2490	1891.7	10	18917	16427	**316.67**
3	Soil test based	224	112	14.5	10.4	4412.8	2729	10	27290	**22877.2**	**324.85**

NB: TVC= total variable costs; MRR = Marginal rate of return

The Marginal rate of returns (MRR) were found to be **325%** for soil test based P fertilizer rate and **317%** for farmers' practice as indicated in Table 1. The economic analysis showed that the highest net income (22,877 Birr) was obtained from soil test based P recommendation with marginal rate of return (325%) which is greater than the minimum rate of return (MRR) 100% (CIMMT, 1998). Based on this result, partial budget analysis indicated that soil test based P recommendation is economically feasible for bread wheat production in the district.

Conclusion and Recommendations

From the verification trial of recommended nitrogen rate (92 kg N/ha), P critical level (9.5ppm) and phosphorus requirement factor (14.23), the economic analysis showed that the highest net income (22877 Birr) was obtained from soil test based P recommendation with marginal rate of return (325%) which is greater than the acceptable minimum rate of return (100%). Using recommended nitrogen rate (92 kg N/ha) and soil test based phosphorus recommendation increased grain yield of bread wheat. Accordingly the highest grain yield was 2729 kg/ha with 44% yield advantage over blanket fertilizer application. Based on this result, soil test based P recommendation is economically feasible for bread wheat production in the district.

The recommended nitrogen rate (92 kg N/ha), established P critical level (9.5ppm) and P-requirement factor(14.23) in conjunction with soil test P critical value can be used to give soil test crop response based P recommendation for bread wheat in Wuchale District. Therefore, demonstrating the determined Pc and Pf for wider promotion to farmers should be followed for adoption of the P recommendation technology to increase bread wheat productivity and production in the district.

Acknowledgment

The authors would like to thank Oromia Agricultural Research Institute for financial support and Fitche Soil Research Center for providing all the necessary facilities required for the research work.

References

Amsal T., Tanner D.G., Taye T. and Chanyalew M., 2000. Agronomic and economic evaluation of the on farm N and P response of bread wheat grown on two contrasting soil types in Central Ethiopia. pp. 329. In: The 11th Regional wheat workshop for central, Eastern and Southern Africa. Addis Ababa, Ethiopia. CIMMYT.

Asnakew W., Tekalign M., Mengesha B. and Tefera A., 1991. Soil fertility management studies on wheat in Ethiopia. Pp.137-170. In: Hailu Gebremariam, D.G. Tanner and Mengistu Huluka (eds). Proceedings of Wheat Research in Ethiopia. A Historical Perspective. Institute of Agricultural Research, Addis Ababa, Ethiopia.

Bacon, P. E., 1995. Nitrogen fertilization in the environment. II. Series. Marcel Dekker, Inc. 270 Madison Avenue, New York.

Brady, N.C. and Weil, R.R. 2002. The nature and properties of soils. 13th ed. Pearson Education Inc. Upper Saddle River, New Jersey, USA.
Daniel, T.C., A.N. Sharpley and J.L. Lemunyon. 1998. Agricultural phosphorus and eutropication: a symposium overview. Journal of Environmental Quality, 27: 251-257.

Henry D.Foth, 1990. Fundamentals of Soil science, (8thEd.)Michigan State University johnwiley&sons
Jackson, M.L.1967.Soil chemical analysis. Practice Hall of India.NewDelhi.

Mathews, B. W; J. P. Tritschler II and S.C. Miyasaka. 1998. Phosphorus management and sustainability. *Crop Sci.,* 39: 395-399.

Parnes, R. 1990. Fertile Soil: A Grower Guide to Organic and Inorganic Fertilizers, Agaccess, California, 190pp.

Tanner, D.G., Amanuel Gorfu and Assefa Ta'a, 1993. Fertilizer effects on sustainability in the wheat based smallholder-farming systems of south eastern Ethiopia. *Field Crop Research,* 33:235-248.

Taye Bekele,Verkuijl,H.,Mwangi,W.and Tanner,D.2000.Adoption of Improved Wheat Technologies in Adaba and Dodola Woredas of the Bale Highlands,Ethiopia.Second National Maize and Wheat Workshop.12-16 November 2000;Addis Ababa. International Maize and Wheat Improvement Center and Ethiopian Agricultural Research Organization (EARO).Addis Ababa, Ethiopia.

Tekalign Mammo, Teklu Erkossa and Balesh Tulema.2001.Soil Fertility and Plant Nutrition Research on Teff in Ethiopia.pp.199-200.In: Hailu Tefera, Getachew Belay and Mark Sorrels (eds.) Narrowing the Rift. Teff Research and Development, Proceedings of the International Workshop on Teff Genetics and Improvement,16-19 October,2000.Addis Ababa,Ethiopia,pp 167-176.

Assessment of Nutrient Contents of Farmers Used Composts for Crop Production in East Shewa and West Arsi Zones of Oromia, Ethiopia

[1]Kefyalew Assefa Gejea and [2]Tilahun Firomsa Erenso

[1]Oromia Agricultural Research Institute, P.O.Box 81265, Finfinne, Ethiopia

[2] Batu Soil Research Center, P.O.Box 59, Batu, Ethiopia

Corresponding author: assefakefyalew@gmail.com

Abstract

The assessment of farmers' used composts for different nutrient contents and quality for agricultural purpose was made in different districts of East Shewa (Ada'a and Boset) and West Arsi (Arsi Negele) of Oromia. The objective was to assess the nutrient contents of farmers' prepared and used composts, maturity status of composts, method used to prepare and dominant raw materials used as a source of composting in different agro-ecologies. A total of 120 matured compost samples were planned to be collected from these three districts for laboratory analysis but because of compost shortage from selected farmers and even from selected kebeles as well as non-selected kebeles, only 52 samples were collected. Sampling of farmers was made systematically by selecting two districts from each zone, five kebeles from each district and 8 farmers from each kebele after detail discussion with agricultural development office at zonal and district levels, and development agents working in the respective kebeles. Researchers went to kebele of each farmer and collected information according to questioner developed and took a kilo of compost sample from each representative farmer's compost preparation sites. The collected samples were analyzed at Batu Soil Research Center laboratory following the standard procedures for required parameters compost pH, EC, percent total nitrogen, percent organic carbon, available phosphorus and potassium. Finally the analyzed compost samples for required parameters were compared with existing established standard compost quality parameters. Accordingly based on all parameters required for quality and nutrient content analysis, nutrient contents and quality of farmers' used composts for crop production were not met the standard. This could be due to raw materials used and thier proportion, standard composting process and storage condition that were not according to guideline provided and lack of close supervision and guidance by local development agents.

Keywords: *Compost, nutrient, assessment, quality*

Introduction

Sustainability issues in agricultural policy are becoming of a high concern worldwide as it reflects the needs of long term fertility and environmental protection. Ethiopia is an agrarian country that depends on agricultural production for the growth of the national economy. The agricultural sector accounts for nearly 46% of gross domestic product (GDP) and close to 80% of export earnings and 73% of total employment (ATA, 2013). The sector is mainly operated by small holder farmers that directly rely on agriculture for their food supply and cash income. But currently growth in food production is not in equal footings with population pressure (CSA, 2015); because increased productivity in the agricultural sector has been constrained by high population pressure, deforestation and resource base degradation, soil erosion and soil fertility depletion (Lemenih *et al.*, 2005a; Feoli *et al.*, 2002; Tadesse, 2001; Shiferaw & Holden, 1999; Hurni, 1988). In addition common problem with soil erosion and soil fertility depletion is due to lack of sustainable Land use systems in the country.

Therefore, in order to accomplish the necessary agricultural intensification, soil fertility management practices should get an attention. While, a more sustainable management of the soil resource can be achieved through improved agricultural management such as crop rotation with N-fixing legumes, addition and recycling of nutrients and erosion control. On the other hand, in order to attain food self-sufficiency and achieve the desired long-term economic growth, the decline in soil fertility need to be halted and land use intensification need to be accompanied by sufficient external nutrient inputs to compensate for the nutrient removal through harvested products and losses (Mugwe *et al.*, 2009). Hence, direct addition of nutrients can be done through mineral fertilizer or organic inputs such as manure and compost, or through combination of both nutrient sources. That means compost is another important alternative source of plant nutrients (Ngwira *et al.*, 2013; Odlare *et al.*, 2011; Vanlauwe *et al.*, 2011) that required for soil fertility management in the process of agricultural intensification.

Compost is the final output of composting process or a rich, humus-like material formed when organic wastes decomposed under controlled conditions. Or Compost also defined as a homogenous and friable mixture primarily composed of stabilized (no longer decaying) organic matter. On the other hand, composting is the natural process of ‘rotting’ or decomposition of organic matter by micro-organisms under controlled condition, which resulted in a reduction of the volume of organic material, destruction of weed seeds and sanitation through reduction of harmful pathogens. Raw organic materials such as crop residues, farm yard manure, green weeds, animal wastes, food garbage, some municipal wastes and suitable industrial wastes enhance their suitability for application to the soil as fertilizing resources, after having undergone composting. Soil organic matter plays an important role in sustaining soil fertility, and hence in sustainable agricultural production. In addition to being a source of plant nutrition, it improves the physico-chemical and biological properties of the soil. As a result of these improvements, the soil becomes more resistant to stresses such as drought, disease and toxicity; helps the crop in improved uptake of plant nutrients; and possesses an active nutrient cycling capacity because of vigorous microbial activity, and allowing root growth. Addition of compost to soil is also an effective treatment for increasing rhizosphere aggregate stability (Caravaca *et al*., 2001). Because compost adds organic matter, particularly carbohydrates, to the soil, the factor most closely related to soil aggregate stability (Albiach *et al.*, 2001). These advantages manifest themselves in reduced cropping risks, higher yields and outlays on inorganic fertilizers for farmers.

The advantage that redder depends on the quality of compost prepared under controlled condition, i.e., quality compost should be required to meet the advantage. This quality composition is pre-determined by the nature of the raw materials which are used to make up the compost, and by the manner in which these materials are treated during the composting process. Hence this quality could be measured or detected based on its C: N ratio, macro and micro nutrient content, texture, level of foreign materials, weeds and etc. Similarly, the properties of immediate importance in judging compost quality for improving soil structural quality are maturity, salinity, sodicity, soluble N concentration (nitrate and ammonia), boron (B) concentration, heavy metal concentrations, and presence of pathogens.

Generally, compost offers benefits such as enhanced soil fertility (because organic inputs replenish SOM fractions that contain different soil micro- and macronutrients) and soil health that increased agricultural productivity, improved soil biodiversity reduces ecological risks and a better environment (SOM is also known to improve soil structure and water holding capacity). While combined use of these often scarce resources (inorganic and organic fertilizers) has the potential of replenishing soil fertility, maintaining SOM and thereby enhancing productivity (Vanlauwe *et al.*, 2011). Despite all these benefit rendered by organic recycling, many farmers, especially those in developing countries find themselves at a disadvantage as they fail to make the best use of organic recycling opportunities. This may be because of lack of knowledge on efficient speedy technology, long time spans, intense labor, land and investments, resources (raw material) and economic factors. In addition to mentioned reason, although organic inputs are potential sources of plant nutrients and have beneficial effects on soil fertility, there is competition from alternative uses of these resources; both manure and crop residues are used for fuel and crop residues are also used as animal feed and for construction (Abegaz & van Keulen, 2009; Haileslassie *et al.*, 2005).

Even though, the reality of failer to make the best use of organic recycling of developing countries, including Ethiopia, different agricultural development bureau report indicates the presence of unorganized beginning of activities for organic recycling in different zones of Oromia, attempting to supplement/replace the use of inorganic fertilizers. But there is no available information concerning the standard preparation process and quality of composts used by farmers.

Therefore, this study was initiated to fill the gap by assessing the quality of currently used composts in Oromia with the objectives (1) to assess the nutrient contents of currently used composts prepared from diversified material sources for agricultural purpose, (2) know the maturity status of composts used for crop production, (3) know type of composting practices, (4) assess dominant raw materials used as source of composting in different agro-ecologies, and (5) make database for composts prepared by farmers.

Materials and Methods

Description of the study area

The assessment of currently used composts for its nutrient content and quality for agricultural purpose was conducted in different districts of East Shewa (Adaa and Boset) and West Arsi (Arsi Negele) of Oromia those found 48, 130 and 220 km toward East and South directions from Finfinne, capital city of Oromia. Geographically the study areas Ada'a, Boset and Arsi-Negele districts are located between $38^0$46'56" E - $39^0$11'30" E and $8^0$33'7" N-$8^0$57'13" N, $39^0$14'1" E-$39^0$49'54" E and $8^0$24'18" N-$8^0$50'55" N, and $38^0$22'55.4" E-$38^0$57'32" E and $7^0$8'45" N-$7^0$44'1.7" N, and altitude ranges are from 1702-2511, 1109-2276 and 1559-3032masl, respectively.

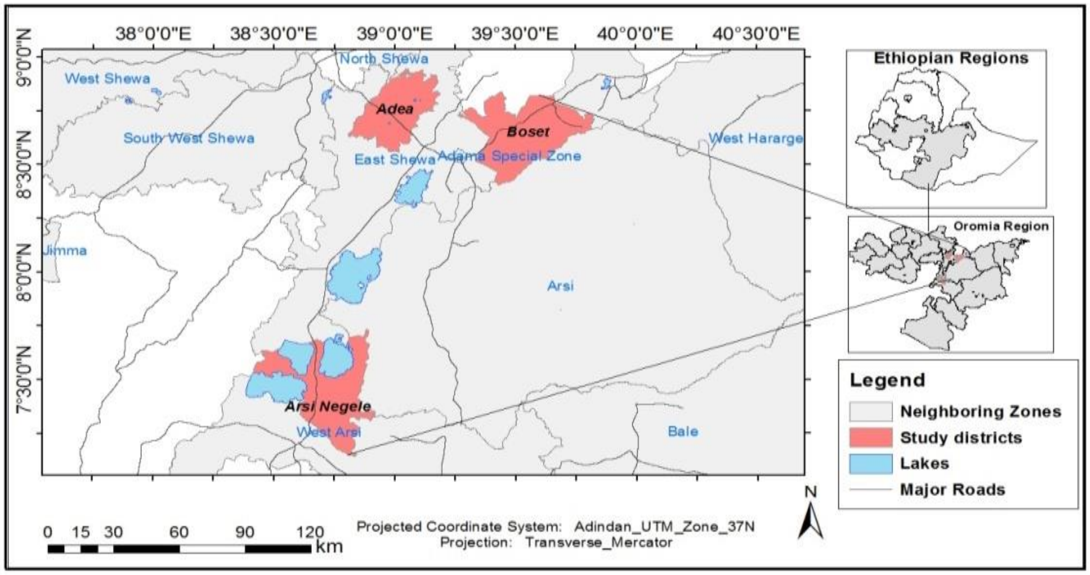


Figure 1. Maps of locations in the study areas

Compost sampling

A total of 120 matured compost samples were planned to be collected from these three districts for Laboratory analysis. The procedure followed was, first two districts from each zone and five kebele from each districts were selected after detail discussion with Agricultural Development Office at zonal and district level, respectively. Then after, selection of 8 farmers from each kebele was made systematically in order to represent the districts and time of sample collection was also scheduled, after detail discussion with development agent found in the respective kebele. Finally, according to schedule researchers' move to the village of each farmer and collected information according to questioner developed. Then a kilo of samples of compost were collected from compost preparation sites of each representative farmer's. The compost samples were labeled and taken to laboratory for farther analysis for the required parameters; however, because of shortage of composts from selected farmers and even from selected kebeles as well as non-selected kebeles, only 52 samples were collected (Figures 2 and 3). The big challenges encountered during samples collection was development agent and farmers perception of compost, i.e., they consider any collected animal and home wastes as compost (Figures 4 and 5).

Figure 2. Compost preparation site

Figure 3. Actual compost prepared in collaboration with PhD student

Figure 4. Collected slurry and animal feeds left over considered as compost

Figure 5. Collected ash, house and animal wastes over long time and considered as compost

Compost samples analysis

Based on laboratory analysis capacity and standard methods, collected compost samples were analyzed for different parameters. First the received composite compost samples were prepared for analysis, which included air drying, removing foreign materials mixing each sample well and Sieving of samples separately to have required aggregate size using 0.2mm mesh size. Then after, Compost pH was determined potentiometrically in a slurry system using an electronic pH meter in 1:5 compost water ratios. Compost salinity (concentration of soluble inorganic salts in the compost) was also measured from compost sample with water (1:5 compost: water ratio) by electrical conductivity (EC) using a conductivity bridge. Finally the analyzed composts for required parameters were compared with existing established standard compost quality parameters by different authors.

Results and Discussion

Inorganic chemical fertilizers that carry a label by law must declare their N-P-K (nitrogen - phosphorus-potassium) content according to rules established more than half a century ago. However, compost, a product that contains nutrients and organic matter, is not subject to any systematic rules for reporting its content, its qualities or potential risks. There are no labeling rules, and no published guidelines to establish such rules. The idea that compost is significantly different from inorganic fertilizers is not new; however, until recently the unique properties of compost were overlooked and instead compost has been generally classified as a nutrient-poor "soil amendment". Because of this, there is no simple way to give a summary concerning compost quality standards as they exist in the world. Therefore, this paper tried to present selected nutrient contents of currently used composts with some comparison using variety of established and published standards.

The composition of compost determines the suitability of the material for a particular task and the maximum amount that can be applied. About half of most forms of commercial composts consist of carbon and much of the remaining half is O_2 and H_2. There are also lower amounts of N, P, and a large variety of other constituents. The composition of these lower constituents depends on the source materials used for preparing compost (Table 1). For example, materials with good nitrogen content help in making good compost, but they should be less than the carbon-containing materials. Carbon containing materials should always be more than those containing high nitrogen, i.e., a ratio of 2:1-3:1 are the best (Edwards and Hailu, 2011).

Table 1. Dominant raw materials used by farmers for compost making

No.	District	Dominant raw materials	Method	Remark
1	Ada'a	Crop residue, Slurry, green leaf, ash (according to guideline)	Pit method	Only one person
		Slurry and left cattle feed (simply mixing, no proportion)	Pit method	Some of them
		Slurry collection in pit and drying	"	Some
2	Boset	Collected animal dug, home west and home used wood ash over the year	Hip method	Most of them
3	Arsi Negele	Crop residue, Slurry, green leaf, ash (according to guideline)	Pit method	Few people
		Slurry and left cattle feed (simply mixing, no proportion)	Pit method	Some of them
		Slurry collection in pit and drying	"	Some

Having this understanding, assessment of nutrient contents of currently used composts for crop production in East Shawa and West Arsi zones of Oromia was made in systematically selected three districts Ada'a, Bosat and Arsi Negele. The assessment depended on few parameters compost pH, electric conductivity (EC), total nitrogen (TN), organic carbon (OC), available phosphorus, available potassium, organic matter (OM) and carbon to nitrogen ratios (C: N ratio). The laboratory analysis results of collected compost samples from selected farmers of three districts are depicted in Table 2.

Compost pH

pH is a numerical measure of the acidity or alkalinity of the soil. The pH scale ranges from 0 to 14 with a pH of 7 indicating neutrality. Based on laboratory analysis results the pH of compost samples collected from farmers of Boset, Arsi-Nagale and Ada'a districts were ranged from 7.56 to 9.14, from 7.45 to 9.45 and from 5.96 to 9.72 while the average was 8.23, 8.35 and 7.84, respectively (Table 2), which were mostly in the alkaline range. According to FAO (2015) and The Pennsylvania State University (2009) most compost has a pH between 6 and 8. While Bord na Mona, (2003) recommends the agricultural compost should fall between a range of pH from 6.9-8.3 as an indication of relative stability. Products derived from wood residuals or peat moss can have pH values as low as 4.5, while manures are frequently alkaline (pH 8.0-8.5). Similarly use of ashes in compost making increase pH levels, since wood ash is derived from plant material that contains most of the 13 essential nutrients the soil must supply for plant growth. When wood burns, nitrogen and sulfur are lost as gases, and calcium, potassium, magnesium and trace element compounds remain constituting 25 % calcium carbonate, which makes them quite alkaline (pH greater than 7.0) by nature.

So, when we compare the assessment result with these standards most of investigated compost samples have high pH value above neutral (pH 7). This could be, as evidenced during survey, a result of high proportion of animal manures and home used wood ashes in the process of compost preparation. Since high pH enhance ammonia volatilization, lowering the pH value of compost help to reduce the problem of ammonia volatilization and reduce odours (woods End Research laboratory,1998).

Electrical conductivity

Soluble salt concentration is the concentration of soluble ions in solution. It is usually expressed as electrical conductivity (dS/m or millimhos per centimeter) of a saturated extract of either soil or compost. That means, electrical conductivity is used to measure the amount of nutrients in the compost that are in the form of salts. Since nutrients occur in compost as salts, high EC may also indicate high levels of nutrients, particularly potassium, calcium and nitrogen typically account for most of the salinity in compost products. Soluble nutrient, Sodium (NaCl) is an undesirable soluble salt (The Pennsylvania State University, 2009).

Accordingly the EC of analyzed compost samples collected from Boset, Arsi-Nagale and Ada'a districts of Oromia Region were ranged from 1.27-12.61(average 6.26 mmhos/cm at 25 ºC), from 0.22-9.86 (average 3.677 mmhos/cm at 25 ºC) and from 0.18-11.67 (average 5.03 mmhos/cm at 25 ºC), respectively (Table 2). As evidenced during survey, this could be the dominance of wood ash and animal dung in the proportion of composting material. The results indicated that most of the representative compost samples had EC values' above 3.5mmhos/cm at 25 ^{0}C, which was above permissive level for use as soil amendments material, especially for alkaline soils and salt sensitive crops (FAO, 2015; Australian Standard for Composts Soil Conditioners and Mulches, 2010). Similarly, according to Tognet *et al*, (2007), the Electric conductivity of matured compost should only range from 1-3 mmho/cm

Nutrient content

Although the nutrient content of compost is low compared to synthetic fertilizer products, the most essential nutrients in composts are inorganic forms which are released slowly and are less subjected to leaching compared to inorganic fertilizers (Larney *et al.*, 2008). Therefore, the incorporation of compost derived from biogenic household and garden waste to soil increseases soil carbon and nitrogen concentration (Lefied *et al.*, 2002). Hence, the most commonly required nutrients are nitrogen, phosphorus and potassium. Composts are often analyzed for total and available nutrients. However, available nutrient levels, rather than total nutrient levels, are a much better indication of the nutrients that compost is likely to contribute to your plants over the short term (Compost for Soils, 2011). Generally, nutrient values vary greatly among organic fertilizers and also vary greatly for a given organic fertilizer. According to Ross Penhallegon (2003), For example, the nitrogen in raw bone meal ranges from 2 to 6 %, and the phosphorus from 15 to 27 %. Differences reflect variations in the age of organic material, its decomposition rate, application method and timing, incorporation time, time exposed to the elements (rain, sun), the percentages of organic matter and water the material contains carbon-to-nitrogen ratio, microbe population, and soil type.

Compost total nitrogen

Nitrogen is one of the primary macro and the most deficient plant nutrient in the country. To replenish the soil with plant nutrient including nitrogen we need to add directly nutrient sources of fertilizer either organic or inorganic or both in combinations**.** Therefore the content of nitrogen and other nutrient in the compost is much determinant to determine how much to use this nutrient source compost. This study survey also made to now the nutrient content level of farmers' used composts for crop production. Accordingly the nitrogen content of compost from Boset, Arsi-Negele and Ada'a ranged from 0.15-0.45 %, 0.12-0.43 % and 0.17-1.15 % while the average was 0.29%, 0.28 % and 0.61%, respectively (Table 2). Even though standard nutrient content of compost vary from country to country, according to the following authors', total nitrogen will normally range from 1.5 to 3.5 % or 15,00-35,000 mg/kg (Ross Penhallegon, 2003) and 0.3 % – 1.5 % or 3g to 15g per kg of compost (Jacob, 1961; Martínez, 2013 in FAO, 2015) on dry weight basis in finished composts. Similarly, According to Alexander (2001), to report compost as having fertilizing capabilities and for it to be used in agriculture the TN content must be over 1 %.

According to this standard, total nitrogen value of most representative compost samples were not meet the standard. This could be due to loss of N through ammonia volatilization (Goyal *et al.*, 2005) during composting process that might be enhanced by high pH (woods End Research laboratory,1998). Composting process and storage of compost should be under shade to protect the reach of strong sun light and wind that enhance loss of nutrients (Sue Edwards and Hailu Araya, 2011). As evidenced during survey, composting process made by farmers was not under controlled condition. That means, proportion of the material used and site of compost preparation and storage were not according to hand book guideline provided for development agents. Besides compost storage was not under shade and it was wind exposed sites for most sampling areas. These all might be contributed for low total nitrogen in addition to raw material used for composting.

Carbon to nitrogen ratio

Poorly composted products can contain animal and plant pathogens, weeds, excessive levels of ammonium nitrogen (can be toxic) and can cause temporary nutrient (nitrogen and phosphorus) draw down, (Compost for Soils, 2011). Whereas, maturity is the degree to which the compost is free of organic phytotoxic substances that can adversely affect seed germination on plant growth. Maturity and stability also relate to the level of biological activity in compost. Stable compost consumes almost no nitrogen or oxygen and generates little carbon dioxide or heat. Therefore, stability and maturity are key elements of compost quality and help to determine its fitness for purpose (suitability for a specific use). Even though, maturity and stability are difficult parameters to evaluate, various maturity indicators for composts have been suggested (Gómez-Brandón *et al.*, 2008; Said-Pullicino *et al.*, 2007). For example, physical characteristics that are suggestive of mature compost include a dark brown to black color and a soil-like or musty odor. There should be little or no recognizable grass or leaves. Compost that has a sour or putrid smell should not be accepted. If the delivered compost is very hot (12 ^{0}F) or if the pile becomes very hot after rewetting, then the product is not stable. Though there is no single parameter that completely defines maturity, but the C:N ratio and reduced rate of CO_2 evolution from mature compost can be used as reliable indicators (The Pennsylvania State University, 2009). Likewise, a good quality compost will have a dark brown color and maturity index (ammonia to nitrate (NH_3: NO_3) and C:N) ratio in the range of 0.5 to 3 and less than 25, respectively (Woods End Laboratories, 2013); while having less concentrations of heavy metals, weed seeds and pathogenic bacteria (Brinton, 2000).

So, according to an assessment made, as indicated in the Table 2, most carbon nitrogen ratio of representative compost samples collected from all study areas were below 25 except for few samples those were as high as 35 and above. Therefore, in relation to carbon nitrogen ratio, most of the analyzed representative compost samples were meet the quality standard because a carbon to nitrogen ratio of below 25 is preferred if the material is claimed to be nitrogen stabilized, (FAO, 2015; Pennsylvania State University, 2009; Compost for Soils. 2011; Woods End Laboratories, 2013). Because Compost C:N ratios typically decrease during composting if the starting C:N ratio Composts with high C:N ratios (>30) will likely tie up (immobilize) nitrogen if applied to soil, while those with low C:N ratios (<20) will mineralize organic nitrogen into inorganic (plant-available) nitrogen (Pennsylvania State University, 2009).

Available phosphorus

Phosphorus plays a role in photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several other processes in plants (Cornell Co-op Extension, 2005)**.** Therefore, to improve production and productivity soil should be supply with fertilizer (organic and inorganic fertilizer), whereas compost is one of the organic sources of nutrient phosphorus. Even though phosphorous availability from compost is much higher than nitrogen availability from compost (Prasad, 2009), similar to other nutrient, phosphorus content of compost varies depending on raw material used for composting and management of the process and the compost after decomposition. However, the most notable exception is manure, which is typically high in phosphorus and potassium as well as nitrogen. This makes manure one of the most balanced compost materials available. Even, if need more phosphorus than nitrogen in compost, horse manure is the smartest choice; it has roughly four times more phosphorus than nitrogen and is also high in potassium, which fuels metabolism in plants, (http://homeguides.sfgate.com/composting-nitrogen-phosphorus-71777.html).

Similarly, the result of compost samples laboratory analysis for an assessment made on nutrient content of the currently used compost are indicated in Table 2. Accordingly the available phosphorus content of compost for Boset, Arsi Negele and Ada'a were ranged from 0.12-10.64 ppm (average 2.67), 0.08-2.86 ppm (average 1.07) and 2.58-24.49 ppm (average 13.01), respectively. According to Jacob, (1961) and Martínez, (2013) p content of standard compost range from 1g to 10g per kg of compost (1000-10,000ppm), similarly according to Ross Penhallegon, (2003), it ranges from % P 0.5 to 1(5000-10,000 ppm). Even though available phosphorus contained in most sampled representative composts samples from all districts were above total nitrogen it was far below the range. This might because of raw material used for compost making and level of compost management during and after preparation. As evidenced during survey observation, combination of raw material, composting process and compost management was not according to guideline.

Available potassium

Potassium is the third major plant and crop nutrient after nitrogen and phosphorus. Therefore it is one of the major nutrients required by all crops and is present in large quantities in the plant in the form of the cation K^+. It is required in very large quantities, with peak potash uptake in cereals reaching more than 250 kg/ha by the end of flowering, (Cavendish Agri Services, 2013). Therefore, potassium is fundamental to many metabolic processes through the activation of a large number of enzymes required for chemical reactions. Generally, because potassium improves the overall health of growing plants and helps them fight against disease, it is known as the "quality" nutrient, (Wikipedia, the free encyclopedia, 2017). So, a shortage of potash will not only result in lower nitrogen use efficiency, but will also lead to greater drought susceptibility, increased lodging, a reduction in photosynthesis and restricted movement of water, nutrients and sugars around the plant, (Cavendish Agri Services, 2013).

Accordingly the available potassium content of compost for Boset, Arsi Negele and Ada'a were ranged from 2632-5367 mg/kg (average 4090 mg/kg), 214-5942 mg/kg (average 2850) and 1130-4218 mg/kg (average 2360 g/kg), respectively (Table 2). As compared to other tested nutrient, potassium content of the compost samples collected from the study areas were high. This is might be because of that K is not incorporated into organic compounds in plants or animals, so K in compost is readily available. But according to established average nutrients content in compost by Jacob, 1961, Martínez, 2013, (Potassium ranges 0.3 - 1.0 % (3000-10,000 mg per kg), except for Boset District, available potassium contained in most sampled composts from the rest districts were below the range (Table 2).

These low potassium contents of compost samples collected from Arsi-Negele and Ada'a districts might be contributed from raw material used that dominated by animal manure without keeping the proportion according to the guideline. On the contrary, relatively high potassium content of compost samples that were collected from Boset district was contributed by the use of high proportion of home used wood ash during compost preparation. These were also evidenced during sample collection and interview made during sample collection. The document organized by Proc. Estonian Acad. Sci. Biol. Ecol., (2006) and Ross Penhallegon, (2003) in Oregon State University Extension Service and offers as educational programs, activities, and materials also reveal that wood ash contained relatively high potassium whereas dry animal manure contained relatively low potassium. Similarly, earlier studies on ash chemistry in Scots pine (Pinus sylvestris L.) have revealed the positive effects of wood ash on Ca and K contents of the soil as well as an increase of K, Mg, S, Bo, Fe and Zn in tissues of the Scots pine (Vuorinen and Kurkela, 2000; Demeyer *et.al.*,2001; Jacobson, 2001).

Organic matter

Organic matter is the measure of carbon based materials in the compost. It plays a vital role in the soil including minimizing soil temperature fluctuations, serving as a nutrient warehouse, buffering the soil to changing pH, increasing the ability of the soil to hold nutrients, provide habitat for beneficial soil microorganisms and can be improve soil structure along with the ability of the soil to hold water and air. It is usually expressed as a percentage of dry weight of compost. There is no absolute value of organic matter, which is ideal for compost. Growers should make notes of the organic matter (OM) content of potential soil amendements when comparing the price and qualities of different composts; it may range from 30-70 % of OM (US Composting Council, 2003). Hence high quality compost will usually have a minimum of 50 % organic content based on dry weight.

As indicated in Table 2, the percent organic matter content of compost samples collected from Boset, Arsi Negele and Adaa districts ranged from 3.83-16.21 % (average 9.13 %), 4.35-18.28 % (average 10.84 %) and 2.73-21.45 % (average 11.76 %), respectively. According NRAES,(1999) and US Composting Council (2003) standard set as quality parameter for finished compost, percent organic matter content should be ranged in between 30 - 70 %. Low percent organic matter content of compost is highly affected by raw material used that have either nitrogen-rich or carbon-rich input materials (Van der Wurff, *et.al.* 2016). Similar to other nutrient level in composts, as evidenced during surveying observation, this low organic matter content of compost could be due to absence or low proportion of carbon rich material like crop residue.

Organic carbon

Organic carbon is an important ingredient in all soils and has an important role to play in maintaining soil structure, nutrient availability and water holding capacity. It also serve as a vital role in maintaining a healthy soil ecology (Paul, 2007). The average of compost organic carbon content samples collected from Boset, Arsi-Negele and Ada'aa districts were 2.67, 1.07 and 24.49 %, respectively (Table 2). When these results correlated with standard sated by Australian (Australian standard, 1999), which is above 19.4 % organic carbon content of all compost representative samples were far below the standard. Similar to Compost organic matter discribed above these low percent organic carbon could be due to absence or low proportion of carbon rich material like crop residue.

Table 2. Summary of chemical analysis results of compost samples collected from Bosat, Arsi-Negele and Ada'a districts

Range	pH	EC (mmhos/cm)	TN (%)	OC (%)	Avail. P (ppm)	Avail. K (mg/kg)	OM (%)	C:N ratio
	Bosat District							
Min	7.56	1.27	0.15	2.22	0.12	2632.00	3.83	15.31
Max	9.14	12.61	0.45	9.41	10.64	5367.00	16.21	21.01
Aver	8.23	6.26	0.29	5.30	2.67	4091.40	9.13	18.56
Arsi-Negele District								
Min	7.45	0.22	0.12	2.52	0.08	214.00	4.35	14.38
Max	9.45	9.86	0.43	10.602	2.86	5942.00	18.28	41.44
Aver	8.35	3.68	0.28	6.289	1.07	2844.80	10.84	24.05
Ada'a District								
Min	5.96	0.18	0.17	1.58	2.11	1130.00	2.73	6.03
Max	9.72	11.67	1.15	12.44	24.49	4218.00	21.45	43.05
Aver	7.84	5.03	0.61	6.82	13.01	2357.91	11.76	12.84

Note: Min = minimum; Max = maximum; Aver = Average

Conclusion and Recommendations

Assessment of nutrient contents of farmers' composts for crop production was made during 2014-2016 in Boset, Arsi-Negele and Ada'a districts of East Shewa and West Arsi zones of Oromia. Based on laboratory analysis capacity and standard methods, collected compost samples were analyzed and interpreted for few parameters pH, EC, TN, OC, Avai. P and K, and compared with existing established standard compost quality parameters.

The results indicated that pH of compost samples collected from farmers of all districts were ranged from 5.96-9.72, while some of the samples were beyond the standard set by FAO (2015) and Pennsylvania State University (2009), range of pH between 6 and 8. Electrical conductivity of analyzed compost samples collected from all districts ranged from 0.18-12.61 mmhos/cm, and most of the representative compost samples had EC values' above 3.5mmhos/cm, which was above permissive level for use as soil amendments material, especially for alkaline soils and salt sensitive crops (FAO, 2015; Australian Standard for Composts Soil Conditioners and Mulches, 2010). Accordingly, the percent total nitrogen and available phosphorus content of composts from all districts ranged from 0.12-1.15 % and 0.08-24.49 ppm, respectively. According to standard set by Ross Penhallegon (2003), Jacob (1961) and Martínez (2013), TN value of most representative compost samples were not met the standard, and avai. P contained in representative composts samples were far below the standard range.

The available potassium content of compost for Boset, Arsi Negele and Ada'a were ranged from 2632-5367 mg/kg. As compared to other tested nutrients, even though potassium content in compost samples was high, most of them were below the standard, 0.3-1.0 % (3000-10,000mg/kg (Jacob, 1961, Martínez, 2013). According NRAES (1999) and US Composting Council (2003), percent organic matter standard set as quality parameter for finished compost ranged in between 30-70 % while organic matter content of the representative compost samples were ranged from 2.73-21.45 %, which were far below the standard established. This low percent organic matter content of composts are highly affected by raw materials used that have either nitrogen-rich input materials (Wurff, *et.al.* 2016).

Carbon to nitrogen ratio of most representative compost samples were below 25 and met the quality standard because a carbon to nitrogen ratio of below 25 preferred if the material is claimed to be nitrogen stabilized (FAO, 2015). In general based on all parameter required for quality and nutrient content analysis, nutrient contents and quality of farmers' composts used for crop production were not met the standard. This could be due to raw materials used and their proportion, composting process and storage condition were not according to guideline provided and lack of close supervision and guidance by local development agents.

Therefore, based on the results of nutrient contents of farmers' composts, the following recommendations were drawn. The EC values of most analyzed compost samples were as high as and above 3.5 mmhose/cm. Such composts should be checked whether high nutrients or high salt (NaCl) content is responsible for any elevated EC readings before using for soil amendment, and not safe to use such compost on alkaline soil. For agricultural sustainability and productivity, encouraging farming community for the use of organic fertilizers will be a prerequest for all stakeholders. Besides, training and close supervision for farmers on site selection and pit preparation for composting process, raw material used, proportions and procedures to be followed, storage condition of finished compost should be a critical concern during compost preparation. Finally, wrong information on farmers' compost quantity and quality at different levels that may bias policy and decision makers should be monitored and checked by concerned institutions.

Acknowledgment

The authors would like to forward gratitude to IQQO for financial support and Batu Soil Research Center staff for their support during the assessment; would also extend special thanks for laboratory workers of the center for unreserved action during compost samples preparation and analysis.

References

Abegaz, A. & van Keulen, H., 2009. Modelling soil nutrient dynamics under alternative farm management practices in the Northern Highlands of Ethiopia. *Soil & Tillage Research*, 103, 203-215.

Albiach, R., R. Canet, F. Pomares, and F. Ingelmo, 2001. Organic matter components and aggregate stability after the application of different amendments to a horticultural soil. Bioresour. Technol. 76:125-129.

Alexander. R., 2001. Field guide to compost use. Bethesda, maryland: U.S. Composting Council

AS-99, 1999. Australian Standard. Composts, soil conditioners and mulches. AS454-1999. Standards Association of Australia. New bush

ATA, 2013. *Transforming Agriculture in Ethiopia. Annual report 2013/2014*. Addis Ababa: Ethiopian Agricultural Transformation Agency.

Australian Standard for Composts Soil Conditioners and Mulches, 2010; compost management; and soil and Plant Laboratory

Bord na Mona, 2003. Compost testing and analysis Service – interpretation of results, available from Bord na Mona, Newbridge, Co. Kildare Natural Resource, Agriculture, and Engineering Service

Brinton. W. F., 2000. Compost quality standards and guidelines: an international view. Woods End Research Laboratory Inc, New York.

Caravaca, F., A. Lax, and J. Albaladejo, 2001. Soil aggregate stability and organic matter in clay and fine silt fractions in urban refuseamended semiarid soils. Soil Sci. Soc. Am. J. 65:1235-1238

Cavendish Agri Services, 2013. Potash Development Association. nfo@pda.org.uk

Central Statistical Agency, 2015. Agricultural sample survey report on crop and livestock product utilization 2014/2015 (2007 E.C.). Bulletin 578, Volume VII. de

Compost for Soils, 2011. *An initiative of Compost Australia.* www.compostforsoils.com.au. Compost – A Guide for Evaluating and Using Compost Materials as Soil Amendments. ByWilliam Darlington, Consultant. Soil & Plant Laboratory, Inc., Orange Office (714) 282-8777

Cornell University Cooperative Extension, 2005. Phosphorus Basics – The Phosphorus Cycle, Agronomy Fact Sheet Series , Fact Sheet 12

Demeyer, A., J.C. Voundi Nkana and M.G. Verloo, 2001. Characteristics of wood ash and influence on soil properties and nutrient uptake: An overview. Bioresource Technology, 77: 287-295

FAO, 2015. Farmers's Compost Handboo Experiences in Latin America. Food and Agriculture Organization of the United Nations Regional Office for Latin America and the Caribbean, Santiago

Feoli, E., Vuerich, L.G. & Zerihun, W., 2002. Evaluation of environmental degradation in northern Ethiopia using GIS to integrate vegetation, geomorphological, erosion and socio-economic factors. *Agriculture, Ecosystems & Environment,* 91, 313-325.

Gómez-Brandón, M., Lazcano, C. & Domínguez, J. (2008). The evaluation of stability and maturity during the composting of cattle manure. Chemosphere, 70, 436-444. Goyal, S., Chander, K., Mundra, Goyal, S., Dhull, S.K. & Kapoor, K.K. (2005). Chemical and biological changes during composting of different organic wastes and assessment of compost maturity. Bioresource Technology, 96, 1584-1591.

Haileslassie, A., Priess, J., Veldkamp, E., Teketay, D. & Lesschen, J.P., 2005. Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances. *Agriculture, Ecosystems & Environment,* 108, 1-16.

Hurni, H., 1988. Degradation and conservation of soil resources in the Ethiopian highlands. Part 2.Climates, soil and water. *Mountain Research and Development,* 8, 123–130.

http://homeguides.sfgate.com/composting-nitrogen-phosphorus-71777.html

Jacob, 1961. Average nutrient content in compost. Inc. Food and Agriculture Organization of the United Nations Regional Office for Latin America and the Caribbean Santiago, 2015 (Farmer´S Compost Handbook Experiences in Latin America). E-ISBN 978-92-5-107845-7 (PDF)

Larney K., Toscano P., and Casachia T., 2008. Guidelines for Specification of Quality Compost for Use in Growing Media. Banbury.

Lefied V., Leal W., and Brandli S., 2002. Evaluation of commercial compost quality and Waste Management & Research, 20, 389-397.

Lemenih, M., Karltun, E. & Olsson, M. (2005a). Assessing soil chemical and physical property responses to deforestation and subsequent cultivation in smallholders farming system in Ethiopia. *Agriculture, Ecosystems & Environment,* 105, 373-386.

Martínez, 2013. Average nutrient content in compost. Inc. Food and Agriculture Organization of the United Nations Regional Office for Latin America and the Caribbean Santiago, 2015 (Farmer´S Compost Handbook Experiences in Latin America). E-ISBN 978-92-5-107845-7 (PDF)

Mugwe, J., Mugendi, D., Mucheru-Muna, M. Merchx, R.Chianu, J. and Vanlauwe, B. 2009. Determinants of the Decision to Adopt Integrated Soil Fertility Management Practices By Small Holder Farmers in the Central Highlands of Kenya. Expl Agricu. 45:61-75. Cambridge University Press

Ngwira, A.R., Nyirenda, M. & Taylor, D., 2013. Toward Sustainable Agriculture: An Evaluation of Compost and Inorganic Fertilizer on Soil Nutrient Status and Productivity of Three Maize Varieties Across Multiple Sites in Malawi. *Agroecology and Sustainable Food Systems,* 37, 859- 881.

NRAES, 1999. Field Guide to On-Farm Composting. Publication. Vol. 114. Ithaca: Print.

Odlare, M., Arthurson, V., Pell, M., Svensson, K., Nehrenheim, E. & Abubaker, J. (2011). Land application of organic waste - Effects on the soil ecosystem. *Applied Energy,* 88, 2210-2218.

Paul E.A. (2007) Soil Microbiology, Ecology and Biochemistry. 3 rd Edition, Academic Press, London, UK. pp. 231-256

Prasad, M. (2009) A Literature Review on the Availability of Nitrogen from Compost in Relation to the Nitrate Regulations SI 378 of 2006. Environmental Protection Agency, Wexford.

Proc. Estonian Acad. Sci. Biol. Ecol., 2006. Influence of wood ash on soil chemical composition and biochemical parameters of young Scots pine. Malle Mandre, Department of Ecophysiology, Institute of Forestry and Rural Engineering, Estonian University of Life Sciences, Viljandi mnt. 18B, 11216 Tallinn, Estonia; mma@rmk.ee

Ross Penhallegon, 2003. OSU/Lane County Extension Horticulture Agent. In: Karen Ailor (eds).

Shiferaw, B. & Holden, S., 1999. Soil erosion and smallholders' conservation decisions in the highlands of Ethiopia. *World Development,* 27, 739-752.

Said-Pullicino *et al.*, 2007. Changes in the chemical characteristics of dissolved organic matter during the composting process and their influence on compost stability and maturity Geophysical Research Abstracts, Vol. 7, 02416, 2005

SUE EDWARDS AND HAILU ARAYA., 2011. How to make and use compost. Climate change and food systems resilience in sub-saharan Africa. Italy: Institute for Sustainable Development (ISD), pp. 385-436.

Taddese, G., 2001. Land Degradation: A Challenge to Ethiopia. *Environmental Management,* 27, 815- 824.

The Pennsylvania State University, 2009. Using Organic nutrient sources. Code # UJ256

US Composting council, 2003. All technical, economic and environmental comparison of composting and anaerobic digestion of biodegradable municipal waste

Van der Wurff, A.W.G., Fuchs, J.G., Raviv, M., Termorshuizen, A.J. (Editors), 2016. Handbook for Composting and Compost Use in Organic Horticulture BioGreenhouse COST Action FA 1105, www.biogreenhouse.org. ISBN: 978-94-6257-749-7

Vanlauwe, B., Kihara, J., Chivenge, P., Pypers, P., Coe, R. & Six, J., 2011. Agronomic use efficiency of N fertilizer in maize-based systems in sub-Saharan Africa within the context of integrated soil fertility management. *Plant and Soil,* 339, 35-50.Vuorinen, M. and J.C. Kurkela, 2000. Granulated wood ash and a N-free fertilizer to a forest soil: effects on phosphorus availability. Forest Ecology and Management, 66: 127-136.

Vuorinen, M. and J.C. Kurkela., 2000. Granulated wood ash and a N-free fertilizer to a forest soil: effects on phosphorus availability. Forest Ecology and Management, 66: 127-136.

Wikipedia, the free encyclopedia, 2017. Creative Commons Attribution-ShareAlike License. Wekipedia is a registered trademark of the Wikimedia Foundation, Inc., a non-profit organization. Info-en@wikimedia.org. https://en.wikipedia.org/wiki/Potash 12/31/2016.

Woods End Research Laboratories, 2013. Laboratory test interpretation. Journal of Woods End Laboratories 10: 1-7.

Woods end Research laboratory, 1998. Processes and plant for waste composting and other aerobic treatment. R&D technical report P1-311/TR. Environment Agency

Assessment of Nutrient Contents of Farmers Used Composts for Crop Production in Buno Bedele Zone, Southwest Oromia, Ethiopia

Gedefa Sori*, Dechasa Mengistu and Abdulmalik Mohammed

Bedele Soil Research Center, P.O.Box, 167, Bedele, Ethiopia

Corresponding authors:*sorigedefa45@gmail.com

Abstract

This assessment was made to study the nutrient contents of farmers' composts for soil fertility improvement and crop production from 2014-2016*. The specific objectives were to assess and evaluate nutrient contents of farmers'composts prepared from diversified material sources and to make database for composting processes. A total 213 samples were collected from Bedele,Gechi and Dabo Hana districts by random sampling methods from a representative sites. The pH, moisture conent, OC, TN,C:N ratio, exchangeable Ca and Mg, available P, EC, Mn, Fe, Cu and Zn were analyzed according to standard laboratory procedures. Average OC and OM contents of farmers' composts were 10.1 and 13.9, 12.1 and 18.9, 23.96 and 20.86% in Bedele, Gechi and Dabo Hana districts, respectively. Average moisture contents of the study area were 7.2, 7.6 and 6.2% in Bedele, Gechi and Dabo Hana, respectively. Moisture content of farmers' composts in the three districts was below the the standard range. This might be due to the problem of watering during compost preparation; average electric conductivity, 1.5, 1.1 and 1.2mmhos/cm in Bedele, Gechi and Dabo Hana disticts,respectively. The majority of the macro- and micro-nutrients analyzed for compost collected from the three districst were below the recommended range. This is due to unbalanced substrate during compost preparation especially absence of legume materials or residue from mixing materials.*

Keywords: *Compost, macronutrient, micronutrient,*

Introduction

The performance of agriculture depends on natural factors and the intensity of agricultural inputs. The vast area of Africa in general and Ethiopia in particular is characterized by low soil fertility, high soil degradation, rain-fed and fragmented land holding, extremely low external inputs such as fertilizer and agro-chemicals, and the use of traditional farming techniques (Gashaw *et al*., 2014). In sustainable and integrated crop production systems the inclusion of compost proved to have significant effect on quantity and quality of crop productions (Vaje, 2007 and Ganjali, *et al*., 2013). Irrespective of its importance in integrated soil fertility management, compost utilization among farmers in Ethiopia is very limited. Farmers are aware of the benefits that could be obtained from use of composts, but they don't have a simple to use and health method of composting (Rader, 2013) which accompanied by seasonal agricultural activities burdens them to use the conventional method of composting.

Several studies indicate that the use of compost on land may improve several plant and soil parameters, thereby making compost an interesting option for soil restoration purposes, while taking advantage of its fertilizer properties (Hargreaves *et al*. 2008).Compost is the best overall for soil amendment that growers can use to increase the quality and the health of soil (Postma *et al*., 2003). Compost provides soil with nutrients, organic matter, and beneficial microorganisms, which can improve crop health, growth, quality, and yields.

Composting is a method of enhancing natural decomposition process, through balanced carbon to nitrogen ratio (C:N) of raw organic materials that should be supplied with adequate moisture and oxygen to intensify the activity of decomposing microorganisms (Rader, 2013). Composting process requires some facilities and knowledge on the decomposing organic materials such the C:N ratio to properly mix a desirable proportion of organic materials in the compost pile (Rader, 2013). In the compost pile mixes when the C:N ratio goes higher or lower the composting process will be hindered or may be stopped at all (Chen *et al*., 2011). It is very important to keep the C:N of the compost pile in the range between 25:1 and 35:1. However, C:N higher than 35 would lower multiplication of decomposing microorganisms due to shortage of N to synthesis their body protein. And C:N lower than 25 result in production of high amount of ammonia by microorganisms, which also cause lower pH, reduced decomposition and unpleasant odor of the compost (Marta *et al*., 2016).

Monitoring and controlling the moisture content, oxygen level and temperature of the composting process is also another important issue to have good quality and large quantity compost within scheduled time desired (Rader, 2013). On the other hand type of raw materials, their proportions in the pile and the methods of composting significantly affect the controllability of composting (rate of decomposition) and the quality of the compost. To have a controlled composting process and good quality compost the choice of composting methods is crucial. The quality of compost is determined by the nutrient composition, concentration of heavy metals, presence of inert materials, inclusion of weed seeds, pathogenic bacteria and compost maturity (Brinton, 2000). Thus, a good quality compost will have a dark brown color and maturity index (ammonia to nitrate (NH_3: NO_3) and C:N) ratio in the range of 0.5-3 and less than 25, respectively (Woods End Laboratories, 2013); while having less concentrations of heavy metals, weed seeds and pathogenic bacteria (Brinton, 2000).

As the price of inorganic fertilizer becoming expensive from time to time, farmers are inclined toward using compost for crop production. It is not the amount of compost that applied to the soil, but the amount of nutrients supplied to the crop that determines the level of crop productivity. Then the use of compost must be based on the materials used for compost preparation rather than the bulk amount of compost applied to soil. It is a necessity to know nutrient composition of any material used for fertility improvement, and composts must be justified with laboratory test to know the initial soil nutrient status, nutrient content of compost used at each cropping time based on the type of composting material sources, and the requirement of addition of chemical fertilizer application to get the targeted yield potential of crop types in use, i.e., integrated nutrient management is essential for our current soil fertility situations rather than single fertilizer source.Therefore an assessment was initiated with the specific objectives were: to asses and evaluate nutrient contents of farmers practiced composts prepared from diversified material sources and to identify the gapand giving the directions for composting processes.

Materials and Methods

Description of the study areas

Bedele, Dabo Hana and Gechi districts are one of the agricultural potential areas selected by the AGP beneficiary districts of Oromia region. They are located in the western part of Oromia, on the main road to Metu, 60 kilometers (km) away from a zonal town (Bedele), and 420 km away from Addis Ababa. The districts are located between 8°14'30"N to 8°37'53"N, 8°30'28.721"to 8°41'34.595"N and 8°14'34.56" to 8°25'39.77"N latitude and 36°13'17"E to 36°35'05"E, 36°26'19.157" to 36°30'41.101" E and 36 °24'59.04" to 36°35'14.19" longitude at Bedele, D-Hana and Gechi respectively. The farming system here is characterized by forest coffee-cereal-livestock mixed farming system. There are two distinct seasons in three districts the rainy season starting in late March and ending in October and the dry season from November to early March. The mean annual temperature is 24.7ºC and the rainfall is often in excess of 1800 mm per annum. Various cereal crops, vegetables, livestock, oil crops and coffee are under production and the rainfall is very good in these potential areas. The three districts has highlands, mid- and low-land agro-ecologies.

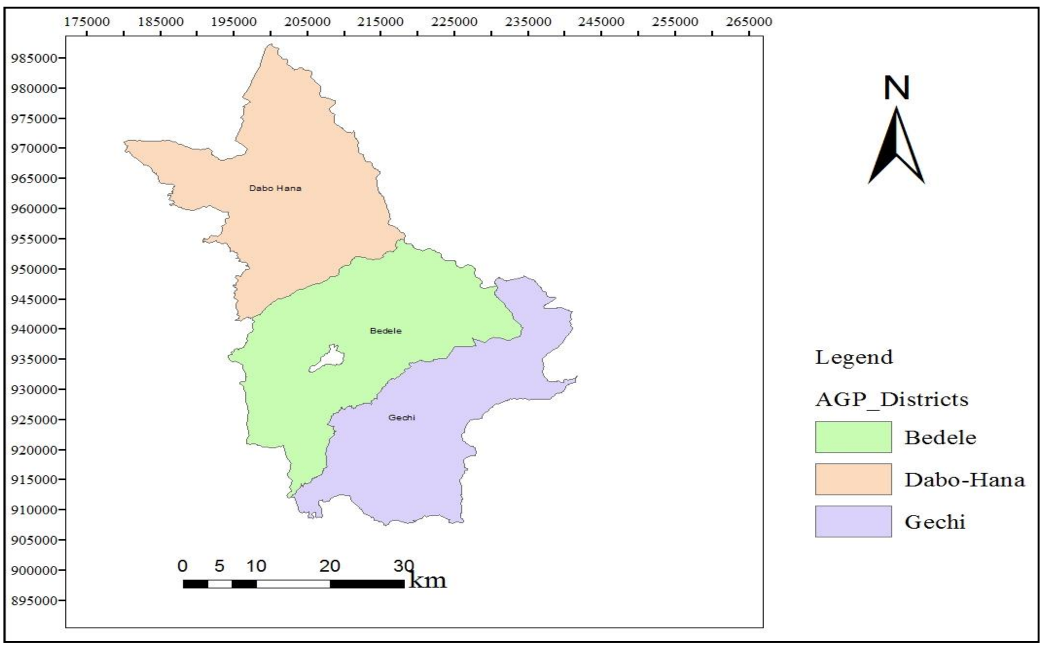


Figure 1. Location map of the study areas

Procedure used to select the districts and farmers

This assessment of Nutrient Contents of Farmers Practices of Compost for Crop Productionwas conducted in different AGP beneficiary districts of Southwestern Oromia regional state such as Bedele, Gechi and Dabo Hana from 2014-2016. A procedure used to select these three districts and 213 farmers first by grouping of administrative zones for the sake of compost samples collection and analysis like Buno Bedele Zone. Secondly we have been selected three of AGP beneficiery districts from this zone and we have selected ten kebeles per district and eight a representative farmers per kebele (i.e 3*10*8*1=240) was proposed. However, according to the accessability only 213 compost samples were thoroughly collected from farmers practiced compost heap.

Collection of raw materials for composting

According to information gathered during survey, various locally available organic materials collected were used as composting materials for all methods of composting. The organic/raw materials used were sorghum leaves and stalks, kitchen scraps, tree leaves, broad leaved weeds, grass weeds, livestock manure, wood ash and saw dust were collected. Finally the common bulking agent top soil was taken from different fertile soil.

Sampling method

Representative samples were taken from three point (at the beginning, middle and end of the pit); 500gm composite samples were taken from all piles using polyethylene bag and transported by vehicle to Bedele soil research center, soil laboratory. The samples were analysed at analytical chemistry and soil laboratory. The samples were taken from each heap from all sides of the heap (i.e. from the bottom, top, left, right side and interior of the heap) by hand using gloves and by turning the heap to take the sample from the bottom of the heap and thoroughly mixed together to get a homogeneous and representative sample of the entire heap of composting.

Laboratory methods used for compost analysis

During the composting process the temperature of the compost was recorded for the first 30 days. The date of compost maturity was recorded when the compost assumed a dark brown colour following their curing phase and confirmed by maturity index. Chemical characteristics of various compost samples analysis were carried out in the Bedele Soil Research Center, Soil Laboratory laboratory using standard procedure. The method used for the analysis of moisture content were (drying at 105^{o}C to constant weight by gravimeter method (Arum Kumar 2008); The pH was measured potentiometrically using a digital pH-meter in the supernatant suspension of 1:2.5 soils to water ratio.; Electrical conductivity (1:2.5 water extract, digital conductivity meter); Calcium and magnesium was analyzed using atomic absorption spectrophotometer following an ammonium acetate extraction method and measured by using flame photometer (Rowell, 1994).; was determined using the wet oxidation method (Walkley and Black, 1934). Organic matter content was calculated from determined organic carbon using conversion factor 1.724 (Mani *et,al*.; 2007) and the C:N ratio of the compost was determined from the ratio of total organic carbon to total Nitrogen. Manganese, iron, copper and Zink were analyzed using atomic absorption spcetro-photometer at JEG Lab and glass.

Results and Discussion

Compost pH

The pH value of compost is important since applying compost to soil may alter the soil pH and therefore have an effect on the availability of nutrients to plants. According to Bord na Mona, (2003) recommends the agricultural compost should fall between a range of pH from 6.9-8.3 as an indication of relative stability, while values near 7.5 are most typical. Most composts are slightly alkaline after curing, but some may be slightly acidic due to properties of their feedstock. According to Bord na Mona recommendation the average pH values of compost collected from Bedele, Gechi and Dabo Hana was 7.6, 7.7 and 8.1 (figure 2, Table 1, Table 2 and Table 3), respectively. The analytical result of compost collected from Bedele, Gechi and Dabo Hana was agree with the sated standard optimum range of compost (Bord na Mona, 2003). Efforts will need to be made to lower the pH value of compost if it exceed 6.9-8.3 range. Lowering the pH value of compost also help to reduce ammonia volatilization and reduce odours (woods End Research laboratory,1998). However, low–pH composts are in many cases incompletely cured, and may contain elevated concentrations of organic acids. Oganic acids are a routine byproduct of decomposition early in the composting process, but they should no longer be present at later stages.

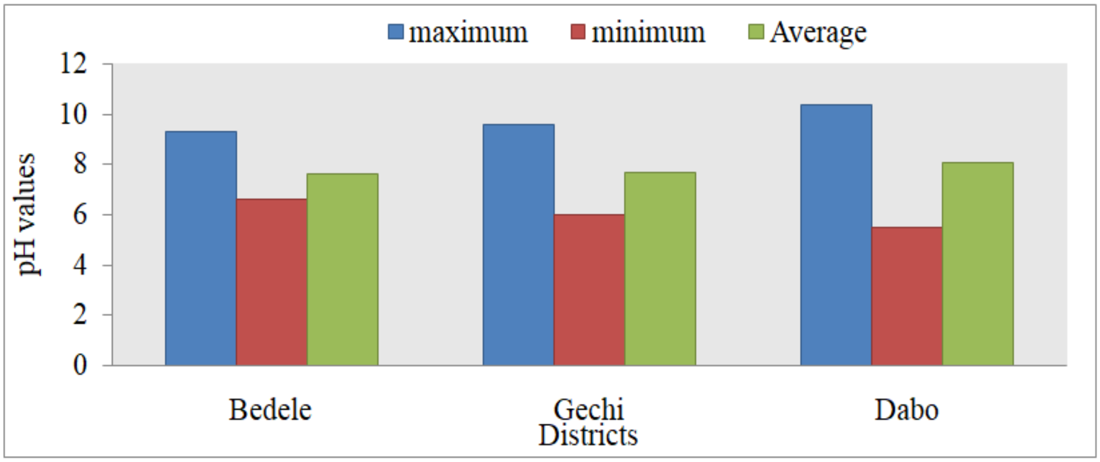


Figure 2**.** pH values of compost from three districts

Organic matter content

Organic matter is an important ingredient in all soils and has an important role to play in maintaining soil structure, nutrient availability and water holding capacity. It also serve as a vital role in maintaining a healthy soil ecology (Paul, 2007). It is usually expressed as a percentage of dry weight of compost. There is no absolute value of organic matter, which is ideal for compost. Growers should make notes of the organic matter (OM) content of potential soil amendements when comparing the price and qualities of different composts; it may range from 30-70% of OM (US Composting council, 2003).

The organic matter contents of compost collected from all sites was calculate from the average organic carbon content of the compost. According to the organic matter range of (US composting council, 2003) the average of organic matter content of compost collected from all sites were found in the recommended range (Figure 3). Composts that contain large amounts of inert materials , such as soil, Silica, or ash, will not provide as many benefits as a compost that is richer in organic materials. For soil amendments, however, an upper limit of 65% OM is commonly imposed, since materials with a greater organic matter may not be fully stable.

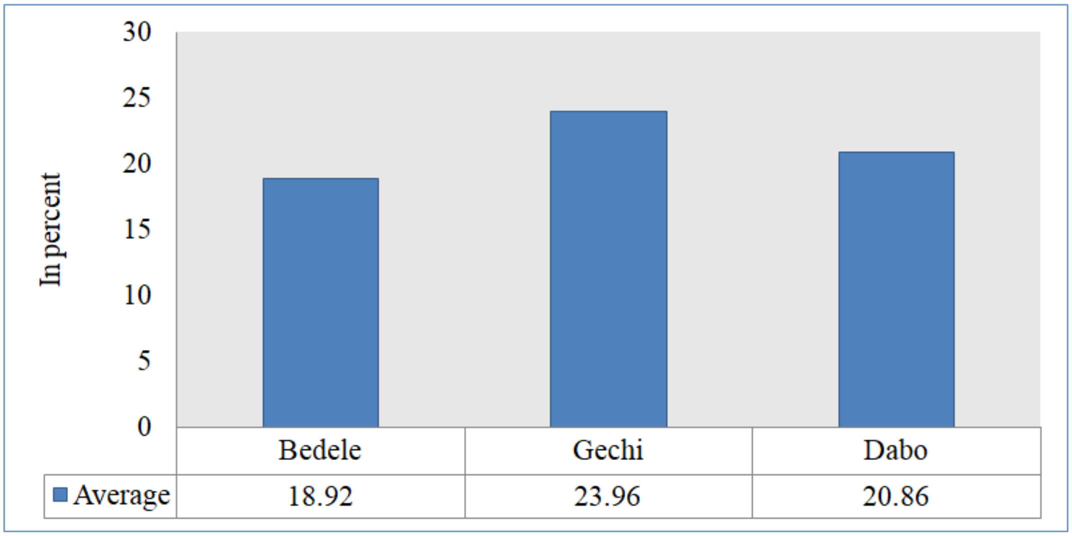


Figure 3. Organic matter contents of compost in the three districts

Moisture content

Moisture content is a measure of the amount of moisture present in a compost sample and is expressed as a percentage of fresh weight. Compost with low moisture content (<35%) may be too dry and dusty, irritating when handled. Compost with too high moisture content (>65%) can become too clumpy and difficult to transport which will limit it's chances of being marketed as a quality product (US composting council, 2003).

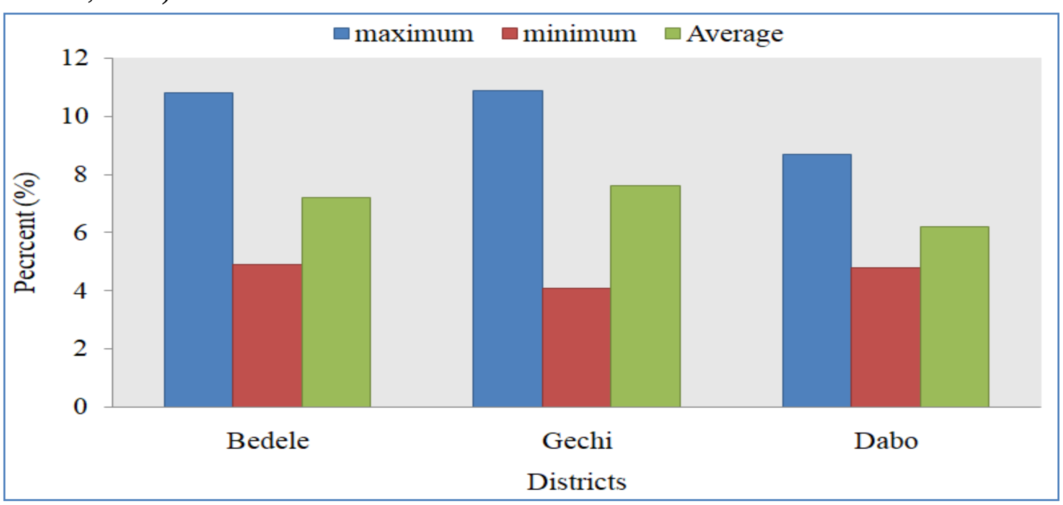


Figure 4. Moisture content of compost in the three districts

An optimum range of moisture for matured compost was 35-55% (Zucconi *et al.*; 1981). Higher moisture increased handling and transportation cost. An average moisture content of compost collected from Bedele, Gechi and Dabo Hana was 7.2, 7. 6 and 6.2 respectively (figure 3). The result revialed that it was bellow the optimal range of matured compost (Zucconi *et al.*; 1981).

Electrical conductivity

Electric conductivity is a measure of the soluble salt content of compost in our case. Repeated addition of high salt compost may result in increases in soil salinity to levels that are toxic to salt sensitive plants but no problem in acidic or high rain fall area. Therefore the Electric conductivity of matured compost should only range from 1 to 3 mmho/cm (Tognet *et al*, 2007). According to this outer the average electric conductivity of the study area wasmatched with the optimal range. The average electric conductivity of Bedele, Gechi and Dabo Hana districts were revialed as 1.5, 1.1 and 1.2mmho/cm, respectively(Figure 5). Estimation of the likely impact of compost on soil EC reqires information on the compost application rate in tons per ha, along with soils texture, organic matter content and pre-compost EC (Reddy and Crohn, 2012).

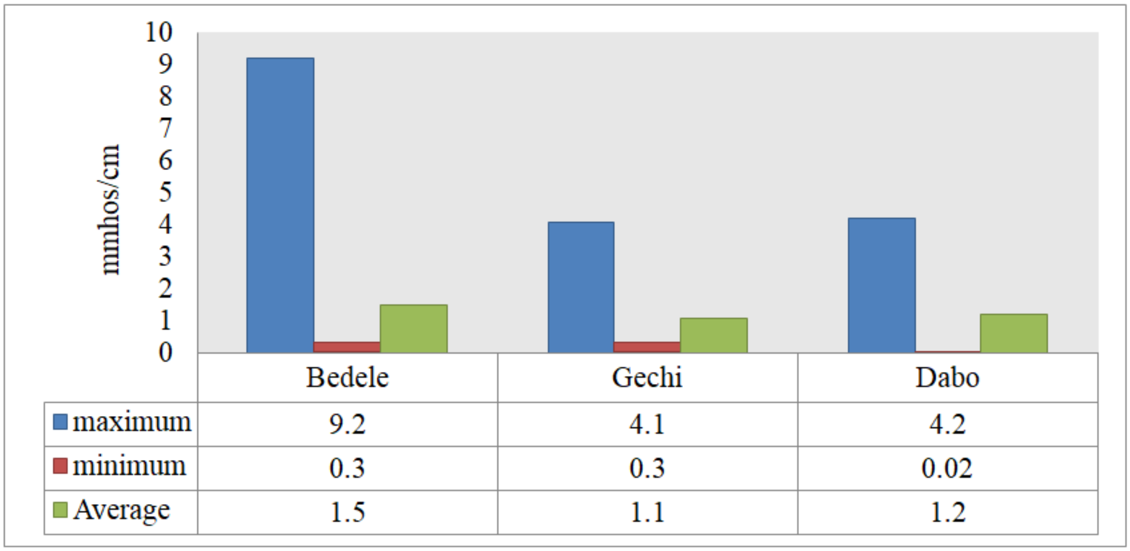


Figure 5. Electrical conductivity of compost in the three districts

Carbon to nitrogen ratio

When soil microbes decompose a compost, they use its carbon for energy while immoblizing some nitrogen (N) to meet their own needs. Immobilized N is temporarily unavailabe to plants until such as those microbes themselves decompose. The carbon-to-nitrogen (C:N) ratio is roughly proportional to the balance between the overall energy contained in the compost (carbon content) and the principal nutrient needed to decompose it, nitrogen, expressed as the total compost C divided by the total compost N (Alexander, 2001). According to (zucconi, *et al.*;1981) C:N ratio of matured compost is <**20 to 1,** however, the study area showed that the C:N result in Bedele, Gechi and Dabo Hana were 16:1, 25:1 and 27:1 (Table 1, Table 2 and Table 3) respectively. According to (zucconi etal;1981) an average C:N ratio of compost collected from Bedele district was agreed with the idea of (zucconi, *et al*;1981).The low C:N ratio less than 20:1 may be expected to gradually mineralize nitrogen with little or no immobilization (Bruun *et al.* 2006), whereas the C:N ratios of compost collected from Gechi and Dabo Hana were above the range stated by Zucconi *et al*. (1981).

Total nitrogen content

Compost can supply considerable nitrogen to soils. Compost ammonium and nitrate are available for plant uptake on application ,while organic nitrogen has to be miniralized to ammonium, or at least decomposed to simple and soluble organic forms, before it can be taken up (Nasholm *et al*., 2009).

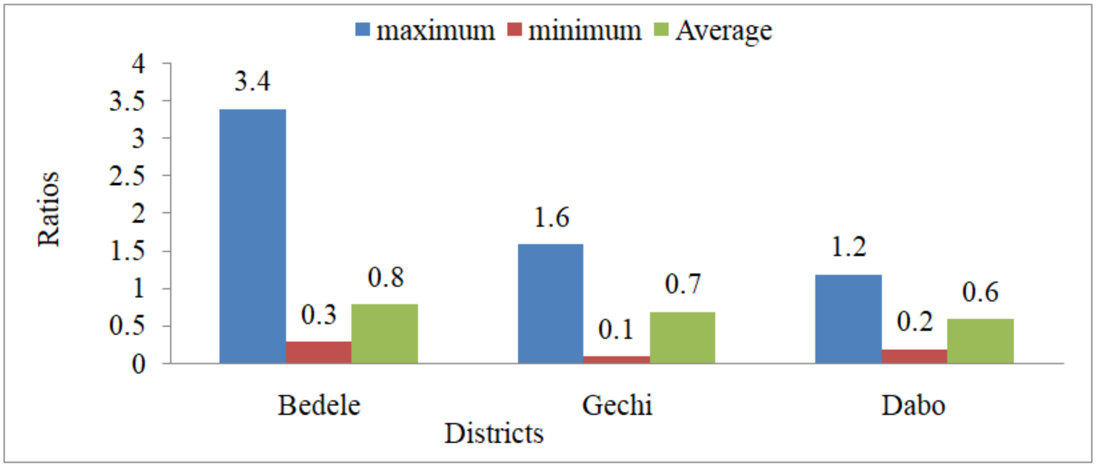


Figure 6. Total nitrogen content of compost in the three districts

In general, high C:N ratio composts supply nitrogen more readily than low C:N composts, but specific miniralization rates cannot be predicted with any precision (Nasholm *et al*., 2009). Because nitrogen is an important fertilizers, it is usually not toxic to crops at agronomic levels. High levels of ammonium can be phytotoxic, especially to seedlings, though susceptibility varies depending on the plant (Britto and kronzucker 2002).

To report compost as having fertilizing capabilities and for it to be used in agriculture the TN content must be over 1% **(**Barker, 1997). An average of total nitrogen content of compost collected from Bedele, Gechi and Dabo Hana was 0.8, 0.7 and 0.6% (Figure 6), respectively. The result was showed below the reference range (1.74 to 2.24%) as suggested by watson (2003) and (1 to 2%) by Alexander (2001). The typical range of total nitrogen in compost is 1 to 3%, compost over 3% of total nitrogen is usually found to be immature and ammonical (Barker,1997).

Organic carbon content

The most essential nutrients in composts are inorganic forms which are released slowly and are less subjected to leaching compared to inorganic fertilizers (Larney *et al*.; 2008). The incorporation of compost derived from biogenic household and garden waste to soil increseases soil carbon and nitrogen concentration (Lefied *et al*.; 2002). The average organic carbon content of compost in the study area was showed as 10.1, 13.9 and 12.1% for Bedele,Gechi and Dabo Hana District (Figure 7) respectively which was bellow the reference range >19.4 by Australian standard (1999).

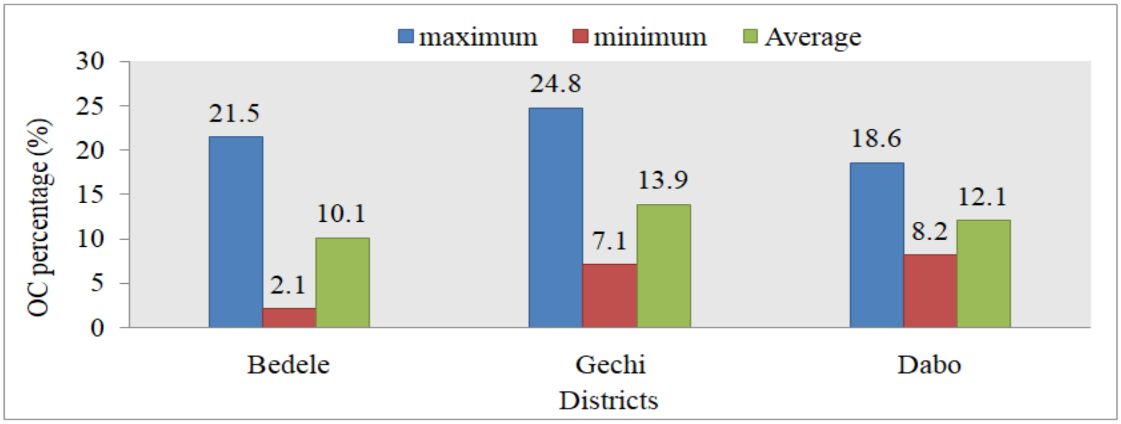


Figure **7.** Organic carbon content of compost in the three districts

Calcium and magnesium content

Calcium is act as bases when they exist as oxides, hydroxide and carbonate. Compost containing these bases when applied to soil, may counteract soil acidification varying pH levels and making soil nutrients more available to plants (Fricke and Vogtman; 1992).

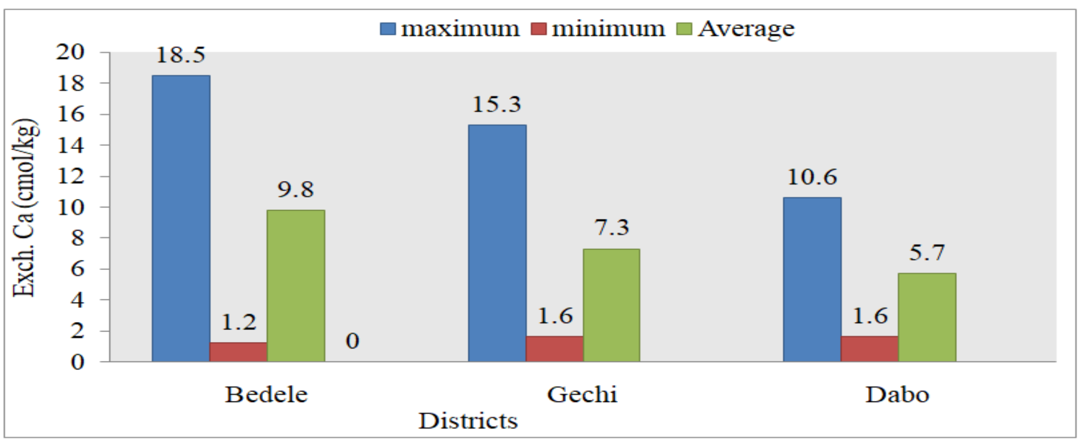


Figure 8. Exchangeable calcium content of compost in the three districts

The average calcium in compost collected from three districts were 9.8, 7.3 and 5.7 cmol kg^{-1} for Bedele, Gechi and Dabo Hana (Figure 8, Tables 1, 2 and 3), respectively. According to the Canada laboratory standards the calcium content of compost collected from Gechi and Dabo districts was below the standard range of compost, while compost colleted from Bedele District was agreed with the standard range of compost. Standard range of compost for exchangeable calcium is 8-13cmolkg^{-1} (Canada laboratory, http://www.al.labs.can.com accessed on September 24, 2018).

Magnesium act as bases when they exist as oxides, hydroxide and carbonate. Similar to calcium compost containing these bases, when applied to soil, may counteract soil acidification varying pH levels and making soil nutrients more available to plants (Fricke and Vogtman; 1992). The average of magnesium in compost for three district was 5.6, 7.5 and 6.6cmolkg-1 for Bedele, Gechi and Dabo Hana districts, respectively (Figure 9, Tables 1, 2 and 3). The standard range for exchangeable magnesium in compost is 1.2-8cmolkg^{-1} (Canada laboratory, http:// www. al. labs. can. com). According to this standard the exchangeable magnesium of all three districts was agree with the standard range (Canada laboratory, http://www.al.labs.can.com accessed on September 24, 2018).

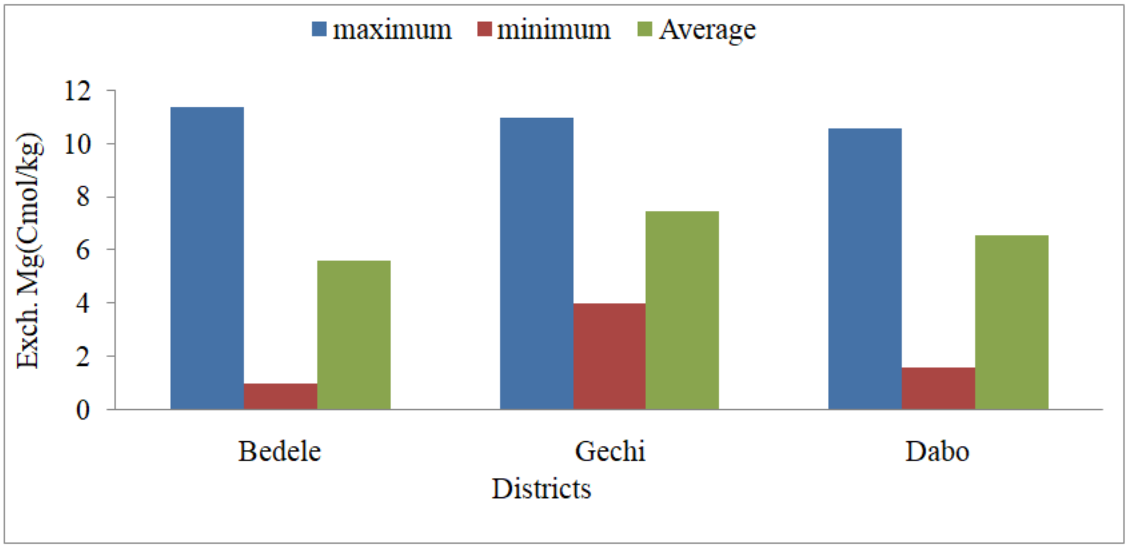


Figure 9. Exchangeable magnesium content of compost in the three districts

Available phosphorous content

Phosphorous availability from compost is much higher than nitrogen availability from compost (Prasad, 2009). The average available phosphorous contents in the compost samples were 32.5, 31.7 and and 28.7 for Bedele, Gechi and Dabo Hana districts, respectively (Figure 10, Tables 1, 2 and 3).

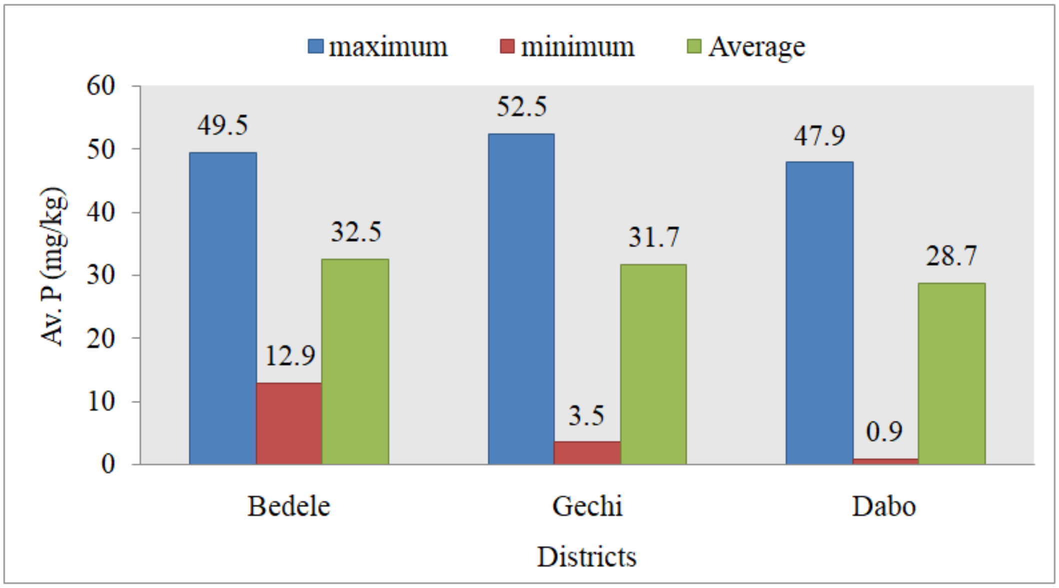


Figure 10. Available phosphorous content of compost in the three districts

Micro-nutrients content

Micro nutrients also required for crop production just like macro-nutriens; the only difference is micro nutrients are required in minimum amount. The micro-nutrients content of compost is just vary based on materials used for composting. Manganese increases seed germination rates and reduces time to harvest because it increases phosphorus and calcium availability to the crop. Zinc affects the rate of maturation of both seed and stalks. There is no ideal range established for micro nutrient content of compost yet. the maximum, minimum and average of micro nutrient analysed for compost of Bedele, Gechi and Dabo Hana districts were listed in Tables 1, 2 and 3, respectively.

Table 1. Summary of laboratory analysis results of farmers' composts collected from Bedele District

Parameter	Unit	Maximum	Minimum	Mean	Std. Deviation
pH(H_2O)	value	6.6	9.3	7.6	0.6
Moisture	%	4.9	10.8	7.2	1.1
EC	mmhos/cm	0.3	9.2	1.5	1.3
TN	%	0.3	3.4	0.8	0.5
OC	%	2.1	21.5	10.1	3.7
C:N	value	2.4	66.7	15.8	10.1
Ex.Ca	$cmolkg^{-1}$ of compost	1.2	18.5	9.8	5.0
Ex.Mg	$cmolkg^{-1}$ of compost	1.0	11.4	5.6	2.1
Av P	$mgkg^{-1}$ of compost	12.9	49.5	32.5	9.7
Mn	$mgkg^{-1}$ of compost	41.6	304.2	99.9	52.3
Fe	$mgkg^{-1}$ of compost	3.3	186.4	65.0	43.4
Cu	$mgkg^{-1}$ of compost	0.9	10.3	3.4	1.8
Zn	$mgkg^{-1}$ of compost	4.8	42.3	14.2	7.9

Ec = Electric conductivity, TN = Total Nitrogen, Ex.Ca = Exchangeable calcium, Ex.Mg = Exchangeable Magnesium, OC = Organic Carbon, Mn = Manganese, Fe = Iron, Cu = Copper and Zn = Zinc

Table 2.Summary of laboratory analysis results of farmers' composts collected from Gechi District

Parameter	Unit	Maximum	Minimum	Mean	Std. Deviation
pH(H_2O)	Value	6.0	9.6	7.7	0.8
Moisture	%	4.1	10.9	7.6	1.3
EC	mmhos/cm	0.3	4.1	1.1	0.8
TN	%	0.1	1.6	0.7	0.3
OC	%	7.1	24.8	13.9	3.8
C:N	Value	12.7	55.9	24.7	9.3
Ex.Ca	$cmolkg^{-1}$ of compost	1.6	15.3	7.3	2.9
Ex.Mg	$cmolkg^{-1}$ of compost	4.0	11.0	7.5	1.7
Av p	$mgkg^{-1}$ of compost	3.5	52.5	31.7	11.3
Mn	$mgkg^{-1}$ of compost	11.2	128.0	70.3	33.0
Fe	$mgkg^{-1}$ of compost	4.7	170.8	79.4	39.7
Cu	Mgkg	1.4	10.3	3.0	1.2
Zn	Mgkg	1.7	27.2	11.5	6.8

Ec = Electric conductivity, TN = Total Nitrogen, Ex.Ca = Exchangeable calcium, Ex.Mg = Exchangeable Magnesium, OC = Organic Carbon, Mn = Manganese, Fe = Iron, Cu = Copper and Zn = Zinc

Table 3. Summary of laboratory analysis results of farmers' composts collected from Dabo Hana District

Parameter	Unit	Maximum	Minimum	Mean	Std. Deviation
pH(H_2O)	Value	5.5	10.4	8.1	1.0
Moisture	%	4.8	8.7	6.2	0.9
EC	mmhos/cm	0.0	4.2	1.2	1.0
TN	%	0.2	1.2	0.6	0.2
OC	%	8.2	18.6	12.1	2.2
C:N	Value	7.4	86.7	27.4	17.0
Ex.Ca	cmolkg^{-1} of compost	0.8	11.6	5.7	2.2
Ex.Mg	cmolkg^{-1} of compost	1.6	10.6	6.6	2.2
Av p	mgkg^{-1} of compost	0.9	47.9	28.7	12.9
Mn	mgkg^{-1} of compost	21.9	304.2	91.9	48.8
Fe	mgkg^{-1} of compost	3.3	186.4	60.1	44.2
Cu	Mgkg	1.7	10.3	3.9	1.6
Zn	Mgkg	4.0	42.3	11.4	5.7

Ec = Electrical conductivity,TN = Total Nitrogen, Ex.Ca = Exchangeable calcium, Ex.Mg = Exchangeable Magnesium, OC = Organic Carbon, Mn=Manganese, Fe=Iron, Cu = Copper and Zn = Zinc

Table 4. Summary of laboratory analysis results of farmers' composts collected from all three districts

Parameter	Unit	Minimum	Maximum	Mean	Std. Deviation
pH(H_2O)	Value	5.5	10.4	7.8	0.8
MC	%	4.1	10.9	7.0	1.2
EC	mmhos/cm	0.0	9.2	1.3	1.1
TN	%	0.1	3.4	0.7	0.4
OC	%	2.1	24.8	11.9	3.7
C:N	value	2.0	87.0	22.3	13.5
Exch.Ca	cmolkg^{-1} of compost	0.8	18.5	7.8	4.0
Exch.Mg	cmolkg^{-1} of compost	1.0	11.4	6.5	2.2
Av. P	mgkg^{-1} of compost	0.9	52.5	31.1	11.3
Mn	mgkg^{-1} of compost	11.2	304.2	88.0	47.3
Fe	mgkg^{-1} of compost	3.3	186.4	68.1	43.1
Cu	mgkg^{-1} of compost	0.9	10.3	3.4	1.6
Zn	mgkg^{-1} of compost	1.7	42.3	12.5	7.0

Ec = Electric conductivity, TN = Total Nitrogen, Ex.Ca = Exchangeable calcium, Ex.Mg = Exchangeable Magnesium, OC = Organic Carbon, Mn = Manganese, Fe = Iron, Cu = Copper and Zn = Zinc

Conclusion and Recommendations

In sustainable and integrated crop production systems the inclusion of compost proved to have significant effect on quality and health of soil, and quantity and quality of crop production. Assessment was initiated with objectives to assess and evaluate nutrient contents of farmers' composts prepared from diversified material sources and to identify the gap for composting processes. In general 213 farmers' compost samples were collected from three districts in Buno Bedele Zone. For each compost sample 14 parameters were analyzed according to the standard laboratory procedures.The majority of the parameters analyzed values included calcium, total nitrogen, carbon to nitrogen ratio (C:N), organic matter and moisture contents were below the standard ranges set by different literatures.These results might be due to unbalaced substrates used by farmers during compost preparation. Based on these analysis results, it can be concluded that all prepared composts by farmers were not fulfilled standard quality that could be due to lack of follow up of standard procedures required from raw materials combination to compost management. Therefore, to upgrade quality of farmers' prepared composts, it requires training of farmers and cloth suppervision by agricultural experts and development agents during compost preparation process by farmers.

Acknowledgment

The authors would like to acknowledge Oromia Agricultural Research Institute for financial, logistic and material support during the assessment; highly indebted to all researchers, laboratory technicians and support staff of Bedele Soil Research Center for providing the necessary attention and follow up to make the assesment successful.

References

Alexander. R., 2001. Field guide to compost use. Bethesda, maryland: U.S. Composting Council.
Australian Standard (AS-99), 1999. Composts, soil conditioners and mulches. AS-454- 1999. Standards Association of Australia. New bush.
Barker, 2002. Bioremediation of heavy metals and organic toxicants by composting, The Sci. World J., 2, 407/420.
Biey W., Akram M., and Ahmad N., 2000. CCME, *PN 1340 Guidelines for Compost Quality*. 2005.
Brinton. W. F., 2000. Compost quality standards and guidelines: an international view. Woods End Research Laboratory Inc, New York.
Britton, D.T., and H.J. Kronzucker., 2002. NH_4^+ toxicity in higher plants: A critical review. Journal of Plant Physiology. 159(6): 567-584.
Bord na Mona., 2003. Compost testing and analysis Service – interpretation of results, available from Bord na Mona, Newbridge, Co. Kildare.
Bruun V. and Barrena D., 2006.Standard methods for the examination of water and wastewater. 21st edition, American Public Health Association, Washington DC Canada, laboratory,http://www.al.labs.can.com. Organic waste treatment using novel composting technologies. University of Plymouth. Accessed in September, 24, 2018.
Chen L, Marti Md, Moore A, Falen C., 2011. The composting process: Dairy compost production and use in Idaho.
Dam A, Nibbelink B, Ward D., 2009. Windrow composting of poultry carcasses. Ministry of Agriculture, Food and Rural Affairs, Ontario.
Ganjali H, Mobasser H, Esmaielzehi A, Tavassoli A., 2013. Effect of organic compost on yield and protein content of corn cultivars in Khash region. Journal of Novel Applied Sciences 2: 369-374
Gashaw T, Bantider A, Gebresilassie H., 2014. Land degradation in Ethiopia: Causes, impacts and rehabilitation techniques. J Environ Earth Sci 4: 98-104.
Ge j ., and Watso E., 2010.The use of respiration indices in the composting process, a review, *Waste Manage.tRes.*, 24, 37–47.
Fricke and Vogtman., 1992. European Compost Network, *European Quality Assurance for Compost is launched*, in *ECN Info paper*.2010. p. 6.

Lambert L., and Taguiling, M.G., 2013. Quality improvement of organic compost using green biomass. European Scientific Journal 9(36), 319-341.

Larney K., Toscano P., and Casachia T., 2008.Guidelines for Specification of Quality Compost for Use in Growing Media. Banbury.

Lefied V., Leal W., and Brandli S., 2002. Evaluation of commercial compost quality and Waste Management & Research, 20, 389-397.

Marta A, Raviv M., 2016. Microbiology of the composting process. In: Van derWurff A, Fuchs

Paul, 2007. Agricultural composting in the United States Compost Science and Utilization, 3, 384-88.95-200.1995.

Prasad and Watson, 2003. To support the development of standards for compost by investigating the benefits and efficacy of compost use in different applications. WRAP Project STA0015.

Rader H, 2013. The compost heap: Basic composting in Alaska. University of Alaska Fairbanks, Alaska.

Raviv M, Termorshuizen A (eds.), Handbook for composting and compost use in organic horticulture. COST, Wageningen.

Reddy, N., and D.M. Crohn, 2012. Compost induced soil salinity: Anew pridiction method and its effect on plant growth. Compost Science and Utilization. 20(3): 133-140. Richard, T. 2005. NMORO-Compost-Mixes.

US Composting council, 2003. All technical, economic and environmental comparison of composting and anaerobic digestion of biodegradable municipal waste.

Tognet B., Zhao S., and Duo L., 2007. Evaluation of seed germination and growth tests for assessing compost maturity. Compost Science & Utilization, 7, 33-37.

Våje.P, 2007. Soil fertility issues in the Blue Nile valley, Ethiopia. In: Bationo A, Waswa B, Kihara J, Kimetu J (eds.), Advances in integrated soil fertility management in Sub- Saharan.

Woods end Research laboratory, 1998. Processes and plant for waste composting and other aerobic treatment. R&D technical report P1-311/TR. Environment Agency.

Woods End Laboratories, 2013. Laboratory test interpretation. Journal of Woods End Laboratories 10: 1-7.

Assessment of Nutrient Contents of Farmers Used Composts for Crop Production in Wollega Zones of West Oromia, Ethiopia

Chalsissa Takele, Temesgen Chimdessa, Geremew Bayeta, Mintesinot Desalegn and Obsa Aga

Nekemte Soil Research Center, P.O. Box 587, Nekemte, Ethiopia

Corresponding author: temesgenchimdessa468@gmail.com

Abstract

The nutrient contents of compost and its quality for agriculture depend upon nature of source materials and composting process. The present study was carried out to know the nutrient contents of farmers' used composts prepared from diversified material sources for crop production in different districts of west Oromia from 2014-2016*. The study was focused on farmers' managed composts prepared by pit method. Compost samples were collected from eight districts of west Oromia (Guto Gida, Sassiga, Guduru, Horro, Jimma Geneti, Hawa Gelan and Nedjo). Composite compost samples were systematically collected from each site and analyzed at Nekemte Soil Research Center following the standard procedures. Electrical conductivity of composts in all study areas was in the desired ranges for crop production; the mean EC values ranged from 1.12mmhoscm*$^{-1}$ *in Guto Gida District to 1.99mmhoscm*$^{-1}$ *in Hawa Gelan District, and all collected compost samples were below the stipulated range for saline toxicity. The pH value ranged from 7.25-8.21 and all of the compost samples were in alkaline range. Over all analysis results of available phosphorus content were 92.29, 60.14, 84.79, 73.74, 99.86 and 130.96 ppm of collected compost samples in Guto Gida, Sasiga, Guduru, Horro, Jimma Ganati and Hawa Gelan districts, respectively. Preparation of conventional compost has to be emphasized on materials for compost preparation, decomposition time, temperature, moisture, and preparation procedure. Therefore, farmers have to be well trained on compost preparation techniques and materials to be used for composting.*

Keywords: *Compost nutrients, conventional compost, diverse materials, farmers' compost*

Introduction

Soil fertility degradation has been described as the most important constraint to food security in sub-Saharan Africa (World Bank, 1996). High population growth of sub-Saharan Africa led to removal of vegetation cover and continuous cultivation of lands with low nutrient replenishment results in depletion of soil nutrients. Hence, crop productivity of sub-Saharan African countries can be increased with supplemental nutrients (Marc *et al*., 2000). However, the cost of fertilizers has been increasing and has reached unaffordable level to small-scale farmers (Maatman *et al*., 2007).

Crop productivity of marginally fertile acidic soils can be improved through integrated use of soil ameliorants and fertilizers. Similarly, the price of inorganic fertilizer becoming expensive from time to time, farmers are inclined toward using compost for crop production. In line with this, soil fertility management in Ethiopia has begun to shift toward integrated approach (IFPR, 2010). Studies depicted that the integrated use of 5 tone compost ha^{-1} either with 55/10 Kg N/P ha^{-1} or 25/11 kg N/P ha^{-1} appeared to be economical. Moreover, the resource poor farmers could use sole application of 5 tone compost ha^{-1} in absence of in organic fertilizers for maize production (Wakene *et al*., 2001).

Due to diverse nature of composting process, the quality of available compost can vary widely. As partially decomposed organic matter, compost can have a range of characteristics. Compost can vary because of the raw materials used, degree of decomposition, moisture content, nutrient content, salt content, acidity/alkalinity and contaminants (organic and non-organic materials or heavy metals). It is not the amount of compost that applied to the soil, but the amount of nutrients supplied to the crop that determines the level of crop productivity (e.g. applying 50 kg of compost with good nutrient contents is by far better than 200 kg compost with low nutrient contents). The use of compost must be based on the materials used for compost preparation rather than then bulk amount of compost applied to soil. Without accurate information about compost material, adding more compost may or may not make a difference. Because of the large variety of materials that can be composted and the differing amount of effort that can be put into making compost, the quality of compost can vary significantly.

Currently there is no formal way of grading compost. Hence, it is a necessity to know nutrient composition of any material used for fertility improvement, and composts must be justified with laboratory test to know (1) initial soil nutrient status, (2) nutrient content of compost (total N, P, K, Ca, Mg, Zn, Fe, Cu and Mn; C/N ratio; pH and EC) used at each cropping time based on the type of composting material sources, and (3) requirement of addition of chemical fertilizer application to get the targeted yield potential of crop types in use, i.e., integrated nutrient management is essential for our current soil fertility situations rather than single fertilizer source. Therefore, compost testing is pre-requisite for applying compost to field; the result of the test will help determine which type of and how much compost to use. The study was aimed to know nutrient contents of currently used composts prepared from diversified material sources and to develop guiding principles on material sources of compost making so as to make quality compost for crops.

Materials and Methods

Description of the study areas

The assessment was carried out in East Wollega, West Wollega, Kellem Wollega and H/G Wollega zones of Oromia Regional State located in Western Ethiopia (Figure 1). The altitude of Wollega zones ranges from 439masl in the West to about 3255masl in the East. The average monthly temperature ranges between 11.9-29.9ºC. The mean monthly rainfall ranges between 10.43 mm to 403.4 mm. The economic activities of the local society of the study area are primarily mixed farming system that involves animal husbandry and crop production. The major crops are coffee (*Coffee arabica* L.*)*, teff *(Eragrostis tef)*, barley *(Hordeum vulgare* L*)*, maize (*Zea mays* L.) breadw heat (*Triticum aestivum*), and potato *(Solanum* *tubersoum* L.), hot pepper (*Capsicum frutescence*). Crop production are based on rainfed agriculture and harvested usually once in a year (Wakene and Heluf, 2006).

Site selection

Compost prepared by pit method in seven districts of western Oromia (Guto Gida, Sasiga, Guduru, Horo, Jima Ganati, Hawa Galan, and Nadjo) were used for the study. Compost sample collection was done on selected model farmers' field with aim of preparing farmers' managed compost. Therefore the sampling employed were systematic method of sampling. The composting experience and accessibility were the main criteria for the selection of these sites. Composite compost samples were taken from these sites for chemical analysis.

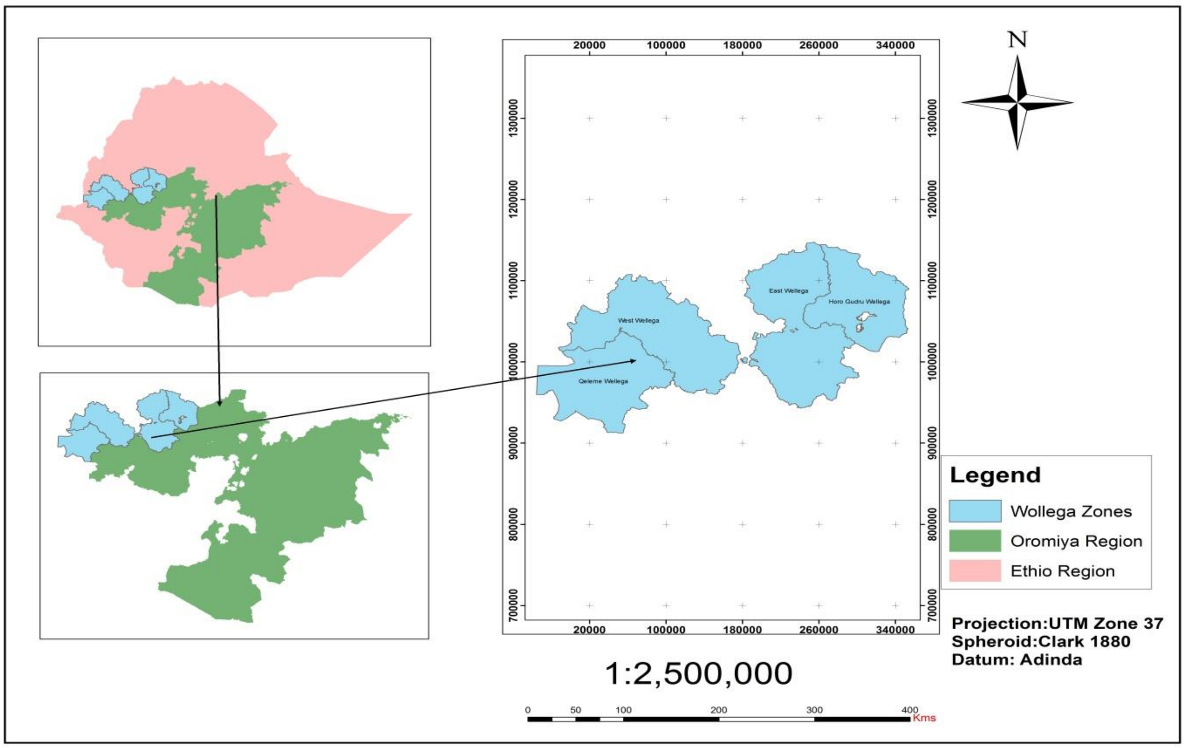


Figure 2. Location maps of the study areas (Source: Ethiopian Mapping Agency)

Compost preparation

Pit composting with the pit size of about 1 x 1.5 x 1.5m was used during the study. The composting materials used in each compost pit were identified through interviewing (Table 1). To get a better understanding on the representativeness of the composting techniques and composting materials, additional compost sites on different farmers in different districts of each zone, and some composts prepared at FTC were visited. The composting techniques and materials used for compost making were more or less similar with those of the study sites (Table 1). The main composting materials in most of the observed sites were top soil, farmyard manure, crop residues, weeds, plant leaves, ash, and leftover vegetables.

Compost sampling and sample preparation

Subsamples were systematically collected from different layers of the compost (upper, middle and bottom layers) to make a composite compost sample for each site. Sample preparation was conducted at Nekemte Soil Research Center (NSRC). The samples were air dried and crushed using a mortar and pestle and sieved through a 2mm mesh sieve.

Table 1. Farmers' material sources and method used for compost preparation in the study areas

Zone	District	Common materials used (Local name)	Method of composting
East Wollega	Guto Gida	Animal manure, top soil, ash, maize stalk, "tufo", "rejji", "eebicha"	Pit
East Wollega	Sassiga	Animal manure, top soil, ash, maize stalk, "rejji", "tufo", "kello", "bala buqqee",	Pit
H/Guduru Wollega	Guduru	Animal manure, top soil, ash, maize stalk, tuufoo, reejjii, different weeds	Pit
H/Guduru Wollega	Horro	Animal manure, top soil, ash, maize stalk, Croton mycrostachus leaf, rejji , eebicha	Pit
H/Guduru Wollega	Jimma Geneti	Animal manure, top soil, ash, maize stalk, weeds, Croton mycrostachus leaf, rejji	Pit
Kellem Wollega	Hawa Gelan	Animal manure, top soil, ash, maize stalk, rejji, tuufoo, kello fi baala buqqee	Pit
West Wollega	Nedjo	Animal manure, top soil, ash, tufo, kello, rejji, different weeds	Pit

Compost laboratory analysis

After sample preparation, compost samples were analyzed in the laboratory following the standard procedures. The pH of composts was measured potentiometrically with a digital pH meter in the supernatant suspension of 1: 5compost: liquid ratio (Baruah and Barthakur, 1997). Organic carbon (OC) content was determined by the dichromate oxidation method (Walkely and Black, 1934). Organic matter content was estimated from the organic carbon content by multiplying the latter by 1.724. Total N was estimated from the percent of organic matter. Available P was analyzed using Olsen method and colorimetrically using ascorbic acid as a reducing reagent and its concentrations was measured using spectrophotometer. Extractable (Fe, Zn and Cu) were extracted using diethylenetriamine pentaacetic acid (DTPA) as described by (Lindsay and Norvell, 1978) and their contents were determined using atomic absorption spectrophotometer (AAS). Exchangeable bases (Ca and Mg) were extracted with diethylenetriamine pentaacetic acid (DTPA). The extracts of Ca and Mg were analyzed using AAS.

Results and Discussion

Compost electrical conductivity

As partially decomposed organic matter, compost can have a range of characteristics. The analytical results for electrical conductivity of compost sample taken from seven districts of western Oromia were shown in (Table 2). The mean electrical conductivity of compost prepared by farmers from diversified materials in Guto Gida, Sasiga, Guduru, Horro, Jimma Ganati, Hawa Gelan and Nedjo districts were 1.12, 1.73, 1.92, 1.40, 1.65, 1.99 and 1.86mmhos/cm, respectively, safely below (< 4.0 dSm^{-1}) the stipulated range for saline toxicity as per USCC (2002, in Evanylo, 2006). According to Leaon (1995), desired ranges for electrical conductivity of compost ratio was < 2.5$mmhoscm^{-1}$. Higher than desired salt levels can be harmful to germinating seeds and plants when compost is a component of the growing medium. The desired ranges may not apply when compost is used as an amendment because of the diluting effect of mixing the compost with soil. Therefore, electrical conductivity of the compost in all study districts was in the range of the desired level. Therefore, in relation with its salinity compost of the study area prepared by farmers from diverse materials is suitable for crop production.

Compost pH

Laboratory analysis pH results of compost prepared by farmers in Guto Gida, Sasiga, Guduru, Horro, Jimma Geneti, Hawa Gelan and Nedjo districts were 7.63, 7.53, 8.04, 7.25, 7.90, 7.90 and 8.20, respectively (Table 2). According to Chude *et al (*2005) reaction classification based on pH (H_2O), compost's pH was slightly alkaline to moderately alkaline (7.4 to 8.4) for all districts. The desired range of compost pH values for crop production was 6-7.5 (Leaon, 1995). Compost pH values below and above these range will affect its growth and yield. Compost pH result in all the study districts except Horro district is clearly indicated that the values were above the described ranges. This pH range is not in the optimum range for growing media as mentioned by (Bunt, 1988) who stated that the optimal range is from 5.2-7.3. However, it is important for acid soils amelioration especially in western Oromia and specifically the study areas. Compost collected from Nedjo District was more alkaline (pH = 8.2), while that of Guduru District (pH = 8.04) is less alkaline.

Composts prepared in different sites of the study area were well matured, as mature composts mature have pH between 7 and 9 (Avnimelech *et al.,* 1996). Compost may help buffer soil toward neutral. It depends on the kind of material composted and the final pH of the compost.

Available phosphorus

Available phosphorus level of compost collected from Guto Gida, Sasiga, Guduru, Horro, Jimma Ganati and Hawa Gelan districts were 92.29, 60.14, 84.79, 73.74, 99.86 and 130.96 ppm (Table 2). The highest P level (130 ppm) was recorded from composts collected in Hawa Gelan district while the minimum (73.74 ppm) was from Horro district. This variation in P levels might be attributed to differences of materials from which the compost was prepared. The desired ranges of phosphorus level of compost varies because of variation in raw materials used, degree of decomposition, moisture content, nutrient content, salt content, acidity/alkalinity and contaminants (organic and non-organic materials or heavy metals). According to Szczech (1988), compost that is prepared through conventional method has standard values of phosphorus, 0.47% and potassium, 0.70%. Therefore, compost prepared by farmers in the study districts of western Oromia had very low level of phosphorus.

Organic carbon and total nitrogen

The compost prepared in the eight districts of Wollega zones Guto Gida, Sasiga, Guduru, Horro, Jimma Geneti, Hawa Gelan and Nedjo had organic carbon content of 7.83, 7.17, 6.79, 8.58, 7.25, 5.19 and 5.38 %, while total N contents were 0.67, 0.62, 0.59, 0.74, 0.63, 0.45 and 0.55%, respectively. Therefore, with C: N ratio of 11.6, it is ratio that favors net mineralization.

National Standard of Canada for organic amendments (1996) indicatee that matured compost must have a C:N less than or equal to 25 since in general report, the decomposition of compost with a C:N ratio lower or equal to 25 in a soil does not involve the immobilization of the nitrogen from the soil to the detriment of plant. The maturity is often assessed by the C:N ratio It has been showed that C:N ratio close to 10-15 corresponds to a mature compost can significantly improve soil on which plants derive nutrients for growth (Namkooing *et al.* , 1999). Nitrogen is slowly released by compost and made available for plant growth. The amount is dependent on the compost application rate and the percent of nitrogen in the compost. Standard values of compost that was prepared through conventional method had total nitrogen of 1.94%. Total N of collected and analyzed compost sample were lower than that of the prescribed range. Low levels of nutrients may indicate incomplete decomposition or low amount of nutrients in the original materials. In the latter stages of composting, nitrate can leach from the compost.

Calcium, magnesium, and micro-nutrients

The nutrient contents of Ca and Mg of the composts ranged from 44.79-83.72ppm and 1.4-8.6ppm, respectively, i.e., generally classified as low contents. Low levels of nutrients may indicate incomplete decomposition or low amount of nutrients in the original materials. In west Oromia soil is deficient in essential nutrients due to soil acidity and other factors. Hence, the materials used for composting in the study areas might have low levels of secondary essential macro-nutrients.

Composting accumulate (concentrate) nutrients and helps for slow-release, i.e., more efficient plant uptake and less nutrient leaching. It provides macro- and micro-nutrients to the plants and improves soil structure, and water holding capacity of the soil for good aeration, thereby improving root growth (Tomati *et al*. 1987).

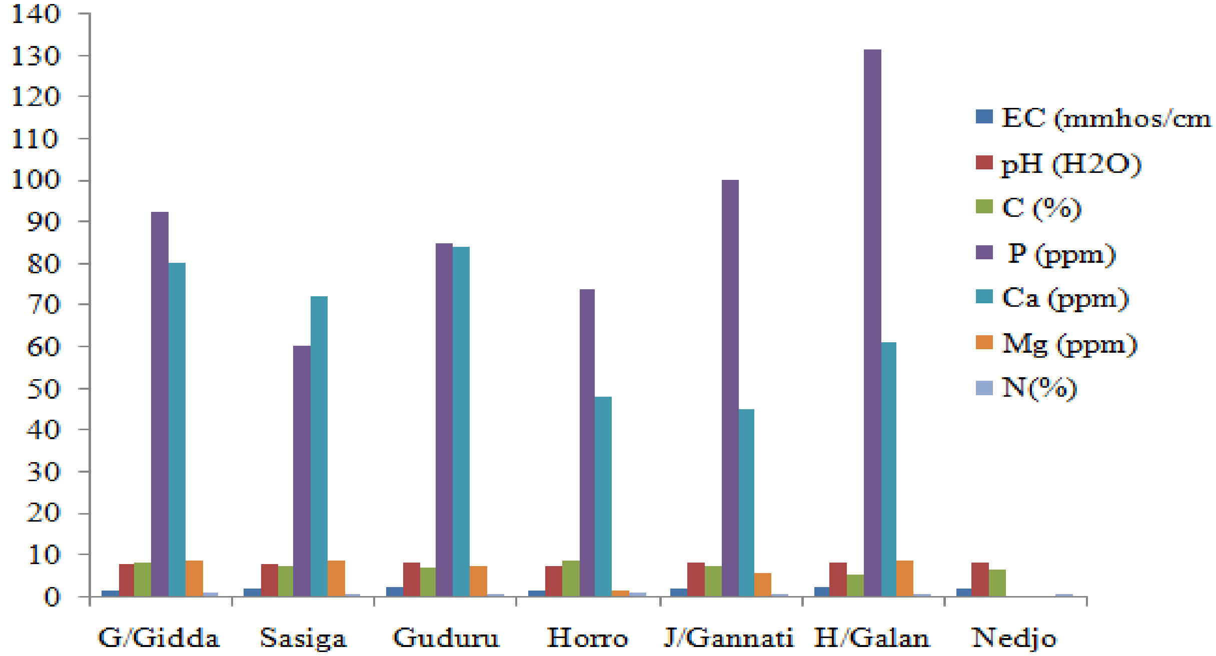


Figure 2. Compost pH and nutriet contents of the study districts

Table 2. Summary of laboratory analysis results of farmers' composts in the study districts

Parameter	District						
	G/Gida	Sassiga	Guduru	Horro	J/Gannati	H/galan	Nedjo
Electrical conductivity (mmhos/cm)							
N	27	24	16	9	10	19	41
Mean	1.12	1.73	1.92	1.40	1.65	1.99	1.86
Std. E. of Mean	0.18	0.31	0.45	0.46	0.33	0.43	0.37
Minimum	0.29	0.06	0.68	3.90	0.73	0.29	0.34
Maximum	3.99	6.33	7.07	9.00	3.69	8.49	6.03
pH (1: 5 H_2O)							
N	27	24	16	9	10	19	41
Mean	7.63	7.53	8.04	7.25	7.90	7.90	8.21
Std. E. of Mean	0.10	0.16	0.19	0.32	0.23	0.16	0.21
Minimum	6.50	5.95	6.65	8.75	6.39	5.73	6.45
Maximum	8.78	8.55	9.19	9.00	9.18	9.15	9.69
Avail. P (ppm)							
N	27	24	16	9	10	19	
Mean	92.29	60.14	84.79	73.74	99.86	130.96	
Std. E. of Mean	5.62	7.03	6.87	8.77	9.28	5.56	
Minimum	50.22	12.30	40.86	110.41	58.81	41.14	
Maximum	136.52	137.82	132.05	9.00	146.08	156.55	
OC (%)							
N	27	24	16	9	10	19	41
Mean	7.83	7.17	6.79	8.58	7.25	5.19	6.38
Std. E. of Mean	0.50	0.58	0.33	1.07	0.82	0.31	0.10
Minimum	3.81	3.12	4.65	12.09	4.95	2.86	3.41
Maximum	13.37	15.45	9.17	9.00	12.60	8.37	12.79
Total N (%)							
No.	27	24	16	9	10	19	41
Mean	0.67	0.62	0.59	0.74	0.63	0.45	0.55
Std. E. of Mean	0.04	0.05	0.03	0.09	0.07	0.03	0.33
Minimum	0.33	0.27	0.03	1.04	0.43	0.25	0.29
Maximum	1.15	1.33	0.03	9.00	1.09	0.72	1.10
Ca (ppm)							
No.	27	24	16	9	10	19	
Mean	79.99	71.88	83.72	47.87	44.79	61.00	
Std. E. of Mean	4.72	5.89	9.22	5.25	7.86	2.32	
Minimum	39.13	21.41	8.60	78.99	18.26	41.86	
Maximum	115.69	127.44	151.91	9.00	85.56	95.43	
Mg (ppm)							
No.	27	24	16	9	10	19	
Mean	8.56	8.61	7.00	1.40	5.60	8.44	
Std. E. of Mean	0.55	0.65	0.79	0.46	1.14	0.36	
Minimum	3.72	2.61	0.89	3.90	1.56	6.11	
Maximum	14.50	13.50	12.78	9.00	12.11	12.16	

Conclusion and Recommendations

Due to diverse nature of composting materials, the quality of the compost varied widely. Compost testing is pre-requisite before applying compost to the field. It can be concluded that only electrical conductivity of the compost is in the desired ranges for crop production. The nutrient contents of the compost were in the desired ranges for crop production. The nutrient contents of compost were very low. The pH values fall in alkaline range posing influences on crop production. The compost in the study area mainly prepared from soil, ash, crop residues, cow dung and waste materials. Ash might make it alkaline and other inputs contain less concentration due nutrient deficiency of soil or may indicate incomplete decomposition. Preparation of farmers' compost has to emphasize on materials to be used for composting, decomposition time, temperature, moisture, procedures and others. Finallly, farmers need to be trained on techniques of compost preparation and selection of materials to prepare quality composts.

Aknowledgment

The authors would like to thank Oromia Agricultural Research Institute and Oromia Bureau of Agriculture and Natural Resource for financial support and Nekemte Soil Research Center for providing all the necessary facilities for the research work; also extend special appreciation to all staff members, especially to laboratory analysis team for their support and unreserved effort for compost samples analysis.

References

Avnimelech, Y., 1996. Stability indexes for municipal solid waste compost. Compost Science and Utilization, page 26.

Barauah, T.C. and Barthakulh, H.P., 1997. A Text Book of Soil Analyses. Vikas Publishing House Pvt. Ltd. New Delhi, pp: 334.

Bunt, A.C., 1988. Media and Mixes for Container-Grown Plants, 2nd edn. Unwin Hyman Ltd, London, UK.

Chapman, H.D., 1965. Cation Exchange Capacity. In: Black, C.A. *et al*., (*ed*.), Methods of Soil Analysis, Part 2 – Chemical and Microbiological Properties. Am. Soc. Agron., Inc., Madison Wisconsin, pp: 891-901.

Evanylo, G., 2006. "*Compost maturity and indicators of quality*", in: Laboratory Analyses and On Farm Tests. http://www. waterquality.org/industry_change/compost_school/Compost quality.

Lindsay, W., and Norvell, W., 1978. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Science Society of America Journal 42, 421-428.

Marc, C. Abebe S., and Mitiku, H., 2000. Farmers' knowledge of soil fertility and local management strategies in Tigray, Ethiopia. Managing Africa's Soils, 10: pp 1-30.

Maatman, A., Wopereis, M., Debrah, K. and Groot, J., 2007. From Thousands to Millions: Accelerating Agricultural Intensification and Economic Growth in Sub-Saharan Africa. *In:* Bationo (Ed.), Springer. Advances in Integrated Soil Fertility Management in Sub Saharan Africa: Challenges and Opportunities, pp 75–84.

Namkooing, W., 1999. A comparative evaluation of maturity parameters for food waste composting. Compost Science of Utilization 7: 55-62.

Wakene Negessa and Heluf Gebrekidan. 2006. Impact of land use and management practice on chemical properties of some soils of Bako area, Western Ethiopia. Ethiopian Journal of Natural Resource 8 (2):177-197.

Walkley, A. and Black, T.A., 1934. An examination of the degtjereff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.* 32: 29-38.

WB (World Bank).,1996. Natural resource degradation in Sub Saharan Africa. Restoration of soil fertility. A concept paper and action plan. World Bank, Washington, USA.

IFPRI (International Food Policy Research Institute), 2010. Fertilizer and soil fertility potential in Ethiopia, Constraints and opportunities for enhancing the system, working paper.

Evaluation of Nutrient Contents of Vermi-compost Made from Different Materials at Mechara Agricultural Research Center, West Hararghe Zone, East Oromia, Ethiopia

Tadele Geremu[1]*, Alamayehu Diriba, Habtamu Hailu, and Eshetu Ararso[2]
[1]Mechara Agricultural Research Center, P.O. Box, 19, Mechara, Ethiopia
[2]Oromia Agricultural Research Institute, P.O.Box, 81265, Finfinne, Ethiopia
*Corresponding author: bekgeremu@gmail.com

Abstract

The experiment was conducted from 2016-2018 cropping seasons at Mechara Agricultural Research Center, on-station, to evaluate nutrient contents of vermicompost made from different material sources. Composting materials as treatment were sorghum, maize, teff, and haricot bean straw, grasses, mixed straw and red worms (Eisenia fetida) were selected to prepare the compost. 2.5kg collected materials were chopped and added to the worm bin through mixing with 1kg decomposed animal manure as a starter and sprayed with water to maintain optimum moisture for worms. Bottompart of plastic bag was drilled to drain excess water in the pin. The mixture straw was prepared from 0.5kg of each material source. After optimum moisture was adjusted 100 earthworms were counted and added to each treatment. Matured composite vermicompost samples were prepared from the three plastic bags were collected for laboratory analysis. The collected samples were air dried, crushed and passed through 2 mm sieve after a careful removal of undecomposed plant parts and other unwanted materials for some nutrient analysis in the laboratory. As laboratort analysis results indicated the contents of CEC, total nitrogen (TN), exchangeable potassium, exchangeable calcium, and exchangeable magnesium were very high when compared to their availability in the compost. The analysis results showed highest primary macronutrients (total nitrogen and available phosphorus) were recorded from vermicompost prepared from grasses and available potassium from teff straw. Highest and lowest CEC were recorded from vermicompost prepared from teff straw and haricot bean straw, respectively. Highest extractable Fe, Mn, Cu and Zn were recorded from vermicompost made from maize, haricot bean and sorghum straw, respectively. In addition, vermicompost made from all materials showed highest nutrient contents. Therefore, vermicompost could be used as organic fertilizer sources for micronutrient for soils deficient in these micronutrients.

Keywords: ***N**utrient content, vermicompost, compost materials*

Introduction

Heavy use of agrochemicals since the “green revolution” of the 1960s boosted food productivity at the cost of environment & society. It killed the beneficial soil organisms & destroyed their natural fertility, impaired the power of ‘biological resistance’in crops making them more susceptible to pests & diseases (Sujit, 2012). Chemically grown foods have adversely affected human health. The scientific community all over the world is desperately looking for an economically viable, socially safe & environmentally sustainable alternative to the agrochemicals is vermicompost (US Board of Agriculture, 1980).

Vermicomposting is defined as a bio-oxidative process in which detritions earthworms interact with microorganisms and other fauna within the decomposer community, thus accelerating the stabilization of organic matter (OM) and greatly modifying its physical and biochemical properties of soil (Domínguez, 2004). Epigeic earthworms are natural colonizers of organic waste and the following properties make them suitable for vermicomposting: high rates of consumption, digestion and assimilation of OM; tolerance to a wide range of environmental factors; short life cycle, high reproductive rates, and endurance and resistance to handling (Domínguez and Edwards, 2010). Few epigeic earthworms display all these characteristics, and only four species have been extensively used in vermicomposting facilities. *Eisenia andrei*, redworms *[Eisenia fetida]*, *Perionyx excavatus* and *Eudrilus eugeniae* (Domínguez and Edwards, 2010). Red worms are local endemic species therefore appear to be appropriate for vermicomposting; as such species are well adapted to different environmental conditions.

According to Ruz-Jerez and Tillman (1992) vermicompost is an excellent soil additive made up of digested compost and worm castings, and are much higher in nutrients and microbial life; therefore, considered as a higher value product and worm castings product contain up to 5 times the plant available nutrients found in average potting soil mixes. Chemical analysis of the casting was conducted and found that it contains 5 times the available nitrogen, 7 times the available potash and 1.5 times more calcium than that found in 15cm of good topsoil. In addition, the nutrient life is up to 6 times more in comparison to the other types of compost.

Ferreras, *et al.,* (2006) and Marinari, *et al.,* (2000) observations indicate that addition of 20tha^{-1} vermicompost to agricultural soil in two consecutive years significantly improved soil porosity and aggregate stability and the number of large elongated soil macro-pores increased significantly after a single application of the dose of vermicompost equivalent to 200kgha^{-1} of nitrogen to corn field. Similarly, Gopinath *et al*., (2008) reported significant decrease in soil bulk density and significant increase in soil pH and total organic carbon after application of vermicompost in two consecutive growing seasons, at the rate equivalent to 60 kgha^{-1} of N; together these changes in soil properties improve the availability of air and water, thus encouraging seedling emergence and root growth.

In nature as a laboratory, earthworms convert organic waste into renewable energy production and enhance biotechnological process of composting action for production of better product, which are sources of plant nutrients and essential for maintaining soil productivity with macro- and micro-nutrients present in organic waste represent a low-cost, environmentally friendly alternative to mineral fertilizers for crop growth and recovery of soil body. Microorganism and earthworms are important biological organisms helping nature with nature to maintain nutrient flow from one system to another and recover the nature to minimize environmental degradation.

The earthworm population is about 8-10 times higher in uncultivated area so most of north-east and central part of Ethiopia suffer under soil degradation and loss of nutrients due to various reasons cultural belief of sand remains of early extension, land tenure systems, scarcity of organic materials, fuel needs, high population densities and deforestation, climate change, inadequate use of synthetic fertilizers, low availability of organic soil amendments and fertilizers, etc. These clearly designate that earthworm population decreases as soil quality diminution and it could be used as a sensitive indicator of soil degradation (Devi, 1998). Thus West Hararghe Zone is grouped under these situations. To alleviate such problem, this study was initiated with the objectives of evaluating the quality and nutrient content of vermicompost made from different material sources, and to identify and recommend the best composting materials.

Materials and Methods

Description of the study area

The evaluation was made at Mechara Center, on-station in DaroLabu District of West Hararghe Zone of Oromia. It is located at 434 km East of Addis Ababa and about 115 km from Chiro town, West Hararghe Zone. The district is located between a range of 1350 and 2450masl. Longitudinal and latitudinal position of experimental site is $40^0$19.114E and $08^0$35.589 N, respectively.

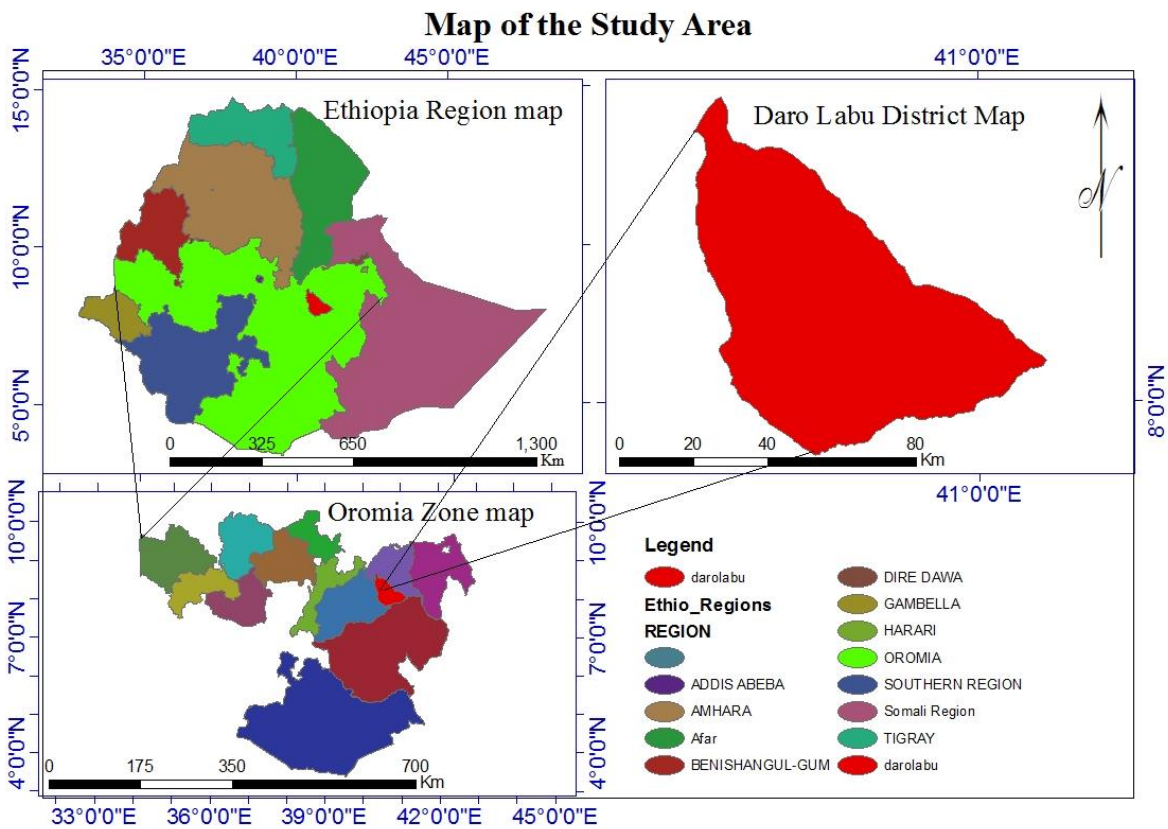


Figure 3. Map of the study area

Soil and climate

The major soil type of the study area is Nitisols and its textural class is sandy loam clay which is reddish in color. The area has bimodal type of rainfall distribution with annual rainfall ranging from 900-1300mm (average annual rainfall of 1094 mm). Short rainy season is from March to April and long rainy season is from June to October. The ambient temperature of the district varies from 14-26^{o}C with average of 20^{o}C (Mechara Center Weather Station, 2009-2014).

Farming system

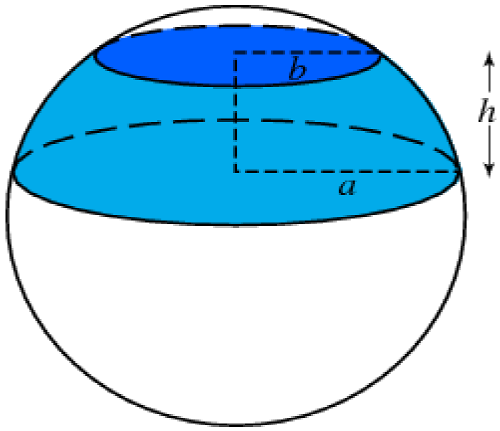
The agricultural activities in the district are mainly characterized by the presence of subsistence mixed farming system, of both crop production and livestock. The livelihood of the people in the district depends on the livestock and crop production. Since the farmer practices the cut and carry grazing system, they use crop residue for livestock/animal feed especially during dry period. In turn, the farmers collect manure from their livestock, distribute on the field, and used as organic fertilizers for crop production. The major cereal crops produced in the district are Sorghum and Maize, vegetables (onion, potato, redroot, tomato and cabbage) in irrigation areas, fruits (banana, mango,), and cash crop such as khat (*Catha edulis*) and coffee. The rarely produced crops are teff, wheat and barley (BoARD, 2014).

Vermiculture establishment

Vermiculture was constructed for vermicompost production and multiplication of worms. The foundation floor was constructed by cements. The size of vermiculture was 4 x 5m depending on the worm bin. Steel iron sheet was used to cover the top of the house to protect worms from sunlight and rainfall. Four sides of the house were covered by meshwire to protect birds and other animals attack and ash was used to control small ants. The worm bin, place where worms live and produce compost, shallow boxes were constructed in the house with the dimension of 0.4m height x 0.5m width x 1m length from concrete cement.

Experimental materials and vermicompost preparation

Vermicompost was prepared from different material sources that were locally available maize, sorghum, grasses, haricot bean, teff and mixed straw. Red worm (*Eisenia fetida*) was used as a decomposer, which was taken from Haramaya University. The collected compost materials were chopped and added to the worm bin. Animal manure was added to all materials in equal amount. However, plastic bags were used to apply the treatments in the vermiculture. All materials were chopped, added to plastic bags, and mixed with decomposed animal manure as a starter, and sprayed with water to maintain optimum moisture for worms. The mixtures of composting materials were prepared from equal amount (0.5kg) and finally mixed with decomposed animal manures; composting materials of 2.5kg were mixed with 1kg of decomposed animal manure and filled based on the volume of worm bin/plastic bag calculated as spherical frustum formula $1/6\pi h\ (3a^2+3b^2+h^2)$ (Harris and Stocker, 1998) and the volume was $0.047m^3$. After optimum moisture was adjusted, 100 earthworms were counted and added to each treatment. Bottom of plastic bag was drilled to drain excess water.Water was sprayed as it is needed to keep the optimum moisture status of the worm feed.



Where $h = 0.175m$

$B = 0.17m$

$a = 0.27m$

$V = 1/6\pi h\ (3a^2+3b^2+h^2$

$= 1/6\pi h\ (3*0.27m^2+30.17m^2+0.175m^2)$

$= 0.047m^3$

Vermicompost sample collection and preparation

Each composting material was digested in three plastic bags. Matured composite vermicompost samples were prepared from the three plastic bags by mixing the three vermicompost and 1kg sample was taken for laboratory analysis. The collected samples were air dried, crushed and passed through 2 mm sieve after a careful removal of undecomposed plant parts and other unwanted materials for some nutrients analysis at Ethiopian Construction Design and Supervision Works Corporation Research, Laboratory and Training.

Vermicompost analysis

Vermicompost samples collected were analyzed for soil reaction pH (H_2O), electrical conductivity, available phosphorus and potassium, organic carbon, total nitrogen, exchangeable bases (Na, K, Mg and Ca), CEC, and extractable micro-nutrients (Fe, Mn, Zn and Cu).

Table 1. Parmeters analyzed from verim-compost prepared and laboratory methods used

No.	Parameter	Unit	Method
1	pH	-	Potentiometric
2	EC	mS/cm	Conductivity Cell Poteniometric
3	Avail. P	mg P_2O_5/kg soil	Olsen
4	Avail. K	mg K_2O/kg soil	Ammonium Acetate
5	OC	%	Walklay Black
6	TN	%	Kjeldehal
7	Exchangeable Ca	meq/100 gm of soil	Ammonium Acetate
8	Exchangeable Mg	meq/100 gm of soil	Ammonium Acetate
9	Exchangeable Na	meq/100 gm of soil	Ammonium Acetate
10	Exchangeable K	meq/100 gm of soil	Ammonium Acetate
11	CEC	meq/100 gm of soil	Ammonium Acetate
12	Extractable Fe	mg/kg soil	DTPA Extraction
13	Extractable Zn	mg/kg soil	DTPA Extraction
14	Extractable Cu	mg/kg soil	DTPA Extraction
15	Extractable Mn	mg/kg soil	DTPA Extraction

Results and Discussion

Table 2. Summary of laboratory analysis results of vermicompost prepared from different material sources

Parameter	Material					
	Haricot bean	**Grasses**	**Mixed straw**	**Teff**	**Maize**	**Sorghum**
pH (H_2O) (1:2.5)	8.41	7.51	8.09	8.15	8.39	8.43
EC(mS/cm) (1:2.5)	4.06	5.27	3.69	4.21	4.51	3.29
Exch.Na (meq/100gm of vermicompost)	1.43	1.05	1.48	1.36	1.57	2.04
Exch.K (meq/100 gm of vermicompost)	11.59	10.00	20.72	20.92	19.90	18.97
Exch.Ca (meq/100 gm of vermicompost)	26.80	31.20	32.00	35.20	34.00	34.00
Exch.Mg (meq/100 gm of vermicompost)	13.20	12.80	10.00	12.00	12.00	12.00
CEC (meq/100 gm of vermicompost)	57.39	58.26	63.04	68.70	66.09	63.04
Sum of Cations (meq/100gm of vermicompost)	53.02	55.05	64.20	69.48	67.46	67.02
Organic Carbon (OC) (%)	21.26	34.66	27.08	27.00	28.21	23.35
Total Nitrogen (TN) (%)	3.04	4.26	3.73	3.77	3.09	3.16
C:N Ratio	7.00	8.14	7.27	7.16	9.13	7.39
Available P (AV.p) (mg P_2O_5/kg vermicompost)	775.39	1277.62	829.91	1023.80	987.38	905.96
Available K (Av.K) (mgK_2O/kg vermicompost)	6963.6	4987.0	4571.5	7327.7	4545.47	3740.40
Fe (mg/kg vermicompost)	29.56	29.05	38.23	54.24	46.01	46.02
Mn (mg/kg vermicompost)	354.35	101.83	120.87	117.66	105.14	112.03
Cu (mg/kg vermicompost)	4.24	1.30	2.67	0.90	4.20	6.67
Zn (mg/kg vermicompost)	32.32	35.81	41.33	45.67	41.05	58.72

Compost pH

The results indicated that the pH of vermicompost ranged from 7.51-8.43 (Table 2 and Figure 1). According to the pH rating by Tekalign (1991), it was ranged from moderately to strongly alkaline. Similarly, Rogelio *et al.*, (2005), Dickerson (1994) and Jouquet *et al.*, *(*2013) reported similar results in which the pH status of vermicompost was ranged from 6.8-8.41; Padmavathiamma, *et al*., 2008 also reported that the pH of vermicompost ranged from neutral to alkaline. A pH greater than 8.5 and electrical conductivity of 8 dS m^{-1} were found to harm earthworms. Alklainity and salinity are harmful to both earthworms and microorganism (Santamaria *et al*., 2001). Thus the prepared vermicompost doesn't have salinity/alkalinity problems. Fares *et al.*, (2005) found that the increased pH at the end of the composting process, which was attributed to progressive utilization of organic acids and increase in mineral constituents of waste.

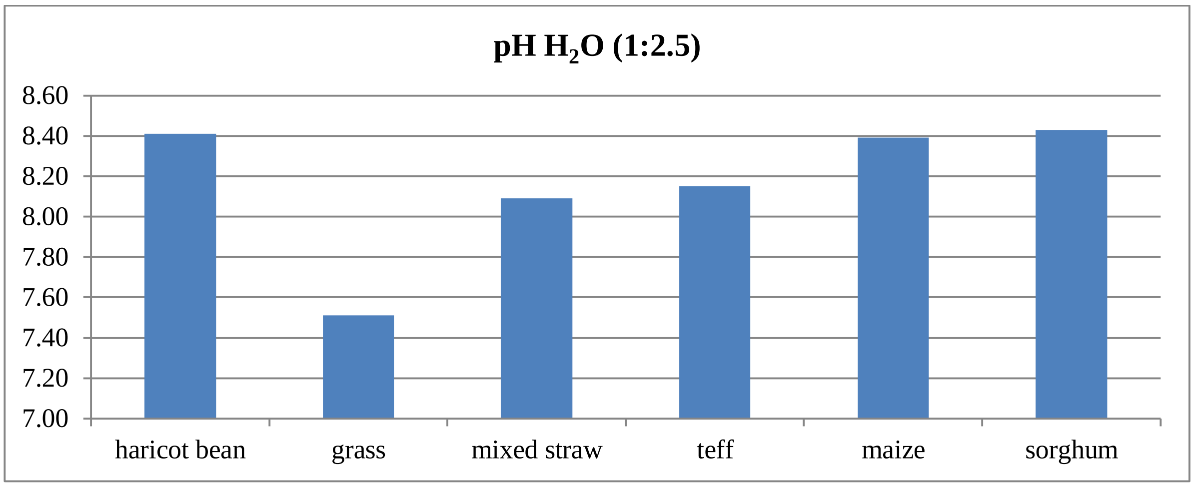


Fig. 1. pH values of vermicompost prepared from different material sources

Electrical conductivity

In order to assess the salinity hazard of vermicompost, electrical conductivity (EC) measurements are carried out. The soluble salt content can be estimated from the electrical conductivity of a vermicompost suspension in distilled water. The highest (5.27 mmhos/cm) and lowest (3.29 mmhos/cm) EC was recorded from grass and sorghum straw respectively (Table 2 and Figure 2). According to Soil salinity status in terms of EC (Richards, 1954), vermicompost made from Sorghum and mixed straw showed slightly saline while from haricot bean, grasses, teff and maize straw showed moderately saline. The increased EC during the period of the vermicomposting processes is in consistence with that of earlier workers Kaviraj and Sharma, (2003); Jadia and Fulekar, (2008), which was probably due to the degradation of organic matter releasing minerals such as exchangeable Ca, Mg, K and P in the available forms, that is, in the form of cations in the vermicompost (Guoxue *et al.*, 2001; Tognetti *et al*., 2005).

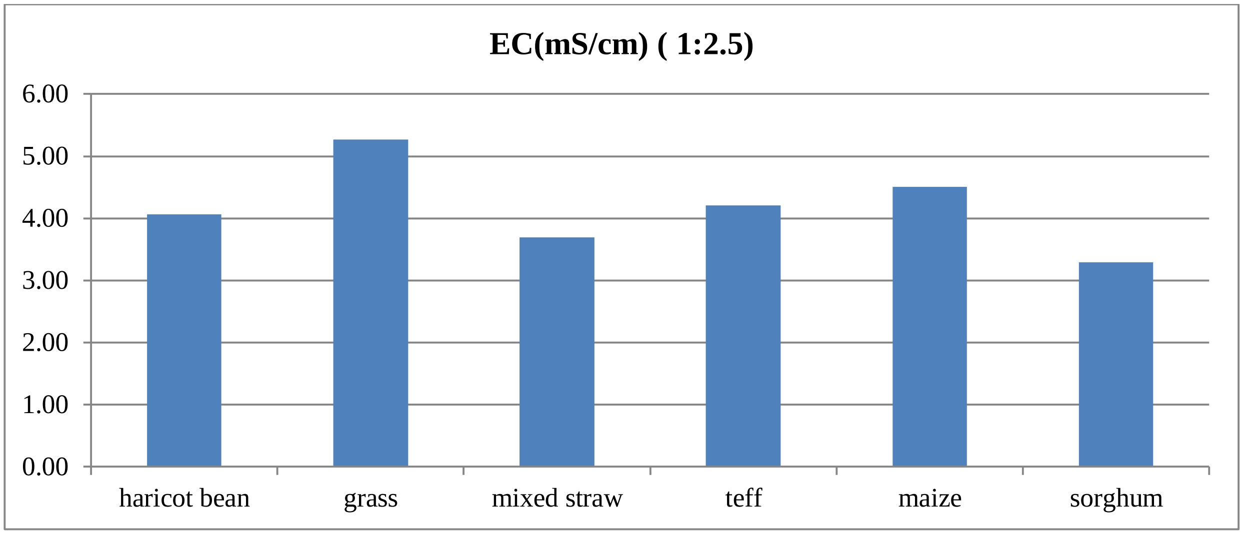


Fig. 2. Total electrical conductivity of different vermicompost materials

Organic carbon

Organic matter is the material in soil that is directly derived from plants and animals, and it supports most important micro-fauna and micro-flora in the soil. This study showed that the highest organic carbon was recorded from grasses 34.66% and the lowest from haricot bean, 21.26% (Table 2 and Figure 3). According to Tekalign (1991) the status of organic carbon in vermicompost is high when compared with its availability in compost.

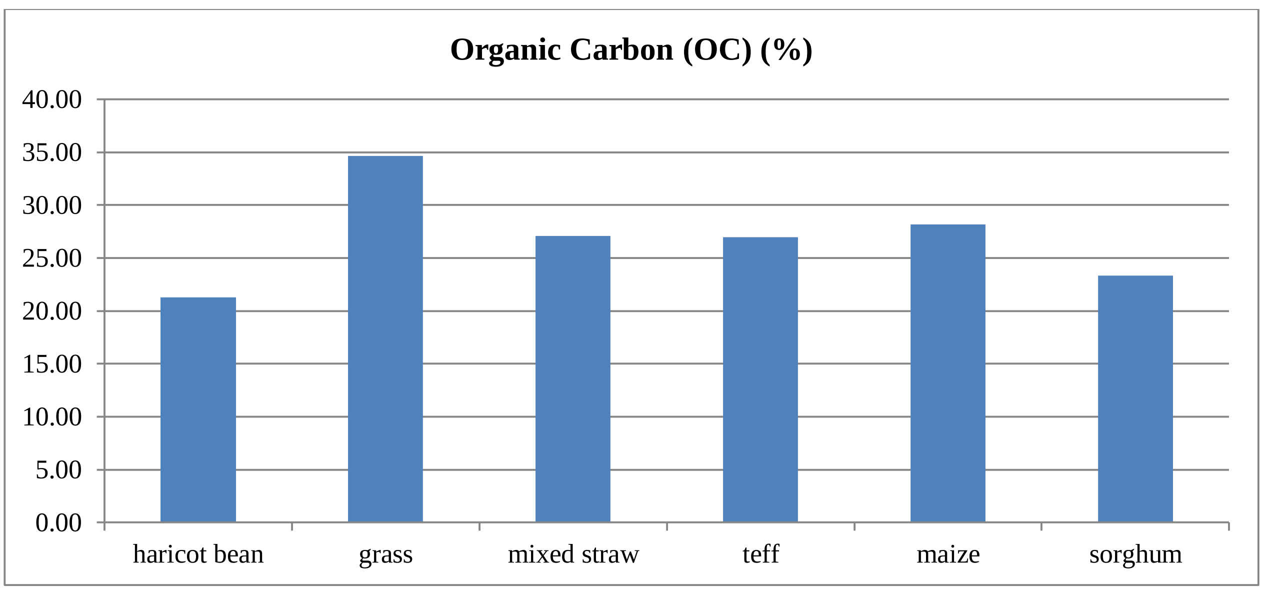


Fig.3. Organic carbon content of vermicompost prepared from different materials

Available phosphorous

The laboratory analysis result showed that lower (775.39ppm) and higher (1277.62ppm) available phosphorous was recorded in vermicompost prepared from haricot bean straw and grasses, respectively (Table 2 and Figure 4). The variation might be attributed to different material sources. The enhanced P level in vermicompost suggests phosphorous mineralization during the process. During vermicomposting, the worms converted the insoluble P into soluble forms with the help of P-solubilizing microorganisms through phosphatases present in the gut, making it more available to plants (Padmavathiamma *et al*., 2008; Ghosh *et al*., 1999). When the values were compared to soil, available phosphorous from vermicompost prepared from all composting materials was very high. This was in agreement with the findings of Nagavallemma *et al*. (2004) that reported the available phosphorous in vermicompost was 0.19-1.02% (1,900-10,200ppm). Thus, application of vermicompost could increase P content of the soil if the soil is deficient with phosphorus.

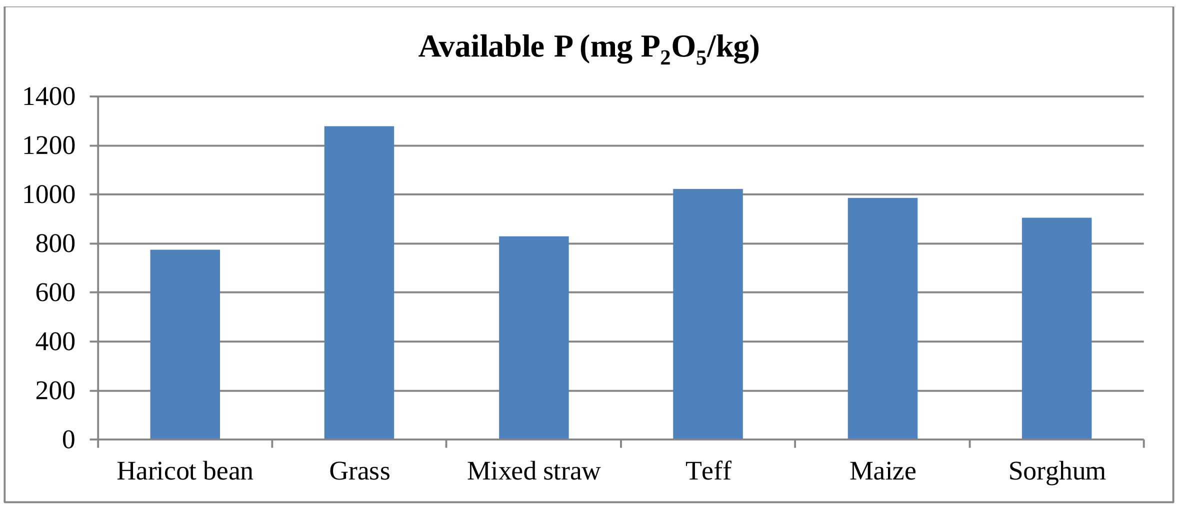


Fig.4. Available phosphorous content of different vermicompost

Available potassium

The result revealed that the highest available K was recorded from grasses followed by teff strow (Table 2 and Figure 5). The result was in agreement with the range that stated by Nagavallemma *et al.*, (*2004*) 1500-7300mg/kg of available K in vermicompost prepared from oganic materials; other study indicated that available K in vermicompost was 950.5mg/kg (Kalantari, *et al.*, 2009). Similar study appeared that backyard vermicompost of total potassium content was 8.2g/kg (8200mg/kg) (Tognettia *et al.*, 2013).

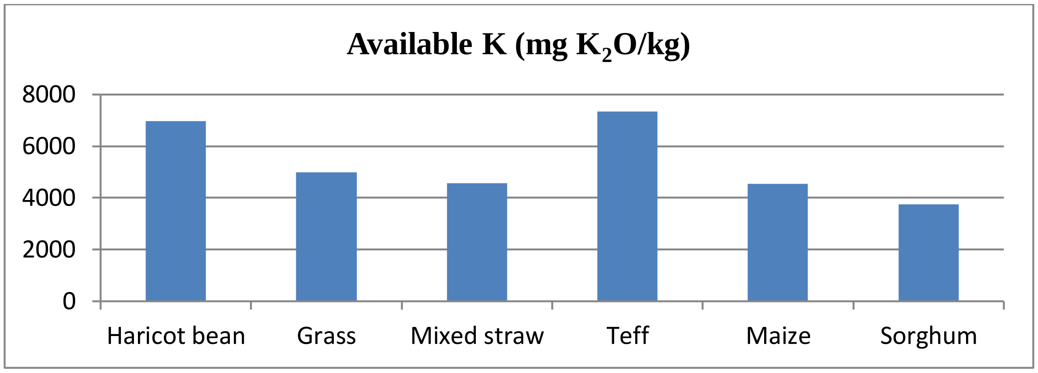


Fig. 5. Available potassium of vermicompost from different straws

Total nitrogen

The highest total N (4.26%) and lowest (3.04%) were recorded from vermicomposts of grasses and haricot bean straw, respectively (Tabel 2 and Figure 6). The variation of TN among the vermicompost attributed to the substrates digested by worms. Because different types of straw contain different nitrogen contents.Similarly, S.Kalantari *et al.* (2009) reported that 3.50% of total nitrogen was recorded from vermicomost. George W. Dickerson (1994) reported that total nitrogen recorded in vermicompost was 1.94%. According to Tekalign (1991) rating of total nitrogenin a soil, vermicompost made from all substrates was high (>0.25%) and significantly greater than that found in the soil. Therefore, vermicompost application in to the soil could increase total nitrogen. Similarly, finding of Tigist *et al* (2017) also revealedthat application of vermicompost could increase total nitrogen in a soil.

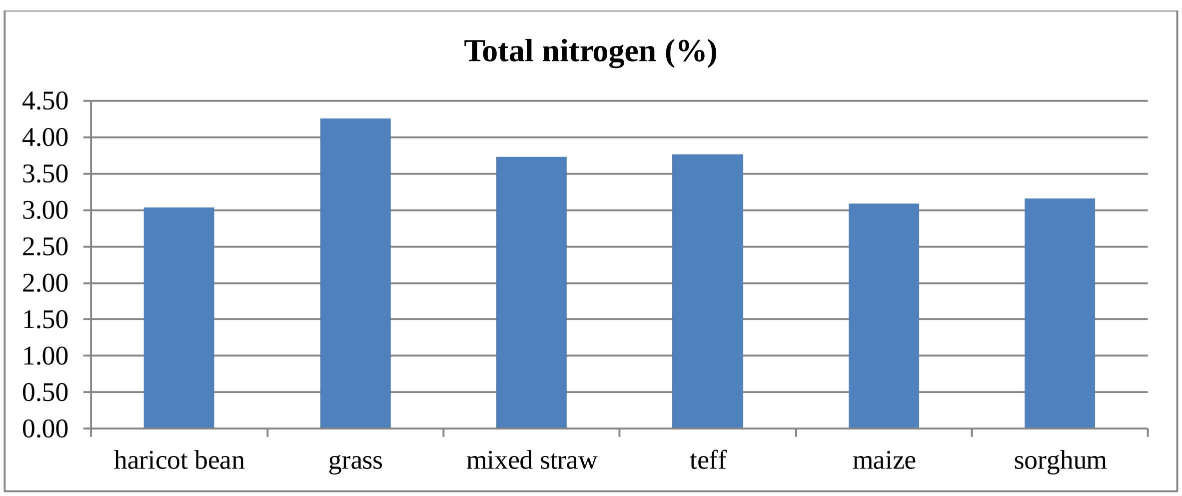


Fig.6. Total nitrogen content of different vermicompost materials

Carbon to nitrogen ratio

The study revealed that highest C: N ratio (9.13) was recorded from maize straw and lowest (7.0) from haricot bean straw (Table 2 and Figure 7). Carbon to nitrogen ratio is an indicator of nutrient mineralization and immobilization whereby low C: N ratio indicates higher rate of mineralization and higher C: N ratio indicates greater rates of immobilization (Brady and Weil, 2002). The laboratory analysis result showed that highest total nitrogen was recorded which was mineralized by earthworms from maize straw. Lower C: N ratio was observed due to higher mineralization of nitrogen; according to Senesi (1989), C: N ratio < 20 indicated advance in organic matter stabilization and reflects a satisfactory degree of maturity of organic wastes. Similarly, several studies confirmed that 7.48 and 5.51 C: N ratios were recorded from vermicompost (Alves *et al.* 2006; Kalantari *et al.*, 2009). The decrease in C: N ratios in vermicompost is inconsistence with the findings of earlier investigators (Suthar, 2007; Garg *et al.*, 2006) which was 9.89-10.4.

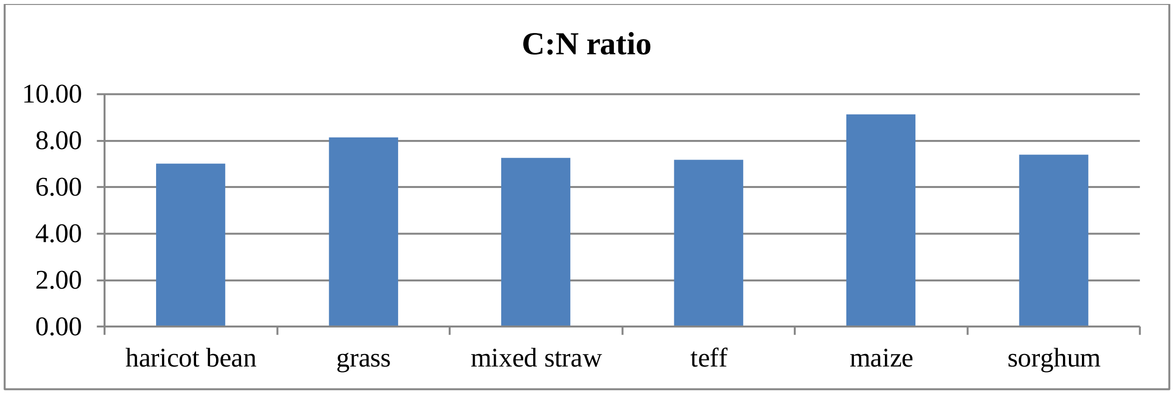


Fig.7. C: N status of vermicompost from different straws

Cation exchange capacity

Cation exchange capacity is the capacity of the soil to hold and exchange cations. If the CEC of a soil is low, the soil is infertile. Among the treatments, teff straw contained the highest CEC (68.7 cmol+kg^{-1}) (Table 2 and Figure 8). However, as per CEC rating indicated by Hazelton and Murphy (2007), the CEC of vermicompost made from all materials was rated to very high status. This result confirmed the study conducted by Jouquet *et al.* (2013) reporting 57.8 cmol+kg^{-1} of CEC. Therefore application of vermicompost made from all substrates could increase CEC content of the soil in areas where soil with low CEC.

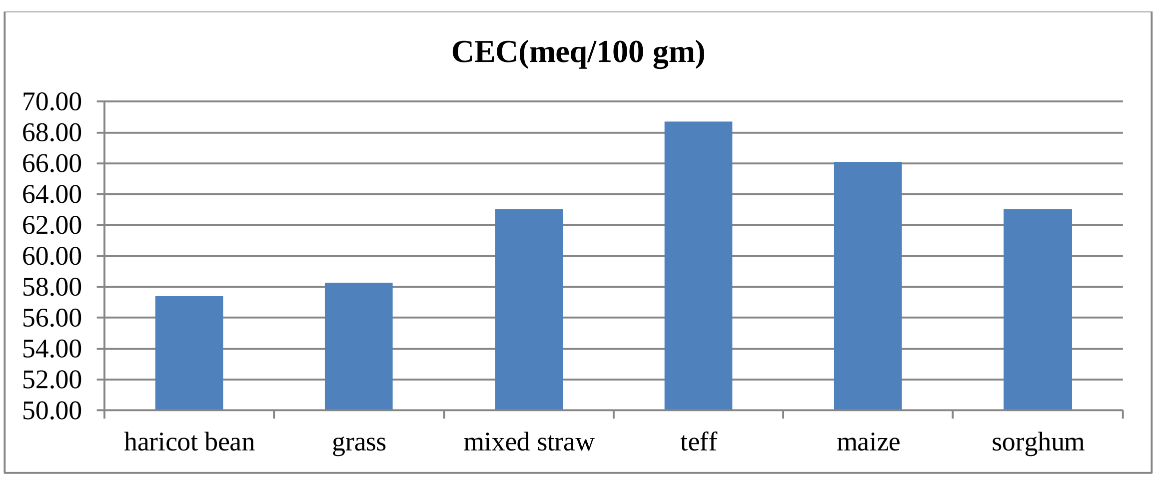


Fig. 8. Cation exchange capacity of vermicompost prepared from different materials

Exchangeable bases

The exchange complexes of the vermicomposts were dominantly occupied by Ca^{2+} than other basic cations in proportion. The analyzed result showed that highest (35.20 meq/100 gm) and lowest (26.80 meq/100 gm) exchangeable Ca^{2+} was recorded from vermicompost made from teff and haricot bean straw, respectively (Table 2). However, according to FAO (2006) rating of exchangeable bases all vermicompost made from all substrates were high in their exchangeable Ca^{2+}. The highest (13.20 meq/100 gm) and lowest (10 meq/100 gm) exchangeable magnesium was obtained from haricot bean and mixed straw substrates, respectively which were rated as very high status (FAO, 2006). All vermicompost made from all substrates were high in their Exchangeable K^{+} according to their ratings. Also exchangeable Na^{+} was very high in all substrates except in sorghum straw substrates which were high in their status. This was in agreement with the findings of Amir and Fouzia (2011) reported that the exchangeable bases (Ca^{2+}, Ma^{2+}, K^{+} and Na^{+}) were significantly increased in vermicompost as compared to pit compost.

Extractable micro-nutrients

Iron

Highest (54.24 mg kg^{-1}) values of DTPA extractable iron was recorded from vermicompost made from teff straw and lowest (29.05 mg kg^{-1}) value from grass straw substrates (Table 2). According to the rating of Jones (2003), the contents of extractable Fe for all vermicompost made from all substrates was high. Similarly, Dickerson, (1994) reported that very high iron contents were recorded from vermicompost. Therefore, vermicompost made from those substrates could be applied to reduce the iron deficiency of soil.

Manganese

Highest (354.35 mg kg^{-1}) and lowest (101.83 mg kg^{-1}) extractable manganese were recorded from vermicompost prepared from haricot bean and grass straw substrates, respectively (Table 2 and Figure 9). According to the rating of Jones (2003), the contents of extractable Mn for all vermicompost made from all substrates wasmet in the range of very high.Nagavallemma KP *et al.* (2004); Rajiv K *et al.* (2010); S.Kalantari *et al.* (2009); George W. Dickerson (1994) indicated that Mn content of vermicompost was very high. Therefore, vermicompost could be used as manganese fertilizers to solve Mn deficiency problem of soils based on the available substrate materials.

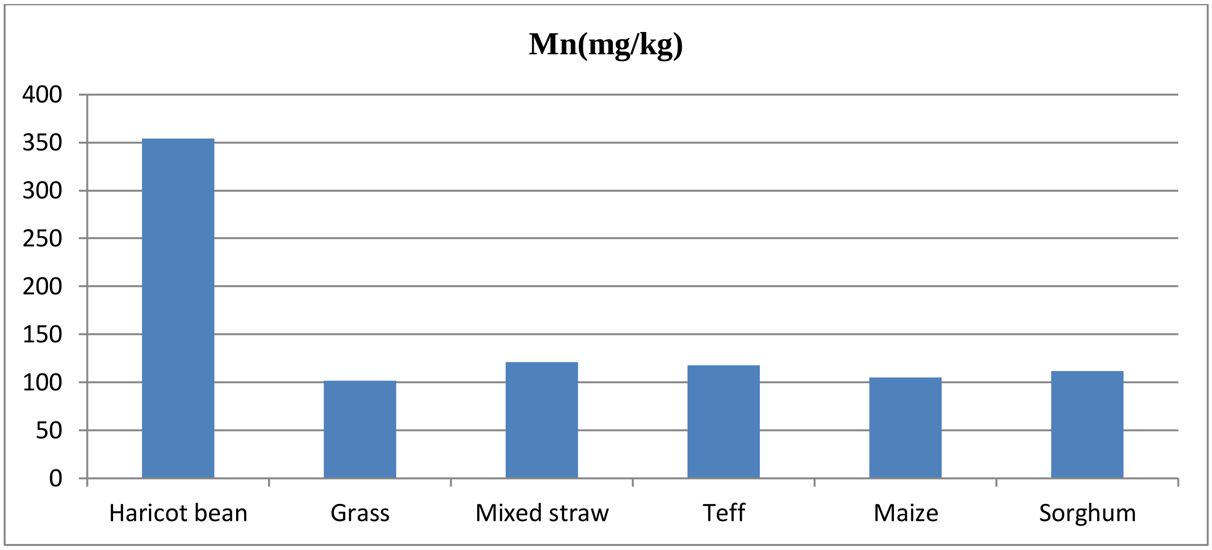


Fig.9. Manganase content of vermicompost prepared from different composting materials

Zinc

The study was revealed that the highest (58.72 mg kg^{-1}) Zinc content among treatment was vermicompost made from sorghum straw while least (32.32 mg kg^{-1}) was recorded from haricot bean straw substrates (Table 2 and Figure 10). Extractable Zn contents of vermicompost were very high and can solve the deficiency of Zn according to the rating indicated for soil (Jones, 2003). This was in agreement with the findings of George W. Dickerson (1994), Rajiv K *et al.* (2010), who found that very high Zn contents were recorded from vermicompost.

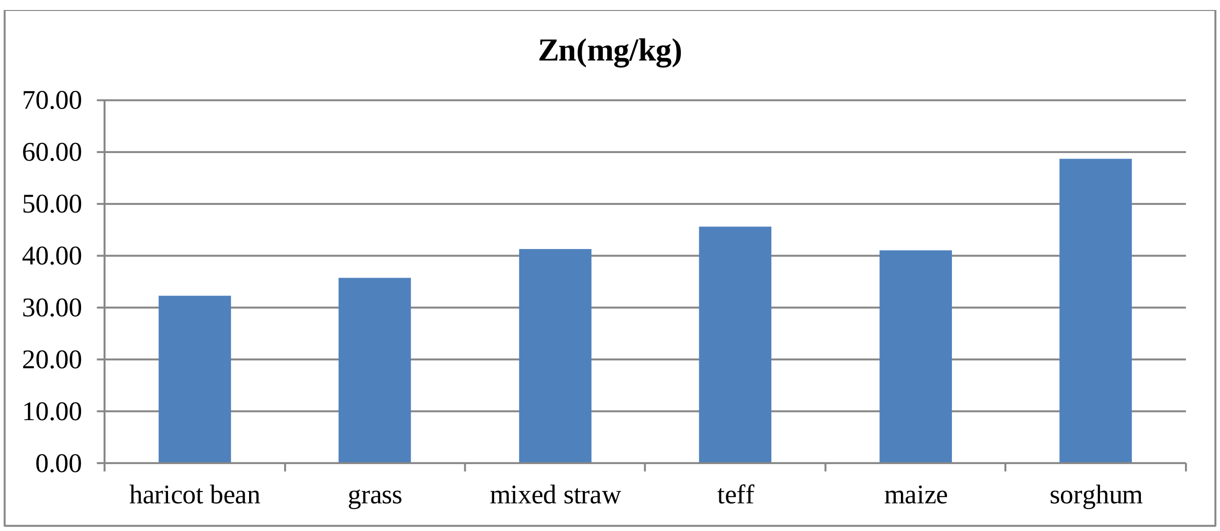


Fig.10. Zinc status of vermicompost prepared from different straws

Copper

Highest (6.67 mg kg^{-1}) and lowest (0.9 mg kg^{-1}) Cu content was recorded from vermicompost made from sorghum and teff straw substrates respectively (Table 2 and Figure 11). According to the rate indicated by

Jones (2003), low Cu content was recorded from grass and teff straw substrates while medium Cu status was obtained from haricot bean, maize and mixed straw substrates. Highest Cu contents were recorded from vermicompost prepared from sorghum straw. These variations might be attributed to the Cu contents of substrates from which vermicompost were made.

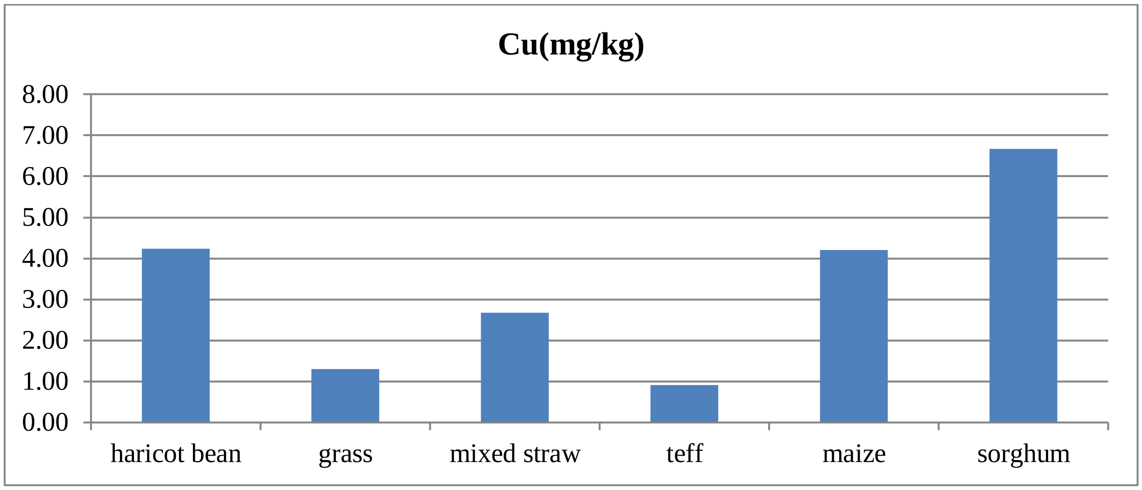


Fig.11. Copper content of vermicompost prepared from different material sources

Conclusion and Recommendations

Vermicompost is nutritionally rich organic fertilizer, which releases nutrients in the soil and improves quality of the plants as well as it renewed physical and biological properties of soil. Vermicompost prepared from locally available materials, haricot bean, grass, teff, maize and sorghum straw and mixture of all straws were analyzed in laboratory for evaluation of their nutrient contents. The laboratory analysis results showed that highest macro-nutrients (total nitrogen, available phosphorus and available potasium) were recorded from vermicompost prepared from grasses and available potassium from teff straw. In contrast, lowest TN and available P were recorded from haricot bean straw and lowest available potassium recorded from vermicompost from sorghum straw. Highest and lowest CEC were recorded from vermicompost prepared from teff straw and haricot bean straw, respectively. The highest extractable Fe, Mn, Cu and Zn were recorded from vermicompost of maize, haricot bean and sorghum straw, respectively.

Generally, vermicompost prepared from all material sources showed highest nutrient contents for all parameters and can play dominent role in enhacing nutrient deficiecy of the soils. Therefore, all composting materials could be used for vermicompost preparation based on the availabilityof materials and could be used as organic fertilizers source for macro- and micro-nutrient of soils deficient with these nutrients. Future research is needed for further studies on application rate of vermicompost and their effect on crop productivity and production, and soil physic-chemical properties under field conditions.

Acknowledgment

The authors would like to express heartfelt and deep gratitude to Oromia Agricultural Research Institute for financial support; staff members of Natural Resource Research directorate of Mechara Agricultural Research Center for their active participation in conducting this assessment; also thank Ethiopian Construction Design and Supervision Works Corporation Research, Laboratory and Training Center for their cooperation of laboratory analysis of verim-compost samples; express gratitude to Mr. Wezir Mohamed for his valuable works.

References

Amir Khan and FouziaIshaq, 2011.Chemical nutrient analysis of different composts (*Vermicompost*and*Pitcompost*) and their effect on the growth of a vegetative crop *Pisum sativum.*Asian Journal of Plant Science and Research, 2011, 1 (1):116-130

Atiyeh, R.M., Subler, S., Edwards, C.A., Bachman, G., Metzger, J.D. and Shuster, W, 2000. Effectsof Vermi-composts and Composts on Plant Growth in Horticultural Container Media and Soil.*Pedobiologia*, 44(5): 579-590.

BerhanuDebele, 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Brady, N. and R. Weil, 2002. The Nature and Properties of Soils, 13th Edition. Prentice Hall. Upper Saddle River, New Jersey. 960 p.

C. Tognetti, F. Laos, M.J. Mazzarino& M.T. Hernández, 2005. Composting vs. Vermicomposting: A Comparison of End Product Quality, Compost Science & Utilization, 13:1, 6-13, DOI: 10.1080/1065657X.2005.10702212

Canellas.L.P., Olivares, F.L., Okorokova, A.L. and Fa-canha, R.A, 2002.Humic Acids Isolated from Earth-worm Compost Enhance Root Elongation, Lateral Root Emergence, and Plasma Membrane H+ - ATPase Activity in Maize Roots. *Journal of Plant Physiology*, 130(4), 1951-1957.

Chaoui, H.I., Zibilske, L.M. and Ohno, T, 2003. Effects of earth worms casts and compost on soil microbial activ-ity and plant nutrient availability. *Soil Biology and Bio-chemistry*, 35(2): 295-302.

Devi, D., Agarwal, S.K., and Dayal, D, 1998.Response of sunflower (Helianthus annuus) to organic manures and fertilizers.Indian Journal of Agronomy. 43(3): 469-473.

Dickerson, W., George, C, 1994.Chemical characteristics of garden compost and vermicompost. Guide H - 164.

Domínguez, J., Edwards, C.A, 2010. Biology and ecology of earthworm species used for vermicomposting, In: C.A. Edwards, N.Q. Arancon, R.L. Sherman (Eds.), *VermicultureTechnology: Earthworms, Organic Waste and Environmental Management*, CRC Press, Boca Raton, Florida, pp. 25-37.

Domínguez, J., Edwards, C.A. and S. Subler, 1997. A comparison of vermicomposting and composting. *BioCycle*, 4: 57-59.

Eastman, B.R., Kane, P.N., Edwards, C.A., Trytek, L., Guandi, B., Stermenr, A.L. and Mobley, J.R. 2001.The effectiveness of vermiculture in human pathogen reduction for USEPA biosolids Stabilization.*Compost Sci. Util.*, 1:38-49.

Edwards, C.A, 1995. Historical overview of vermicomposting.*BioCycle*, 6:56-58.

EP.Jouquet, E. Bloquel, T. Thu Doan, M. Ricoy, D. Orange, C. Rumpel & T. Tran Duc, 2011. Do Compost and Vermicompost Improve Macronutrient Retention and Plant Growth in Degraded

Tropical Soils, Compost Science & Utilization, 19:1, 15-24, DOI: 10.1080/1065657X.2011.10736972

FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16, Rome, Italy.

Fares, F., Albalkhi, A., Dec. J., Bruns, M.A., and Bollag, J.M, 2005.Physicochemical characteristics of animal and municipal wastes decomposed in arid soils, Journal of Environmental Quality, 34, pp 1392-1403.

Ferreras,L.,Gomez,E.,Toresani,S.,Firpo,I.andRo- tondo,R,2006.Effectoforganicamendmentsonsome physical,chemicalandbiologicalpropertiesinahorti- culturalsoil.*BioresourceTechnology*,97,635-640. doi:10.1016/j.biortech.2005.03.018]. doi:10.1007/s10705-008-9168-0.

Gandhi, M., Sangwan, V., Kapoor, K.K. and Dilbaghi, N, 1997.Composting of household wastes with and without earthworms.*Environment and Ecology*.15, 432-434.

Garg, P., Gupta, A. and Satya, S, 2006. Vermicomposting ofdifferent types of waste using *Eisenia foetida*: A comparativestudy. *Biores. Technol*., 97: 391-395.

Ghosh, M., Chattopadhyay G.N. and K. Baral, 1999. Transformationof phosphorus during vermicomposting.*Bioresource Technol*., 69: 149-154.

Golueke, C.G, 1991. Understanding the process.*In*: Staff of BioCycle (Eds.). *The BioCycle Guide to the Art and Science of Composting*.The JG Press, Inc., Emmaus, Pennsylvania, USA. pp. 14-27.

Gopinath, K.A., Supradip, S., Mina, B.L., Pande, H., Kundu,S.andGupta,H.S,2008. Influenceoforganic amendmentsongrowth,yieldandqualityofwheatand onsoilpropertiesduringtransitiontoorganicproduction. *NutrientCyclinginAgroecosystems,*82,51-60.

Gouxue, L., Zhang, F., Sun, Y., Wong, J.W.C. and Fang, M, 2001. Chemical evaluation of sewage sludge composting as a mature indicator for composting process.Water, Air, Soil Pollut., 132, 333–345.

Harris, J. W. and Stocker, H, 1998."Spherical Zone (Spherical Layer)." §4.8.5 in *Handbook of Mathematics and Computational Science.* New York: Springer-Verlag, pp. 107-108.

Hazelton, P. and Murphy, B, 2007."Interpreting Soil Test Results", CSIRO Publishing, 150 Oxford Street Collingwood VIC 3066, Australia.

Inbar, Y., Hadar, Y., Chen, Y, 1993. Recycling of cattle manure: the composting process and characterization of maturity. J. Environ. Qual. 22, 857–863.

JadiaC.D., and Fulekar M.H, 2008. "Phytoremediation: The application of vermicompost to remove zinc, cadmium, copper, nickel, and lead by sunflower plant", Environmental Engineering and Management Journal, 7, pp 547-558.

Jones JB, 2003. Agronomic Handbook: Management of Crops, Soils, and Their Fertility. CRC Press LLC, Boca Raton, FL, USA. 482p

Li, K. and Li, P.Z, 2010. Earthworms helping economy, improving ecology and protecting health. In: Sinha, R.K. *et. al*., Eds. Special Issue on 'Vermiculture Technology', *International Journal of Environmental Engineering*, In-derscience Pub.

Marinari,S.,Masciandaro,G.,Ceccanti,B.andGrego,S, 2000.Influenceoforganicandmineralfertilizerson soilbiological andphysical properties. *Bioresource Tech- nology*, 72, 9-17. doi:10.1016/S0960-8524(99)00094-2].

Mirian R. Alves , Maria D. Landgraf & Maria O. O. Rezende, 2001. Sorption And Desorption ofthe Herbicide Alachlor On Humic Acid Fractions From Two Vermicomposts, Journal of Environmental Science andHealth, Part B: Pesticides, Food Contaminants, and Agricultural Wastes, 36:6, 797-808, DOI: 10.1081/PFC-100107413

Munroe, G, 2007. Manual of On-farm Vermicomposting and Vermiculture. Publication of Organic Agriculture Centre of Canada, Nova Scotia

Nagavallemma KP, Wani SP, StephaneLacroix, Padmaja VV, Vineela C, BabuRao M andSahrawat KL, 2004. Vermicomposting: Recycling wastes into valuable organic fertilizer. Global Themeon Agrecosystems Report no. 8. Patancheru 502 324, Andhra Pradesh, India: International Crops ResearchInstitute for the Semi-Arid Tropics. 20 pp.

Padmavathiamma, P. K., Li, L. Y., & Kumari, U. R, 2008.An experimental study of vermi-biowaste composting for agricultural soil improvement. [10.1016/j.biortech.2007.04.028]. *Bioresource Technology, 99*, 1672-1681.
Pajon, S. 2007. The Worms Turn-Argentina. Intermediate Technology Development Group. Case Study Series 4; Quoted in Munroe. http://www.tve.org./ho/doc.cfm?aid. Accessed on Feb. 20, 2014.
Parkin,T.B.andBerry,E.C.1994.Nitrogentransformationsassociated withearthworm casts.*SoilBiologyand Biochemistry*, 26,1233-1238. doi:10.1016/0038-0717(94)90148-1
Patil, B.B. 1993. Soil and Organic Farming.*Proceeding of the Training Program on* '*Organic Agriculture*, Insti-tute of Natural and Organic Agriculture, Pune.
Reinecke,A.,Viljoen,S.V.andSaayman,R.1992.The suitabilityof*Eudriluseugenie*,*Perionyxexcavatus*and *Eisenia fetida* (Oligochaeta) for vermicomposting in southern Africa in terms of their temperature require- ments.*SoilBiologyandBiochemistry*,24,1295-1307 doi:10.1016/0038-0717(92)90109-B].
Richard , L.A, 1954 . Diagnosis and improvement of sa line and alkalinesoil. U.S. D.A. Deptt. Agriculture Handbook No. 60, Washington ,D.C., USA.
Rogelio Nogales , Celia Cifuentes& Emilio Benítez, 2005. Vermicomposting of Winery Wastes: A Laboratory Study, Journal of Environmental Science and Health, Part B: Pesticides, Food Contaminants, and Agricultural Wastes, 40:4, 659-673, DOI: 10.1081/PFC-200061595
Ruz-Jerez, B.E., Ball, P.R. and Tillman, R.W. 1992. Laboratoryassessmentofnutrientreleasefrom apasture soilreceivinggrassorcloverresidues,in thepresenceor absenceof*Lumbricusrubellus* or*Eiseniafetida*.*SoilBi- ologyandBiochemistry*,24,1529-1534. doi:10.1016/0038-0717(92)90145-N).
S. Kalantari, S. Hatami, M. M. Ardalan, H. A. Alikhani and M. Shorafa,2010. The effect of compost and vermicompost of yard leaf manure on growth of corn, African Journal of Agricultural Research Vol. 5(11), pp. 1317-1323, 4 June, 2010
S. Suthar, 2007. *Production of vermifertilizer from guar gumindustrial wastes by using composting earthworms* Perionyxsansbaricus *(Perrier)*, Environmentalist 27 (2007),pp. 329–335.
Santamaria-Romero-S; Ferrera-Cerrato-R; Almaraz-Suarez-JJ; Galvis-Spinola-A; Barois- Boullard-I, 2001. Dynamics and relationships among microorganisms, C-organicand N-total during composting and vermicomposting. Agrociencia-Montecillo,
Satchel, J.E. and Martin, K. 1984.Phosphatase activity in earthworm feces.*Journal of Soil Biology and Bio-chemistry*, 16(2), 191-194.
Senesi, N., 1989. Composted materials as organic fertilizers.*The Sci. Total Environ.*, 81/82: 521-524.
Sharma, M. and Shweta, 2003. Biomass and vermicompost *production by* the earthworm, Lampito mauritii in different organic wastes .Journal of Applied Zoological Researchers, 14(1) : 98-100.
Subler, S., Edwards, C. and Metzger, J. 1998.Comparing vermicomposts and composts.*BioCycle*, 7: 63-66.
Sujit A.,2012 Vermicompost, the history of organic gold Agricultural Sciences Vol.3 No.7(2012), Article ID:24396,
Suhane, R. K. 2007. Vermicompost.Publication of Ra-jendra Agriculture University, Pusa, Bihar, India, 88.info@kvksmp.org Accessed on Feb. 20, 2014.
Tara, C. 2003. Vermicomposting.Development Alternatives (DA) sustainable livelihoods.http://www.dainet.org/livelihoods/default.htm. Accessed on Feb. 12, 2014.
TekalignTadese. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13.International Livestock Research Center for Africa, Addis Ababa, Ethiopia.and Subtropics. Longman Scientific and Technical, Essex, New York. 474p.
Tigist, A., Lemma, W., Tesfaye, F(2017).Soybean (*Glycine Max* L.) Response To Lime Andvermicompost Amelioration Of Acidic Nitisols OfAssosa, North Western Ethiopia. Msc thesis, Haramaya University.
Tiwari, S.C., Tiwari, B.K. and Mishra, R.R. 1989.Mi-crobial populations, enzyme activities and nitrogen, phosphorus, potassium enrichment in earthworm casts and in surrounding soil of a pineapple plantation.*Journal of Biological Fertility of Soils*, 8(1): 178-182.

Tognetti, C., Laos, F., Mazzarino, M.J. & Hernández, M.T. 2005. Composting vs. Vermicomposting: A vermicomposting, In: C.A. Edwards, N.Q. Arancon, R.L. Sherman (Eds.), *Vermiculture.*

Tomati, V., Grappelli, A. and Galli, E. 1985.Fertility factors in earthworm humus.*Proceedings of International Symposium on* '*Agriculture and Environment*: *Prospects in Earthworm Farming*, Rome, 49-56.

Tomati, V., Grappelli, A. and Galli, E. 1995.The Hor-mone like Effect of Earthworm Casts on Plant Growth.*Biology and Fertility of Soils*, 5(4): 288-294.

USBoardofAgriculture.1980. Reportandrecommendationsonorganicfarming—Casestudies of69organic farmersinUSA. Publication ofUSBoardofAgriculture.

USEPA. 1993. Standards for the use or disposal of sewage sludge. Federal Register 58: 9248 -9415. Washington, D.C.

Vermi Co, 2001 Vermicomposting technology for waste management and agriculture: An executive summary. Vermi Co., Grants Pass.http://www.vermico.com/summary.htm.Accessed on Feb. 15, 2014.

Webster, K. 2007. Compost as part of a vineyard salinity remediation strategy.3rd National Compost Research and Development Forum Organized by COMPOST Aus-tralia, Murdoch University, Perth.www.compostforsoils. com.au Accessed on Feb. 20, 2014.

Whalen, J.K., Parmelee, W.R., McCartnney, A.D. and Vanarsdale, J.L., 1999. Movement of nitrogen (n) from decomposing earthworm tissue to soil microbial and ni-trogen pools. *Soil Biology and Biochemistry*, 31(4): 487-492. www.tandfonline.com/page/terms-and- conditions. Accessed on April 15, 2014.

Agro-forestry Research

Effect of Different Propagation Methods on Lowland Bamboo Species under Bako Condition, East Wollega Zone, West Oromia, Ethiopia

RegassaTerefe*, Mezgebu Senbeto, Lemma Lalisa and Dawit Samuel

Bako Agricultural Research Center, P.O. Box 03, Bako, Ethiopia

* Corresponding author: regassaterefe@yahoo.com

Abstract

Bamboo is one of the fast growing and well responding against drought which can make the species more acceptable in making ever green environment in addition to soil and water conservation, and rehabilitation of degraded lands. The experiment was conducted on the effect of different propagation methods using three lowland bamboo species to recommend the best propagation methods. It was conducted at Bako Agriculture Research Center, on-station, from 2015-2017 production years. Factorial arrangement of randomized complete block design (RCBD) with three replications was used. The vegetative propagation materials were rhizome and branches, lower and middle culms cutting parts of three species (Oxythenantera abyssinica, Dendrocalamus hamlitonii, and Dendrocalamus memebranceous) were used. A total of 144 planting materials were planted in the experimental site. Four planting materials were used in each plot. There was significant difference between the species and propagation methods. The newly emerging shoots revealed significant difference under Dendrocalamus hamlitonii (1.30±0.8) among other species. Under all propagation methods Dendrocalamus hamlitonii showed better performance than others in survival rate, root collar diameter, culm height and internodes length; however, branch propagation method under all species showed poor performance. Therefore, this study confirmed that following rhizome part using lower and middle culm part is promising in selected bamboo species. Further investigation on the biological factors that hampers the initiations of new shoots and survival in using branch cutting methods is recommended.

Keywords: *Bamboo, branch, culms, propagation, rhizome, shoots*

Introduction

Bamboo is a woody perennial belonging to the family of grasses, *Gramineae* (*Poaceae*) with unique qualities (Wang, 2006). It is a self-regenerating and renewable non-timber natural resource. It's a fast growing and self-sustaining species once established (Bystriakova et al. 2004). In bamboo growing countries of the world, bamboo is well known as a multipurpose plant with a numerous of application ranging from construction material, furniture, fence, handicraft, pulp and paper, edible shoots and animal fodder (CIBART, 2004; Kassahun, 2004). Ethiopia has an estimated one million hectares of natural bamboo forest, the largest in African. Despite the versatile resource base and advanced bamboo utilization at a global scale, its great potential to enhance socio-economic and ecological development remains un-realized in Ethiopia (Zenebe et al. 2014).

The bamboo species found in Ethiopia are the African alpine bamboo (*Yushinia alpina)* and the lowland bamboo (*O. abyssinica)*. *Yushinia alpine* was previously called *Arundinaria alpina (A.alpina*). These two species are indigenous to Ethiopia and endemic to Africa (Ensermu, et al. 2000). The solid-stemmed *O.abyssinica* covers area of more than 800,000 ha, which accounts 85% of the bamboo area coverages in the country (Embaye, 2000). In Ethiopia, *O. abyssinica* is prominent in river valleys and locally on the escarpment of western part of the country such as the Benshangul Gumuz Regional State (Ensermu et al. 2000). It co-exists with several other species especially the *Combretum-Terminalia* broad leaved deciduous woodland vegetation common to this part of the country (Sebsebe et al. 2003). Even though, Ethiopia has huge bamboo resources, as a result of demand for fuel wood and wood products, currently suggested the resource is declined in higher rate.

At present, high population growth in the country has led to increase the demand for food and natural resources and hence increase the need of additional agricultural land at steeper and higher upland areas for agricultural cultivation that leads to soil erosion which is damaging agricultural production supporting ecologies and their services. According to Banik (1995), bamboos can be propagated either by sexual (reproductive) or asexual (vegetative) means. Sexual propagation is by means of seeds. However, this is not popular in the country due to the irregularity and rarity of flowering of common bamboo species plus difficulties to transport and store seeds (Lal, et al. 1998; Reddy, 2006, Azene, 2007). In addition to this the nature of bamboo seeds is difficult to manage since this species gave seeds once in its life time. After giving the first seed within 30-70 years old the species immediately collapse so it's difficult to propagate through seed since the resource of seed is very limited. Propagation makes use of different parts of bamboo plants as propagation material. Various methods of vegetative propagation were described by (Tesfaye et al. 2005). This method is suitable to farmers and different stakeholders for their low cost and eases of management techniques (Jiménez and Guevara, 2007).

To diversify bamboo resources as a beginning, different research was conducted at national and regional research center level. Although, East African Bamboo and Rattan Project conducted research on adaptation trial by importing three exotic lowland bamboo species from China *Guadua amplexofolia, Dendrocalamus hamlitonii* and *Dendrocalamus memebranceous* at different agro ecologies, the same trial was conducted at Bako Agriculture Research Center to check the adaptation and performance of these exotic species on similar agro-ecologies; the results obtained from the trail were very good. In Ethiopia, the indigenous method of bamboo propagation by farmers is the offset method. Offset method makes the use of the rhizomes and the portion of culms (Ahlawat et al. 2002). However, the problems in using this method are excavating out offsets is unmanageable and labor intensive, offsets are also difficult to transport for long distances because of their heavy weight and long length, and excavating out offsets can damage the adjoining rhizome of the neighboring culms (Yared et al. 2017). Establishing large scale bamboo plantations by using this technique is very expensive. Therefore, based on these problems and limitation of seed resources this research was initiated to develop appropriate propagation methods on three selected lowland bamboo species using rhizome, culm and branch cuttings for effective supply of quality planting materials for large scale plantation.

Materials and Methods

Description of the study area

This experiment was conducted at Bako Agricultural Research Center, on-station. The study area is located at 9°06’N latitude and 37°09’E longitude as indicated in Figure 1. The area is mid-altitude, sub-humid tropical climate with unimodal rainfall pattern, experiencing average annual rainfall of 1270 mm and average annual temperature of 20°C (maximum 27°C and minimum 13°C). The altitude of the area is about 1650masl. The soil is dominantly reddish brown Nitisols, pH 5-6, and clay dominated in texture (Legesse et al. 1987).

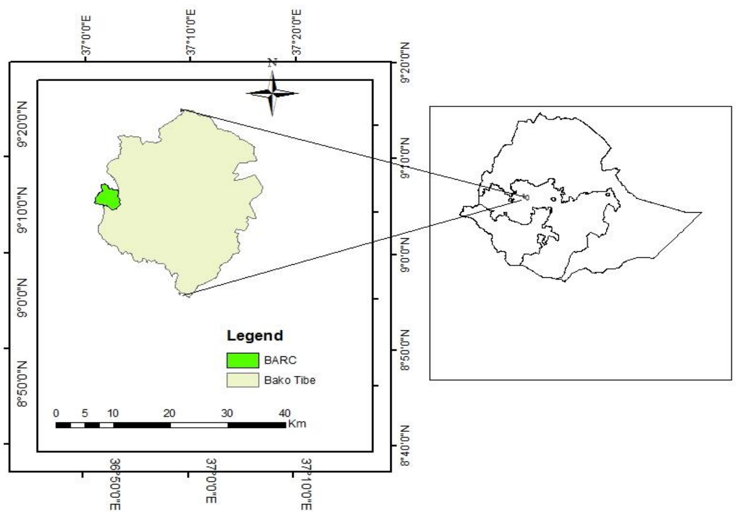


Figure 4. Location map of the study area

Table 1. Meteorological data of the experimental years (2015-2017)

Year	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May.**	**Jun.**	**Jul.**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**	**Total**	**Mean**
							Rainfall (mm)							
2015	0.00	0.00	0.00	3.50	138.70	144.00	270.90	193.80	88.03	9.80	72.70	22.90	**944.33**	
2016	3.20	2.90	12.80	58.04	220.30	297.30	184.20	236.10	222.80	79.10	0.00	0.00	**1316.74**	
2017	0.00	57.80	33.00	155.80	146.50	270.00	240.70	291.30	230.20	86.40	86.30	0.00	**1598.00**	
							Average temperature (°C)							
2015	20.5	21.2	21.5	21.6	21.4	20.15	20.45	19.8	20.25	21.5	21.6	22.25	**252.20**	**21.05**
2016	22.7	22.55	24.25	24.45	22.6	20.6	20.15	19.7	20.45	21.75	22.2	20.35	**261.75**	**21.8**
2017	20.5	20.5	21.45	21.7	21.4	21.05	20.65	19.45	19.95	20.6	20.85	22.65	**250.75**	**20.9**
							Relative humidity							
2015	45.70	48.00	46.00	47.00	48.00	50.00	52.70	54.70	52.00	50.00	49.30	48.50	**591.90**	**49.33**
2016	46.40	46.20	45.50	46.00	49.00	52.30	56.30	56.60	53.00	51.70	50.00	49.00	**602.00**	**50.20**
2017	46.00	47.00	48.60	47.00	49.00	52.30	57.00	55.30	55.00	54.00	52.30	49.00	**612.50**	**51.00**

Planting materials and tending operation

The planting materials were taken from *Oxythenantera abyssinica* (OA), *Dendrocalamus hamlitonii* (DH), and *Dendrocalamus memebranceous* (DM) with one and half to two years old were prepared based on the manuals for tropical bamboos (Banik, 1995; Ronald, 2005, Njuguna and Kigomo, 2008). Accordingly, the propagation materials (rhizomes, braches, lower and middle culm) cutting parts were prepared based on the procedures. Therefore, rhizomes with the presence of roots were prepared using digging axes to separate from parent rhizome. For culms and branch parts hacksaw was used to cut and prepare the cuttings from the selected culm parts which had nodes. After preparation the next step was keeping the moisture of planting materials up to the planting date through applying water and mulch for three days before planting taken place. The experiment was set up for a period of three year started in June, 2015 in the main rainy season when the soil became adequately wet and watering was done in the dry season (December to April).

Experimental design and treatments

The treatments were in 4*3 factorial arrangement of randomized complete block design (RCBD) with three replications; based on that the total samples used for the experiment were 36. The sizes of the plots were 4 m* 4 m (16 m^2) and per plot 4 propagation materials planted in 2 m spacing. The distance used between plots and blocks was 2m and 3m respectively. A total of 144 planting materials were planted in the whole experimental site. The propagation materials were used as a treatments (rhizomes, braches, Lower and middle Culm parts). Those materials were prepared and arranged on time for the experiments accordingly since all the material is available on station.

Data collection

This experiment was conducted from 2015-2017 for three consecutive years. Data such as; number of new emerging shoot was counted, and their culm height, root collar diameter, culm diameter, internodes length, and survival rate in percent were measured within two months' interval.

Data analysis

The data was arranged and summarized using Excel sheet before the actually data analysis takes place. Data analysis was made using SAS 9.0, 2004 software. Two-Way-ANOVA was conducted and Tukey's Honest Significance Difference (HSD) test was used throughout the comparison when statistically significant differences ($p<0.05$) were observed between factors. The different graph analysis presented using Microsoft excel sheet.

Results and Discussion

Survival rate

In this experiment the survival rate was vary among bamboo species and the treatments used. At the early planting stage almost all species and treatments showed a better performance in producing new shoots and survival conditions. However, the newly sprout shoots were not extend for more than two months gradually it becomes dried due to moisture stress and diseases infested the leaf part. This problem was observed on some of the treatments that indicated in Table 2.

Table 2. Comparisons of survival rate in percent between species and cutting parts

No	Propagation method	At 6 month survival (%)	At one & half year age (%)	At three year age (%)
1	Lower Culm of OA	50	25	25
2	Middle Culm of OA	0	0	0
3	Rhizome of OA	100	75	75
4	Branch of OA	0	0	0
5	Lower culmof DH	75	50	25
6	Middle Culm of DH	25	25	25
7	Rhizome of DH	100	100	100
8	Branch of DH	25	25	25
9	Lower Culm of DM	0	0	0
10	Middle Culm of DM	50	25	25
11	Rhizome of DM	100	100	100
12	Branch of BDM	0	0	0

NB: OA = *Oxythenantera abyssinica; DH = Dendrocalamus hamlitonii* & *DM = Dendrocalamus memebranceous*

Obviously, the selected species has no problem in adaptability since the adaptation trial was done before in the same agro-ecology by Regassa T. et al. 2016, and the result of adaptability of *Oxythenantera abyssinica*, *Dendrocalamus hamlitonii*, and *Dendrocalamus memebranceous* was revealed 100% survival in Bako Agriculture Research Center. According to the three years data *Dendrocalamus hamlitonii* showed a difference in survival rate in all treatments (rhizome 100%, branch 25%, lower culms 25% and middle culms 25%) as we compare with other species this indicates that how the specie is promising for propagation method. Furthermore, among the four treatments indicated above in the Table 1, the only propagation method showed a better performance in survival rate was rhizome followed by lower culms under each species.

New emerging shoots

The emerging of new shoots always begins during the rainy season of the year after planting this might be due to the presence of enough moisture and access of water helps to develop newly sprout shoots. On the other hand the numbers of newly emerged shoots always differ among the species (Kamesh S. and Nipan D. 2007) this depends up on the potential of species in producing new shoots. The newly emerging shoots revealed a significant difference under *Dendrocalamus hamlitonii* (1.30±0.8) among others (Table 3). Although, among all propagation method used as treatments rhizome showed a better performance under all species this might be due to the presence of residual roots which highly facilitate the growth of new shoots through providing water and nutrients.

Table 3. Summary of NES, RCD, CH and IL under each bamboo species

Species	NES	RCD	CH	IL
DM	1.17±01.26[b]	0.97±1.57[b]	1.60±1.85[c]	9.49±5.50[b]
DH	1.30±0.8[a]	1.26±1.18[a]	3.49±2.28[a]	11.67±3.89[a]
OA	1.06±0.69[b]	0.88±0.71[b]	2.01±0.55[b]	6.58±5.22[c]
Overall mean	1.18±0.45	1.04±1.12	2.37±1.55	9.26±3.87
P-Value	*0.4305*	*0.3717*	*0.4873*	*0.2544*
CV (%)	*10.18*	*19.32*	*9.29*	*17.58*

***NB:** NES = New Emerging Shoots (No.), RCD = Root Collar Diameter (cm), CH= Culm Height (m) and IL= Internodes Length (cm), †Means within a column followed by the same letter are not significantly different at P <0.05*

In this experiment there is a significant difference observed in newly produced shoots between the species and the treatments as indicated in the Table 3 and 4. The lowest result of newly emerging shoots was recorded under lower culm of OA, Middle culm of DH and Branch of DH 0.33, 0.33 and 0.33, respectively as indicated in Table 3.

Table 4. Comparisons among propagation methods

Propagation method	NES	RCD	CH	IL
Lower Culm OA	0.33±0.06[c]	0.15±0.25[c]	0.20±0.35[d]	2 ±0.67[d]
Middle Culm OA	00	00	00	00
Rhizome OA	2.00±0.72[a]	1.92±0.65[b]	2.3 ±0.9[b]	13.9±0.43[b]
Branch OA	00	00	00	00
Lower Culm DH	1.00±0.52[ba]	0.25±0.2[c]	0.73±0.21[c]	9.5±0.89[bc]
Middle Culm DH	0.33±0.53[c]	0.15±0.18[c]	0.77±0.32[c]	12.8±0.92[b]
Rhizome DH	3.00±0.78[a]	3.32±0.49[a]	4.38±1.2[a]	16.6±1.1[a]
Branch DH	0.33±0.24[c]	0.17±0.2[c]	0.53±0.45[c]	7.77±0.66[c]
Lower Culm DM	00	00	00	00
Middle Culm DM	0.67±0.42[b]	0.37±0.24[c]	0.54±0.4[c]	11 ±0.71[b]
Rhizome DM	2.00±0.87[a]	2.87±0.76[a]	4.21±0.63[a]	16 ±0.95[a]
Branch DM	00	00	00	00
Overall Mean	0.78±0.49	0.77±0.37	1.14±0.65	7.46±0.96
P-Value	*0.125*	*0.164*	*0.129*	*0.361*
CV (%)	*43.18*	*46.84*	*59.5*	*28.4*

†Means within a column followed by the same letter are not significantly different at P < 0.05

As presented in Tables 3 and 4, the interaction between propagation methods and species was significantly different at P <0.05. According to the results *Dendrocalamus hamlitonii* revealed good preformance under all propagation methods, while the performance of *Dendrocalamus memebranceous* and *Oxythenantera abyssinica* under all methods was nearly comparable.

Root collar diameter and culm height

The root collar diameter is indicated by the thickness of the lower parts of the culms which is directly or indirectly related with the quality of bamboo production (Kamesh and Nipan, 2007). In this study, there is a significant difference in the mean root collar diameter increment under all propagation method and species used. Accordingly, the root collar diameter of *Dendrocalamus hamlitonii* and *Dendrocalamus memebranceous* was showed higher under rhizome than other propagation methods, while the lowest root collar diameter was observed at the lower and middle culms of *Oxythenantera abyssinica* and *Dendrocalamus hamlitonii* as indicated in Table 4 above. Culms are solid in the lower internodes, and are hollow from the upper half up to the top of the culm. The culms of *Oxythenantera abyssinica* are semi-solid when young but solid in older culms. Whereas, *Dendrocalamus hamlitonii* and *Dendrocalamus memebranceous* relatively semi-solid and hollow at the upper part of the culms when compare to *Oxythenantera abyssinica*. The full length of the culm may vary among the species as reported by Maoyi (2005). The increments of culms height across the species and the treatments were significantly different as indicated below in the Figure 3. According to the result obtained from the analysis showed that rhizome propagation method under each species were highly significant in comparing with others propagation methods, while others methods showed similar culm height increment throughout the experiment period (Table 4 and Figure 2).

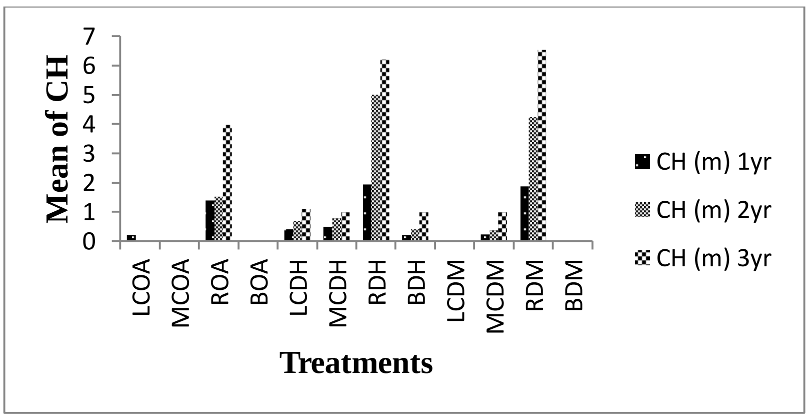


Figure 2. Culm height (CH) increment under each species and propagation method

Internodes length

Bamboo culms structure is cylindrical and is divided into sections by diaphragms or nodes. The section between two nodes is called internodes. In most of the species internodes are hollow, but solid in some others. It indicates the quality of bamboo production which used for different purposes (Ronald, 2005).In the current study there is a significant difference in the mean values of internodes length between the propagation methods and species as presented in Table 3, 4 and 5. Following the rhizomes propagation methods for each species lower and middle culms of *Dendrocalamus hamlitonii* and *Dendrocalamus memebranceous* showed a good performance in internodes length. Whereas, branch propagation method of all species showed poor performance in internodes length as indicated in Table 4.

Table 5. Mean value of internodes length under each propagation method

No.	Propagation method	Internode length (IL) (cm) 1yr	IL (cm) 2yr	IL (cm) 3yr
1	Lower Culm OA	5	0	0
2	Middle Culm OA	0	0	0
3	Rhizome OA	12.5	13.8	15.4
4	Branch OA	0	0	0
5	Lower Culm DH	4.5	11	13
6	Middle Culm DH	6	14	18.4
7	Rhizome DH	13.8	17	19
8	Branch DH	3.3	8	12
9	Lower Culm DM	0	0	0
10	Middle Culm DM	8.9	11.2	13
11	Rhizome DM	10	18.3	21.5
12	Branch DM	0	0	0

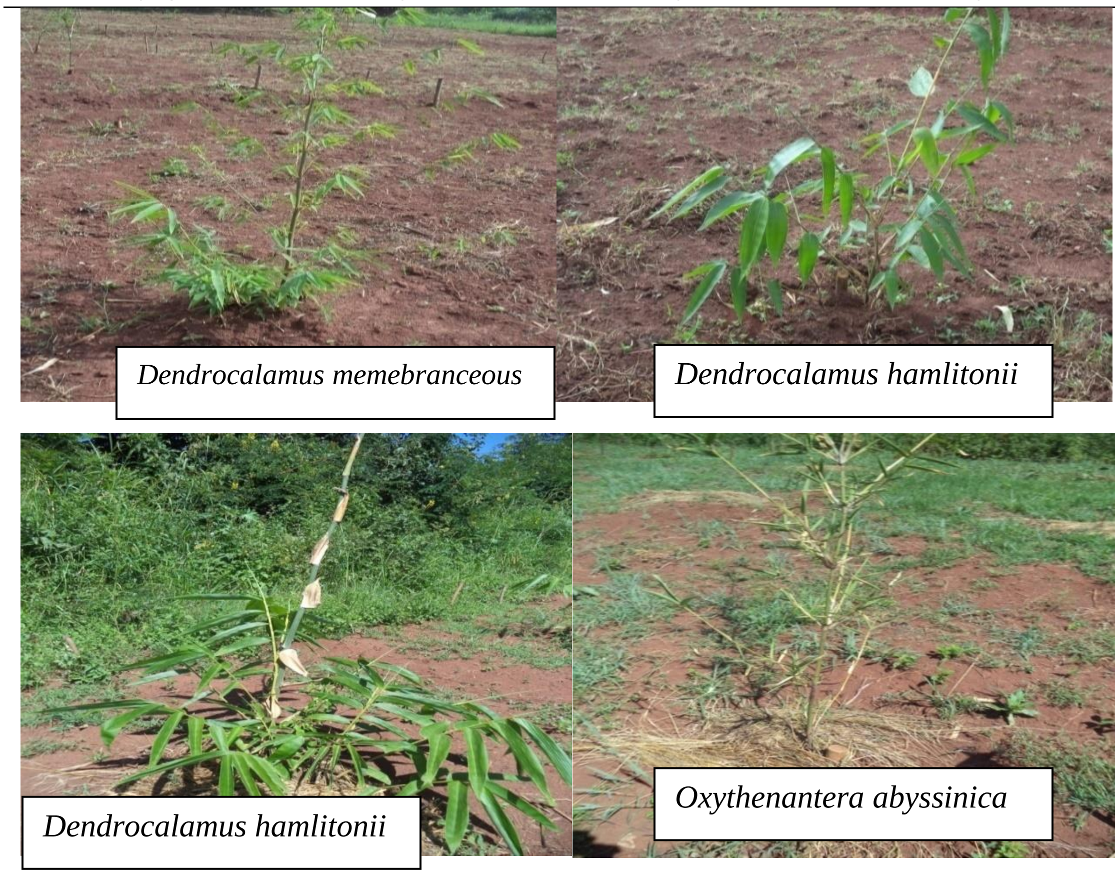


Figure 3. The performance of seedlings at the first year of establishment

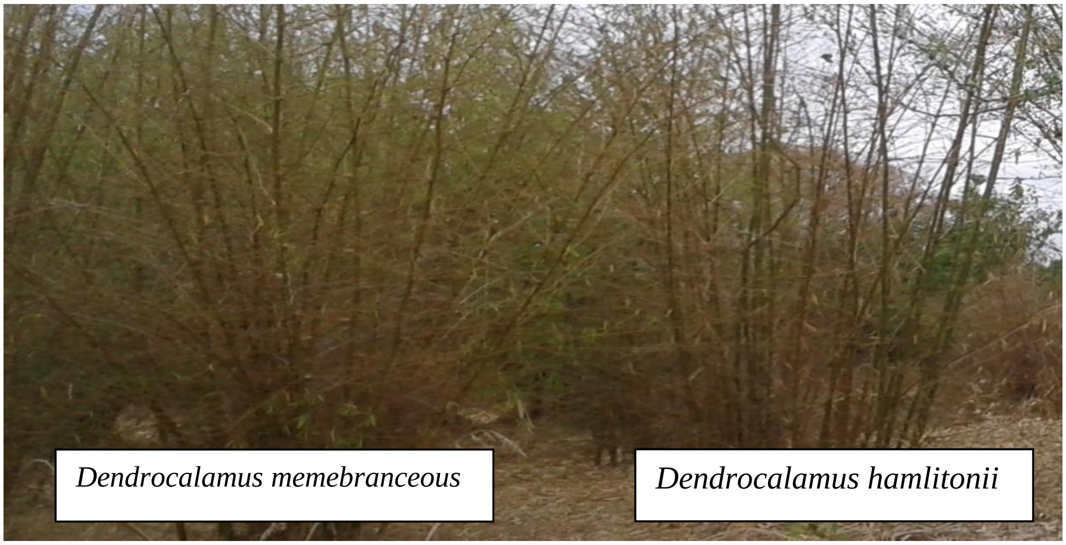


Figure 4. *Dendrocalamus memebranceous* and *Dendrocalamus hamlitonii* stand performances after three years

Conclusion and Recommendations

Vegetative propagation by means of offset method (rhizome with the whole culms) is traditional and common method for bamboo propagation elsewhere. However, due to shortage of seeds, using different vegetative propagation methods is becoming an alternative method for the propagation and expansion of bamboo resources at small and large scales. The present finding showed that there is a significant difference between the species and propagation methods used. According to the current results rhizome propagation method for all species revealed better performance when compared with other propagation methods. Among the species *Dendrocalamus hamlitonii* was the one showed the best performance under all propagation methods except some variation observed in survival rate, culm height and root collar diameter. Therefore, based on these findings, *Dendrocalamus hamlitonii wa*s the one which is appropriate and best option for all propagation methods using rhizome, braches, and lower and middle culm parts. However, both *Dendrocalamus memebranceous* and *Oxythenantera abyssinica* showed relatively poor performance in all propagation methods compared with *Dendrocalamus hamlitonii*. In general, based on the current results of bamboo propagation methods, it is concluded that using different cutting parts is easy and appropriate methods next to rhizome for further expansion of bamboo resources. Further, using different parts of culms are promising propagation methods, since the seed limitation is one of the big challenges in bamboo propagation. Finally, to use bamboo's full potential, it is recommend that more fundamental research is needed for the future bamboo expansion in particular to western Oromia and generally to Ethiopia.

Acknowledgment

The authors express their gratitude to Oromia Agricultural Research Institute for financial support, the staff of Agroforestry Research Team of Bako Agricultural Research Center, and particularly to Sultan Seid, Bogalech Olkeba and Arage Agazyi for their follow-up during the experimental period and data collection. Finally, the authors thank and recognize Mr. Tesfaye Hunde, from East Africa Bamboo and Rattan Project, who provided the seedlings of exotic bamboo species at the start.

References

Ahlawat, S. P., Haridasan, K., and Hegde, S. N. 2002. Field manual for propagation of bamboo in North-east India. Bulletin No. 4.

Azene B., 2007. Useful Trees and Shrubs of Ethiopia: Identification, Propagation and Management in 17 Agro ecological Zones. Nairobi, RELMA in ICRAF Project, 552 p.

Banik R. L. 1995. A Manual for Vegetative propagation of Bamboos. International Development Research Centre, Bangladesh Forest Research Institute, Bangladesh.

Bystriakova, V. Kapos and L. Igor. 2004. *Bamboo Biodiversity*: Africa, Madagascar and the Americas. UNEP-CMC/INBAR. UNEP World Conservation Monitoring Centre, Cambridge, UK. International Network for Bamboo and Rattan. Beijing, China, 90 pp.

CIBART. 2004. Let's strengthen the bamboo movement. Center for Indian Bamboo Resource and Technology.

Embaye K. 2000. The Indigenous Bamboo Forests of Ethiopia: an overview. *Ambio* 29, 518-521.

Embaye K. 2003. Ecological aspects and resource management of bamboo forests in Ethiopia. Doctoral dissertation, ISSN 1401-6230, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Ensermu Kelbessa, Tamrat Bekele, Alemayehu Gebrehiwot and Gebremedin Hadera. 2000. A socio-economic case study of the bamboo sector in Ethiopia: An analysis of the production-to-consumption system. INBAR Working Paper, 41 pp.

Fu Maoyi., 2005. Bamboo resources and utilization in China.

Jiménez V. M. and E. Guevara. 2007. Micro propagation of bamboo species through axillary shoot proliferation, Protocols for Micro propagation of Woody Trees and Fruits. Universidad de Costa Rica, CIGRAS: pp. 465-476.

Kamesh S. and Nipan D., 2007. Training Manual on Nursery Raising, Commercial Plantation, Preservation And Primary Processing Of Bamboo, National Bamboo Mission Ministry of Agriculture Government of India.

Lal P. A., G. S. A. Rawat and N. S. Bisht. 1998. Nursery techniques of bamboo - Standardization of planting method. Indian Forester, 124 (3): 184-191.

Legesse Dadi, Gemechu Gedeno, Tesfaye Kumsa and Getahun Degu., 1987. Bako mixed farming zone, Wellega and Shoa Regions. Diagnostic survey report No. 1.Institute of Agricultural Research, Department of Agricultural Economics and Farming Systems Research, Addis Ababa, Ethiopia.

Njuguna C. and N. Kigomo. 2008. Raising bamboo from stem cuttings. A guide for extension workers and bamboo growers, Kenya forestry institute, Kenya.

Reddy G. M. 2006. Clonal propagation of bamboo (*Dendrocalamus strictus).*Current Science, 91 (11): 1462-1464.

Regassa T, Dawit S, Mezgebu S, and Mokonin D., 2016. Adaptation and Growth Performance of Different Lowland Bamboo Species in Bako, West Shoa, Ethiopia. ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online) Vol.6, No.9, Journal of Natural Sciences Research

Ronald P. 2005. Tropical Bamboos, Propagation Manual. International Network for Bamboo and Rattan (INBAR), Beijing, China.

Sebsebe Demissew, Inger Nordal and Odd E. Stabbetorp. 2003. *Flowers of Ethiopia and Eritrea*: Aloes and other Lilies. Master printing press, Addis Ababa, Ethiopia. 227pp.

Tesfaye H., A. Yohanis and A. Mohammed. 2005. Assessment of different vegetative propagation techniques on rooting and shooting *of Arundinaria alpina. Ethiopian Journal of Natural Resources,* 7(1): 131-139.

Wang X. 2006. Comparative Analysis and Policy Recommendations on Developing Bamboo Resource Tenure Systems in Asia and Africa. Joint Project in Cooperation with INBAR and WFI.

Yared K, Zebene T, Abera G, and Yigardu M. 2017. Vegetative Propagation Techniques of Highland Bamboo (*Yushania alpina*) in Amhara Region North- Western Ethiopia, EISSN 2392-2192, WSN 61(2) 2017, 122-136.

Zenebe Mekonnen, Adefires Worku, Temesgen Yohannes, Mehari Alebachew, Demel Teketay, and Habtemariam Kassa. 2014. Bamboo Resources in Ethiopia: Their value chain and contribution to livelihoods. *A Journal of Plants, People and Applied Research*, 512.

Adaptation and Growth Performance Evaluation of Agroforestry Tree Species under Babile Condition, East Hararghe Zone, East Oromia, Ethiopia

Musa Abdella and Bira Cheneke

Fadis Agricultural Research Center, P.O. Box 904, Harar, Ethiopia

Corresponding author: birracheneke7@gmail.com

Abstract

Tree growth is a function of the genetic potential of the species and environmental conditions. Hence, before introducing any species to a given agroecology there is always a need for a well conducted field trial for matching species/provenance to a particular location. This study was conducted to evaluate adaptation and growth performance of five agroforestry tree species at Erer sub-station of Fadis Agricultural Research Center for three years (2015-2018). The five agroforestry tree species, Moringa oliefera, Gravilea robusta, Azadarichta indica, Leuceana leucocephala and Cordia africana, were compared in randomized complete block design with three replications. Growth parameters, diameter, plant height and survival rate were measured and recorded at three months interval. Results revealed that there were highly significant (P<0.05) variations among tree species in height growth, root collar diameter development, diameter at breast height and survival rate after three years of age. This could be due to environmental factor and/or genetic potential of the species, which generally govern the growth of a given species. Among the species tested, Azadarichta indica showed the highest performance followed by Leuceana leucocephala, Moringa oliefera in terms of height growth, root collar diameter and diameter at breast height. After four years establishment, Moringa oliefera, Azadarichta indica, and Leuceana leucocephala showed the highest survival rate with 84, 83.7 and 82.3%, respectively. However, Gravilea robusta and Cordia africana showed lowest performance. The long dry season, which extended from eight to ten months in the study area, clearly explained the poor survival and growth response in some of the species. Hence it can be inferred that the conditions of Babile matched with the environmental requirement of Moringa oliefera, Azadarichta indica, and Leuceana leucocephala. The species therefore have better performance for future use in agroforestry practices in the area. Generally, these findings may help forest and agroforestry users to properly allocate species into the location in which the species adapted and well grown. Further testing of provenances of the best performing species is recommended to select the most adaptable ones for such areas for future agroforestry practices at wider scale on which success of agroforestry practices and forest plantations depends.

Keywords: *Agroforestry, diameter at breast height, height growth, root collar diameter, survival rate*

Introduction

Land degradation in Ethiopia is a major problem due to a number of factors. One of the important causes is the removal of forest and vegetative cover as a result of increased human population leading to high demand for forest products and land for expanding the agricultural activities (Demel *et al*., 2001).
Consequently, these areas are now characterized by loss of soil fertility and soil erosion problems. Eastern Ethiopia particularly, East Hararghe highland is well known by vegetation cover and most of the surrounding area is covered by forests comprising a rich mixture of woody species (Abebe *et al*., 2000).

In spite of the importance of forest ecosystem to the livelihoods of the people in the area, the forest is dwindling from time to time due to high exploitation of woody and non-woody products. Rapid deforestation caused by an escalating demand for fuel wood expansion for agriculture has brought an ever-increasing pressure on native woodland species (Mebrate et al., 2004). If no remedial action is taken, this will cause severe impact on agricultural productivity leading to energy poverty and environmental degradation. Frequent and severe droughts often present a serious threat for millions of lives (Brockerhoff, 2008), which have occurred once in a decade in the 1970s and 1980s. Shortages of animal feed and biomass energy are also such an unsustainable use of natural resources. Currently, biomass energy constitutes 88.7% of all energy consumed in Ethiopia which is mainly derived from the woody biomass resources (forests, woodlands, shrub lands, planted trees, agro forests). Agro forestry system has much potential for supplying fodder, poles, farm equipment, fuel wood and agricultural improvements (Abebe, 2000).

Multipurpose tree and shrubs species (MPTS) play a considerable role in addressing such multifaceted demands in the mixed crop-livestock production system (Betre *et al*. 2000). They have the ability to fit into the farming system to be used as a source of manure, mulch, soil conservation, forage, fuelwood, farm implements and others like shade and shelter (Kahsay *et al*., 2001). However, each tree/shrub species has its own biotic and abiotic factors in which it performs to its maximum potential. It has specific edaphic and climatic requirements (Abebe *et al*., 2000).

Some possible research needs include soil-plant interactions, soil fertility and N-fixation studies on wide range of species, crop tree yield studies and optimum tree density, socioeconomic studies, and species selection and screening including seed tests, establishment, and management. In Babile District, farmers practice on farm and homegarden for economic, social and environmental benefits (Getahun *et al*., 2014). These traditional agroforestry practices could be intensified by using fast growing MPTS to satisfy the demands of the growing population. Thus, before introducing any species to a given agroecology, there is always a need for a well conducted field trial for matching of the species/provenance to a particular location (Mebrate *et al*., 2004). The first trial should be a species screening trial that will test the survival and early growth of the species in one to three years. Deciding what species to plant in any agroforestry system to meet the intended objectives require a well-conducted field trial to match a species to a particular location.

Many agroferstry tree species screening experiments have been conducted in different parts of the country (Betre et al., 2000). However information is scarce in Babile area to recommend promising multipurpose tree and shrubs species for use in agroforestry. Hence, there is a need to study adaptation of promising tree and shrubs species in the area; and this experiment was initiated to evaluate the adaptation and growth performance of five agroforestry tree species under Erer condition.

Materials and Methods

Description of the study area

The experiment was conducted in Babille District, Erer sub-station. Babille District is found in East Hararghe Zone of Oromia, Ethiopia. It is located 31 km away from the Harar town and about 557 km east from Addis Ababa, the capital city of Ethiopia. Erer sub-station is located at latitude of 09^{o} 10' 41.5" North and longitude of 042^{o} 15' 27.3" East, and the area is in the vicinity of extreme lowlands n the range of altitude of 1200-1300 masl. The area is characterized by very short rainy season of 3-4 months (a quarter of the year), with all its intermittent condition and erratic distribution. The mean annual temperature was 24^{o}C. The soil is clay loam in texture and medium in organic matter content and high in exchangeable potassium. Generally, the pH of the soil (7.94) is in the optimum range for growth of most plants.

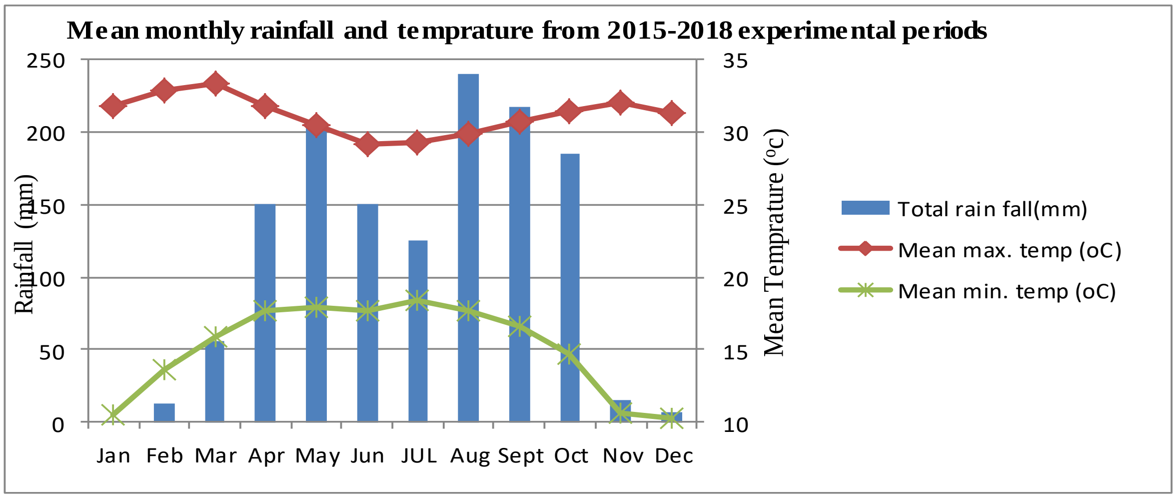


Figure 1. Mean monthly rainfall and temperature during experimental period of Erer, based on 2015-2018 meteorological data at Fadis Agricultural Research Center

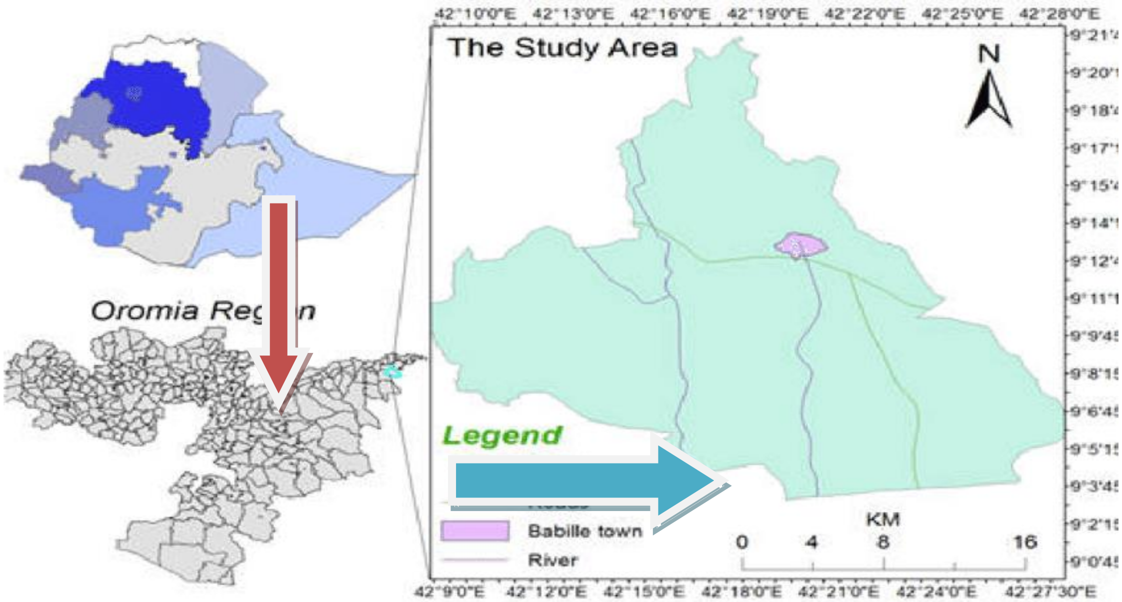


Figure 2.Map representing the study area (Babile District)

Tree seed source

Seeds of five multipurpose tree species were obtained from Central Ethiopian Environment and forestry Research Center (Table 1).

Table 1. Detail description of tree species used in the adaptation trial

Tree species	Family name	Seed source
Cordia Africana	Boraginaceae	CEFRC
Leuceana leucocephala	Leguminosae	CEFRC
Moringa oliefera	Moringaceae	CEFRC
Azadarichta indica	Meliaceae	CEFRC
Gravilea robusta	Proteaceae	CEFRC

CEEFRC: Central Ethiopian Environment and Forestry Research Center

Treatments and experimental design

Seeds of the tree species *Cordia africana, Gravillea robusta, Azadarichta indica, Leuceana leucocephala and Moringa oliefera* were used for the experiment. Seedlings were raised directly into polythene tubes at Kurfa Kasa nursery site, Babile District with the recommended nursery management pactivities. Seedlings with the same age of these species were planted in the field in June 2015 using randomized complete block design with three replications. Each block had five experimental plots, representing five species of sixteen seedlings each. The spacing between blocks and plots was 2.5m, plot size was 6m x 6m, and the space between trees in a plot was 2m. In each plot, 16 trees were planted, and the four inner seedlings were taken as a sample for data collection. After planting, the site was protected from animal grazing and human interferences for the study duration. Plantation plots were neither irrigated nor fertilized. Survival, height (from ground level to the tip of the plant), diameter at breast height (DBH) and root collar diameter (RCD) were recorded every three months from June 2015 to June 2018.

Data collection

In order to fit the given objectives, data were collected on four growth and adaptation parameters such as plant height, root collar diameter, diameter at breast height and survival rate for the three years at interval of three months. Root collar diameters were collected only up to the tree reaches 1.3meters in height whereas plant height and survival rate were up to the end of the period of the activity by interval of three months survival count was made for the whole trees in a plot (sixteen trees per plot), while the trees in the middle (four trees per plot) were taken as sample for height, root collar diameter and diameter at breast height measurement so as to minimize the border effect. Height growth was determined by using measuring tape and root collar diameter and diameter at breast height by digital caliper.

Data analysis

Analysis of variance was computed using Genstat software package to test the significant difference among tree species. Least significant different (LSD) test was employed to separate statistically different means using the software package at $P < 0.05$ level of probability.

Results and Discussion

Survival rate

Among tree species, differences were highly significant ($P<0.05$) for survival and others as well (Table 3). After three years of establishment, three species: *Moringa oliefera, Azadarichta indica and Leuceana leucocephala* showed the highest survival rate with values of 84, 83.67 and 82.33%, respectively. Hence, it can be inferred that the condition of Babile matched well with the environment requirement of these species. Yitebitu (2004) also reported that *Moringa species we*re quite drought resistant species which is similar to the observation of the present study. This can be attributed to the low moisture stress experienced, which as Kozlowski et al. (1991) also stated can affect the growth, survival and distribution of forest trees. *Gravilea robusta* (35.33%) and *Cordia africana* (23%) on the other hand, showed lowest survival rate. The long dry season, which extended from seven to nine months in the study area, clearly explained the low survival of *Gravilea robusta and Cordia africana* seedlings during this season. On the other hand, *Azadarichta indica, Moringa oliefera*, and *Leuceana leucocephala* were found to be highly resistant to low moister stress in the study area. In the present study, the mortality was subjectively attributable to abiotic factors such as drought during the initial growth from October to June, although biotic problems like termites were also experienced during the study period. Thus, the environmental condition of Erer may not be suitable for *Gravillea robusta* and *Cordia africana* which require adequate moisture for survival and potential growth. Soil and below ground competition are also other factors that influence the growth and survival rate (Casper and Jackson, 1997). Highly significant variation was among species in survival rate ($P<0.05$) was recorded in all three years of age after transplanting. The survival trend for all tree species (*Moringa oliefera*, *Azadarichta indica*, *Leuceana leucocephala*, *Cordia africana*, *Gravillea robusta*) showed declining trend in their survival rate in all the study period (Table 2).

Table 2. Mean survival rate (%) of agroforestry tree species planted in Erer sub-station, Babille District in three years (2015-2017)

Tree species	**Age of seedlings after transplanting**		
	Year I	**Year II**	**Year III**
Gravilea robusta	42.67[c]	39[b]	35.33[b]
Azadarichta indica	89[ab]	85.33[a]	83.67[a]
Leuceana leucocephala	89.67[a]	83.67[a]	82.33[a]
Moringa oliefera	86.33[b]	84.67[a]	84[a]
Cordia Africana	44.67[c]	26.67[c]	23[c]
LSD(0.05)	3.046	3.866	4.009
CV (%)	2.3	3.2	3.5
Mean	70.47	63.87	61.67
P value	<.001	<.001	<.001

NB: Means in column with the same letters are not significantly difference using LSD.

Height growth

Analysis of variance revealed that variations in height among species were highly significant ($P < 0.05$) after three years of age. Height growth trend (Table 3) shows that *Azadarichta indica* (3.32 m) and *Leuceana leucocephala* (3.3 m) were the tallest tree , followed by *Moringa oliefera* (2.92 m) but *Cordia africana* was the shortest tree (1.8 m). Results of growth performance also showed that *Azadarichta indica*, *Leuceana leucocephala* and *Moringa oliefera* were higher than the other species. Similarly, Raebild et al. (2003) also stated that apart from indicating productivity, height may also be seen as a measure of the adaptability of trees to the environment as tall trees usually being better adapted to the site than short trees (Cossalter, 1987). *Moringa* species could also play a great importance in the rehabilitation process especially during periods of drought or in areas where nutrient resources are not available. Several similar studies also showed that fast growth of seedling is an important indicator in terms of determining the situation of growth response especially in the first growing period and it is commonly assumed that the early fast growth rates of tropical trees reflect productivity status of the trees (Baris and Ertenkin, 2010).

Diameter growth

As depicted in Table 3, there was significant variation among tree species in root collar diameter growth. The highest root collar diameter was recorded for *Azadarichta indica* (4.20 cm) followed by *Moringa oliefera* (4.00 cm) and *Leuceana leucocephala* (3.85 cm) but the lowest root collar diameter was recorded for *Cordia africana* (1.83 cm). Growth in diameter at breast height was also highly significant ($P < 0.05$)

for the five tree species. The difference in growth of diameter at breast height (1.3 m) above the ground of tree species *Azadarichta indica* (3.2 cm), *Moringa oliefera* (2.9 cm), *Leuceana leucocephala* (2.6 cm) showed highest diameter at breast height within four years data records. On other hand *Gravillea robusta* (1.49 cm) and *Cordia africana* (1.46 cm) showed lowest diameter growth at breast height.

Table 3. Survival rate, plant height, root collar diameter and diameter at breast height of agroforestry tree species for four years (June 2015 to June 2018)

Tree species	Survival rate (%)	Plant height (m)	Root collar diameter (cm)	Diameter at breast height (cm)
Gravillea robusta	35.33[b]	2.55[c]	2.713[d]	1.497[d]
Azadarichta indica	83.67[a]	3.317[a]	4.197[a]	3.2[a]
Leuceana leucocephala	82.33[a]	3.3[a]	3.85[c]	2.6[c]
Moringa oliefera	84[a]	2.917[b]	4[b]	2.85[b]
Cordia africana	23[c]	1.8[d]	1.833[e]	1.467[d]
LSD(0.05)	4.009	0.107	0.109	0.108
CV (%)	3.5	2.1	1.7	2.5
Mean	61.67	2.777	3.319	2.323
P value	<.001	<.001	<.001	<.001

CV = Coefficient of Variation   LSD = Least Significant Difference

NB: Means with the same letters in column are not significantly different using LSD

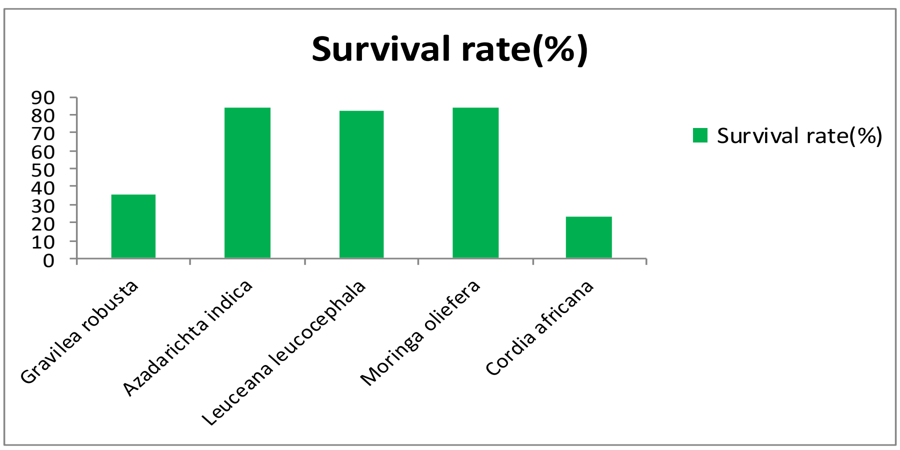


Figure 3**.** Means of survival rate (%) of *Gravillea robusta*, *Azadarichta indica* ,*Leuceana leucocephala*, *Moringa oliefera* and *Cordia africana* through sequential periods from June 2015 to June 2018

Figure 4. Performance of agroforestry tree species at Erer sub-station, Babille District

Conclusion and Rcommendations

The experiment was conducted to evaluate adaptation and growth performance of five agroforestry tree species. The results indicated that there were significant difference among tree species for plant height, survival rate, root collar diameter and diameter at breast. The result revealed that the survival rate of *Moringa oliefera* was the highest followed by *Azadarichita indica* and *Leuceana leucocepha*la. While *Gravilea robusta* and *Cordia africana* showed poor survival rate. Poor survival rate and growth performance might be explained as response to low moisture condition of the site and termite problems of the study area. *Azadarichta indica*, *Leuceana leucocephala* and *Moringa oliefera* were the species attained the highest mean heights, while *Gravilea robusta* and *Cordia africana* species had the lowest values. The comparisons between the height and diameter at breast height of the species showed that *Azadarichta indica* had the highest mean height followed by *Moringa oliefera* and *Leuceana leucocephala.*

Generally, the results on growth performance showed that *Azadarichta indica*, *Leuceana leucocephala* and *Moringa oliefera* had better performance than *Gravillea robusta* and *Cordia africana*. Therefore planting of these better performing tree species and encourage their promotion as agroforestry practices. They were recommended as important tree species for soil conservation, shading, forage, fuel wood, and in general as multi-purpose trees in the area. For *Leuceana leucocephala* and *Moringa oliefera*, on farm evaluation of their contribution to soil improvement and crop yield either in inter-cropping or biomass transfer has to be further investigated to make use of their potential in agroforestry practices.

Acknowledgment

The authors would like to thank Oromia Agricultural Research Institute for financial support and Fadis Agricultural Research Center for provision of the necessary facilities for the research work; and also express sincere appreciation to the Central Ethiopian Environment and Forestry Research Center for provision of tree seeds for the study.

References

Abebe Yadessa, Diriba Bekere and Taye Bekele.2000. Growth performance of different multipurpose tree and shrubs species at Bako, Western Oromia. pp 177-186. In: Proceedings of the Fifth Conference of the Ethiopian Society of Soil Science. Addis Ababa, Ethiopia, 30-31 March 2000, Ethiopian Society of Soil Science .Addis Ababa, Ethiopia.

Baris H and Ertenkin M (2010). Growth models in investigating oriental beech (Fagus orientalis Lipsky). Romanian Biotechnological Letters 16: 5850-5857.

Betre Alemu, Tekelign Mamo, Alemayehu Zewdie and Ebrahim Ahmed, 2000. Promising multipurpose tree species and their response to land form on highland vertisols at Chefe Donsa, central highland of Ethiopia. Pp. 145-155.In:

Brockerhoff EG, Jactel H, Parrotta JA, Quine CP, Sayer J (2008). Plantation forests and biodiversity: oxymoron or opportunity? Biodiversity Conservation. 17: 925-951.

Cossalter C (1987). Introduction of Australian acacias into dry, tropical West Africa. Forest Ecology and Management 16: 367-389.

Kahsay Berhe, Giulia Conchedda and Mohammad A.Jabbar.2001. Areas suitable for five leguminous trees and shrubs in Ethiopia: A digital data based analysis. Ethiopian journal of Natural Resources (EJNR) 3 (1): 77-97.

Kozlowski TT, Kramer PJ and Pallardy SG (1991). The physiological ecology of woody plants. Academic Press, Toronto. Pp: 657.

Mebrate Mihretu, Alemu Gezahegn and Belachew. 2004. Early survival and height performance of some Australian species in field trials at Didessa, western Ethiopian Journal of Natural Resources (EJNR) 6(2): 253-263.

Raebild A, Graudal L and Rehman SK (2003). Evaluation of a provenance trial with Acacia albida, A. senegal and A. tortilis at Dagar Kotli, Pakistan. Trial no. 21 in the arid zone series. Results and Documentation No. 26.

T. Demel. Deforestation, wood famine, and environmental degradation in Ethiopia's highland Ecosystems: urgent need for action.Northeast African Studies, 2001, vol. 8(1), pp. 53- 76.

Y. Getahun, A. Zebene, and Z. Solomon. Wood production and management of woody species in homegardens agroforestry: The case of small holder farmers in Gimbo district, South West Ethiopia. International Journal of Natural Sciences Research, 2014, vol. 2(10), pp. 165-175.

Yitebitu Moges (2004).Recommended Agroforestry/Multipurpose Trees for Borana Lowlands/Midlands and their Production Techniques. Subreport, No.4.

Adaptation Study of Multipurpose Tree Species under Bore Condition, Guji Highland, South Oromia, Ethiopia

Aschalew Emire, Sintayew Demise and Temesgen Giri

Bore Agricultural Research Center, P.O. Box 21, Bore, Ethiopia

Corresponding authors: aschu1511@gmail.com

Abstract

This study was conducted at Bore Agricultural Research Center, on-station for five years, 2014-2018. The objective was to identify the best adaptable agro-forestry multipurpose tree species for the study area. Seedlings of multipurpose tree species were out planted in a randomized complete block design (RCBD) with three replications. A plot size of 13mx7m was used for each multipurpose tree species selected for this study. A plot consisted of three rows of multipurpose trees, on each row three multipurpose trees were planted and each plots had nine multipurpose trees. Based on the objective, the following parameters survival rate, tree height and diameter at breast height (DBH) were quarterly recorded until the end of the study. The results revealed that multipurpose tree species Acacia abyssinica, Gravilia robusta, Hygenia abyssinica, Acacia saligna and Pinus patula had the highest survival rate at the study site. In addition, their survival rates were significantly (P<0.05) higher than Cordia africana, Sesbania sesban and Leuceana leococephala. However, from all multipurpose tree species selected for this study Leuceana Leococephala shown poor survival rate. The reason of low survival rate of Leucaena leucocephala was observed at study site was due to agroecology of the study site was not suitable for the species. The height data recorded by the end of the experiment revealed that there were not significant (P<0.05) differences in height among tree species, Acacia saligna, Acacia abyssinica, Gravilia robusta and Hygenia abyssinica, and all the tree species attained the highest mean values, respectively. However, Cordia africana, Sesbania sesban and Leucaena leucocephala were multipurpose tree species with the lowest mean values, respectively. Diameter at breast height (DBH) data recorded at the end of the study showed that Acacia abyssinica and Accacia saligna were tree species attained the highest mean values of DBH and Grevillea robusta, Pinus patula, Haygenia abyssinica and Sesbania sesban attained medium mean values of DBH. However, from multipurpose tree species selected, Cordia africana and Leuceana leococephala had the lowest value of DBH. Generally, these findings could be used to promote those adapted promising native and exotic multipurpose tree species for promotion of agroforestry practicesin the study area. Moreover, it can help all stakeholders to properly allocate species into the site that grow and adapt well.

Keywords: *Agroforestry, diameter at breast height, height growth, multipurpose tree species, survival rate*

Introduction

Agro-forestry is a sustainable land management practice that incorporates trees and shrubs in crop lands and pastures. The trees help to moderate air temperature, serve as wind breaks and improve water infiltration by reducing evapo-transpiration by the extent proportional to tree height. In addition vegetation produces wood, fruits, fodder and medicine which diversify livelihood sources for the rural poor (Bashir et.al.2006). The major role of agro forestry, to maintain soil fertility, is based primarily on observation of higher crop yields in association with multipurpose tree species. Multipurpose tree species play a crucial role in sustenance of soil productivity through litter production, regular supply of viable nitrogen over a longer period by nitrogen fixation, fine roots turn over and nutrient cycling and improvement in soil structure (Solanki, et.al, 2008)

Diversification of agro forestry practice contributes to biodiversity conservation through reducing pressure on natural forests and protected conservation areas. Agro forestry systems that are structurally complex and floristically diverse can contribute significantly to the conservation of biodiversity within fragmented landscapes (Ashley et.al, 2006). The integration of woody species in agricultural landscape could reduce the pressure on the surrounding natural forest. For instance, agroforestry, which combine forestry and agriculture, have the capacity to sustain the productivity of farmlands. Moreover, diversification of agroforestry system could also serve as buffer zone for forest degradation and deforestation (Nair, 1993).

In Ethiopia, efforts have been made to develop and promote agro forestry technologies. The different agro forestry practices currently promoted in Ethiopia are home stead tree planting, planting of trees on farm as shelter belt, alley cropping, boundary planting, wind breaks, live fences, improved fallow and wood lot establishment. However, technologies developed and promote so far are not sufficient to address the problems of soil erosion, loss of soil fertility, loss of bio diversity, shortage of fodder and woody material scarcity for industrial and house hold consumption(Zebene and Agren, 2007). Many research findings indicated that, the major problems in promoting agro forestry are lack of awareness about the benefits, improper selection of tree species, non availability of good planting material, in adequate supply of multipurpose germplasm and weak extension systems were among the factors that constrained agro forestry development. Similarly, in high land Districts of Guji Zone, Southern Ethiopia diversification of agro-forestry technology is constrained by lack of awareness about the benefits of agro forestry practice and non availability of good quality planting material of multipurpose tree species.

Presently, existing traditional agro forestry in high land districts of Guji zone is very limited and natural forest of the area is disappearing at alarming rate due to expansion of agricultural lands, for fuel wood consumption, illegal timber product producer and timber producing firms, a wide range of both material and intangible benefits of trees decrease from time to time. The disappearance of the resource at an alarming rate resulted in a number of consequences such as soil erosion, loss of soil fertility, shortage of animal feed, woody material scarcity for timber producing firms and for house hold consumption. Therefore, designing strategies to address the problem through planting of agro-forestry multipurpose tree species used for soil and water conservation, for apiculture, animal feed, timber and for house hold consumption and for conserving natural forest of the area is very significant.

This can be achieved by adaptation of suitable multipurpose agroforestry tree species and through motivating farmers to plant different types of multipurpose tree species appropriate to their agro-ecology. So far, available information on the performance of multipurpose agroforestry tree species in high land districts of Guji zone is very limited. Thus, introduction and improved management of adaptable multipurpose agroforestry tree species can be one of the strategies to minimize the current wood, feed and soil related constraints of the study area. Therefore, this study was conducted to identify the best productive and adaptable agro forestry multipurpose tree species for high land districts of Guji Zone.

Materials and Methods

Description of the study area

The experiment was conducted at Bore Agricultural Research Center, on- station for five years, 2014-2018. The experimental site is about 378km far from Addis Ababa. Geographically, the experimental site is situated at latitude of $06^{0}23^{1}55''$N and longited $38^{0}35^{1}5''$E.The experimental site represented high land agro-ecologies of Guji Zone having altitude range of 2200-2780masl. The area receives annual rainfall ranging from1400-1800mm with bimodal pattern that is extended from April to November. The mean annual minimum and maximum temperature of the experimental site were 10^{o}C and 20^{o}C, respectively. The soil type is red basaltic soil (Nitisols). The soil is clay loam in texture and strongly acidic with pH 4.53 -5.13, while moderately acidic with pH 6.5 (Wakene *et al*, 2014).

Multipurpose tree species seed sources and nursery management

As indicated in Table 1 below, seeds of three indigenous and five exotic multipurpose tree species included in the trials were obtained from National Forestry Research Center, Addis Ababa. Seedlings of multipurpose tree species were raised at nursery site of Bore Agricultural Research Center, on-station. During the seedlings for the trials were raised at nursery site universal soil ratio of 3, 2, 1 (local soil, forest soil and sandy soil) was used so that seedlings have a ball of earth around their root system. This is intended to ensure high survival rate of seedlings when planted out in the field. Seed of multipurpose tree species was done on seedbeds and after germination the seedlings were pricked out in a pot size of 8cm-12 cm and pot height of 10 cm based on type of multipurpose tree species selected for the trials. Optimum care, such as watering, mulching, shading and weeding were provided at the nursery site to produce healthy and vigorous seedlings for field planting.

Table 1. List of indigenous and exotic multipurpose tree species selected for the study

Tree species scientific name	Tree species family name	Tree species common name
Cordia africana(Lam.)	*Boraginaceae*	Broad leave *Cordiana*
Acacia abyssinica (Hochst.)Benth	*Mimosoideae*	Flat-top *Acacia*
Hagenia abyssinica	*Rocaceae*	African redwood
Accacia Saligna.	*Fabaceae*	Weeping wattle
Sesbania sesban (L.) Merr.	*Papilionoideae*	African tulip tree
Grevillea robusta (R. Br.)	*Proteaceae*	Silky oak
Pinus patula	*Pinaceae*	Mexican weeping pine
Leucaena leucocephala	*Fabaceae*	White lead tree

Treatments and experimental design

After all the multipurpose tree species seedlings were ready for field planting, they were planted at Bore Agricultural Research Center, on-station in a randomized complete block design (RCBD) with three replications. Seedlings were out planted at the study site on a plot size of 13mx7m for each multipurpose tree species. A plot consisted of three rows of multipurpose trees. On each row three multipurpose trees was planted and each plots had nine multipurpose trees. Distance between the trees in the same row was 4m and distance between rows in the same plot was 3m. Based on the objective of the study, quarterly for five years the following parameters such as survival rate, tree height and diameter at breast height (DBH) were collected. Multipurpose tree species heights were measured using either meter tape or graduated stick depending on the height of the multipurpose tree species being assessed. Diameter at breast height (DBH) of the planted multipurpose tree species were assessed at the base of the seedlings or saplings using caliper. Survival assessment of the planted multipurpose tree species was carried out based on the original number of trees planted.

Data analysis

The analysis was performed by using Statistical Analysis System (SAS version 9). Survival rate, tree height and diameter at breast height data recorded from each selected multipurpose tree species were subjected to analysis of variance and Least Significance Differences (LSD) tests to enable comparison of multipurpose tree species.

Results and Discussion

Survival rate

Analysis of variance on comparisons of survival rate for multipurpose tree species selected for this study showed that, there were not significance ($P<0.05$) differences observed in survival rate between *Acacia abysinica*, *Acacia saligna, Gravilia robusta, Pinus patula* and *Hygenia abbysinica*(Table 2). The lack of significant differences in survival rates among the five multipurpose tree species in the same category showed that their level of survival rate in the study area is more or less the same. However, in terms of their survival % from all multipurpose tree species selected for this study *Accaia abbysinica* and *Gravilia robusta* were totally (100%) survived. Survival data of *Haygenia abyssinica*, *Acacia saligna* and *Pinus patula* showed that their survival were 94, 89 and 72%, respectively.

Based on the finding of this study, there were not significance ($P<0.05$) difference in survival rate between *Cordia africana* and *Suspania susban* multipurpose tree species. However, there was significance ($P<0.05$) differences in survival rate between *Leucaena leucocephala* and the remaining multipurpose tree species used on this study. Because, from all multipurpose tree species selected for this study *Leucaena leucocephala* was totally (100%) not survived. The reason low survival of *Leucaena leucocephala* was observed at study site was due to it grows best in humid tropical and Moist and Wet lowland agroclimatic zones in full sunlight on well-drained neutral or calcareous soils, 0-1,600m (Azene, 2007).

Height growth

As the findings of this study indicated that, the combined analysis of the five years height of the multipurpose tree species seedlings transplanted at the study site showed that, there were not significance ($P<0.05$) differences in height were viewed between *Acacia saligna*, *Acacia abyssinica, Gravilia robusta* and *Hygenia abyssinica* multipurpose tree species (Table 3).

The recorded mean height of both *Acacia saligna* and *Acacia abysinica* were: 4.4m and mean height of *Gravilia robusta* and *Hygenia abyssinica* multipurpose tree species were 4.2m and 4.1m respectively. In addition, there were not significance ($P<0.05$) differences in height were observed between *Cordia africana* and *Susbania susban* as indicated in Table 3 below. Their recorded mean heights were: 1.9m and 1.84m respectively. On the other hand, mean height of *Acacia abyssinica*, *Acacia saligna*, *Gravilia robusta* and *Hygenia abyssinica* multipurpose tree species were significantly ($P<0.05$) higher than the remaining multipurpose tree species selected for this study.

Table 2. Mean survival rate of multipurpose tree species

Tree species	**Survival rate (%)**
Acacia abyssinica (Hochst.)Benth	100[a]
Acacia saligna	83.3[a]
Gravilia robusta(R.Br.)	100[a]
Pinus patula	77.77[a]
Hygenia abyssinica	94.43[a]
Cordia africana(Lam)	44.43[b]
Leuceana leococephala	0[c]
Sesbania sesban (L.) Merr	40.12[b]
Mean	20.5
LSD (0.05)	24.99
CV (%)	22.8

**Means in column with the same letters were not significantly different at P<0.05*

Table 3. Mean height and mean diameter at breast height (DBH) for multipurpose trees

Tree species	**Height (cm)**	**DBH (cm)**
Acacia abyssinica	438.7[a]	8.333[a]
Acacia saligna	441.9[a]	7.663[a]
Gravilia robusta	417.8[a]	6.220[ab]
Pinus patula	317.9[b]	5.417[b]
Hygenia abbysinica	407.7[a]	5.033[b]
Cordia africana	190.4[c]	1.143[c]
Leuceana l eococephala	0[c]	0.000[c]
Sesbania sesban	184.2[c]	5.172[b]
Mean	**241.8**	**2.23**
LSD (0.05)	**78.69**	**1035**
CV (%)	**17.2**	**27.5**

**Means in column with the same letters are not significantly different at P <0.05*

Diameter growth

The analysis of variance of the mean diameter at breast height (DBH) data recorded by the end of the experiment revealed that there were not significance ($p<0.05$) differences observed between *Acacia abysinica* and *Acacia saligna* multipurpose tree species. As well, as indicated in Table 3 above there were not significance differences($p<0.05$) of mean diameter at breast height(DBH) revealed between *Gravillea robusta*, *Pinus patula, Hagenia abbysinica* and *susbania susban* tree species. As the combined analysis of the five year DBH data recorded indicated that, *Acacia abysinica* and *Accacia saligna* were the species attained the highest mean values of DBH and *Grevillea robusta*, *Pinus patula, Hagenia abbysinica* and *susbania susban* attained medium mean values of DBH. While, *Cordia africana* and *Leuceana Leococephala* multipurpose tree species had the lowest value of DBH from the rest of multipurpose tree species used for the study (Table 3).

Conclusion and Recommendations

The findings of this study indicated that from the eight multipurpose tree species selected, *Acacia abysinica, Gravilia robusta, Hygenia abysinica, Acacia saligna* and *Pinus patula* had the highest survival rate at the study area. In addition, the results revealed that survival rate of *Cordia africana* and *Sesbania sesban* were intermediate. However, *Leuceana leococephala* showed poor survival rate. The reason for low survival of *Leucaena leucocephala* observed was due to its growth best in humid tropics and moist and wet lowland agroclimatic zones.

The height data recorded by the end of the experiment revealed that there were not significance ($P<0.05$) differences in height were viewed between *Acacia saligna, Acacia abysinica, Gravilia robusta* and *Hygenia abbysinica* multipurpose tree species and all the tree species were attained the highest mean value respectively. However, as the finding of this study indicated that *Cordia africana, Susbania susban* and *Leucaena leucocephala* were multipurpose tree species achieved the lowest mean value respectively.

In terms of diameter at breast height (DBH) data recorded at the end of this study showed that, *Acacia abysinica* and *Accasia saligna* were the species attained the highest mean values of DBH and *Grevillea robusta*, *Pinus patula*, *Hagenia abbysinica* and *susbania susban* attained medium mean values of DBH. However, from multipurpose tree species selected for this study, *Cordia africana* and *Leuceana Leococephala* had the lowest value of DBH.

Generally, from the eight multipurpose tree species their growth performance were done at Bore Agricultural Research Center on station, *Acacia abysinica*, *Gravilia robusta*, *Hygenia abysinica*, *Acacia saligna* and *Pinus patula* were showed good performance than the remaining multipurpose tree species. Therefore, planting and promotion of those good performed multipurpose agroforestry tree species and increase their importance for animal feed, apiculture, timber production, shading purpose, soil and water conservation and for household consumption is very vital to conserve natural forest of the area.

References

Azene Bekele-Tesema.2007.useful trees and shrubs for Ethiopia. SIDA'S Regional Soil Conservation unit. Nairobi,Kenya.

N. K. R. Nair. An introduction to agroforestry. Kluwer Academic Publisher, Dordrecht, The Netherlands, 1993. pp. 499

Solanki, Bisaria and Handa(2008) Multipurpose Tree Species: Research, Retrospect and Prospect, India Wakene T,Walelign W, Wassie H(2014) Effect Nitrogen and phosphorus fertilizer levels on growth and development of barly(Hordeum vulgare L.) at Bore district, Southern Oromia, Ethiopia. American Journal of Life Sciences 2(5):260-266)

Zebene, A. and Agren.G. 2007. Farmers' local knowledge and top soil properties of agroforestry practices in Sidama, southern Ethiopia. *Journal of Agroforest system*,Vol.71:35-48.

Assesment of Reproductive Phenology of Most Usable Indiginous Tree Species of Anferara Forest, Guji Zone, South Oromia, Ethiopia

Sintayew Demise, Aschalew Emire, and Temesgen Giri

Bore Agricultural Research Center, P.O. Box 21, Bore, Ethiopia

Corresponding authors: sintedem@gmail.com

Abstract

The reproductive phenological study of ten most usable indigenous tree species was investigated in Anferara forests for three years, 2015-2017. Prior to the study, by using key informant interview and focus group discussion the most usable indigenous tree species were identified from Anferara natural forests. Based on the preferences of the community of the study area, the following ten indigenous tree species Cordia africana, Croton macrostachyus, Albizia gumifera, Podocarpus falcutus, Prunus africana, Ekerbergia capensis, Milletia ferrugenia, Polysias ferrugenia, Strichynos spinosa and Aningeria adolffriedrin were selected for this phenological study. From each indigenous tree species selected from Anferara natural forests, five mother trees were selected and a total of fifty mother trees were tagged for data collection. Based on the objective, the following parameters flowering, fruiting, seed maturity and seed collection times were monthly recorded until the end of the study. The findings indicated that the timing of flowering, fruiting, seed maturity and seed collection of selected indigenous tree species were concentrated in long dry season and during rainy season of the study site. Majority of indigenous tree species selected for this study were flowered during main rainy season (Genna season) of the study site. However, the rest of indigenous tree species were flowered during long dry season. In fruiting time phenology, only three tree species Cordia africana, Croton macrostachyus and Albizia gumifera were bearing fruit during main rainy season (Genna season). However, from the findings of this study the remaining indigenous tree species were bearing fruit during long dry season of the study site. Seed maturity and seed collection time of the indigenous tree species selected were more or less similar and after maturity time of their seeds, close supervision is very important to collect their matured seed at proper time.

Keywords: *Flowering time, fruiting time, phenology, seed collection time, seed maturity time*

Introduction

Phenology is the study of periodicity or timing of recurring biological events, and explains the relationship between climatic factors and periodic phenomena in organisms (Moza & Bhatnagar, 2005; Sakai, 2001; Yadav & Yadav, 2008). Pheno-logical patterns are basic for understanding bio-logical processes and functioning of tropical trees and ecosystems (Tesfaye *et al*., 2011). Seasonal duration of leafing, flowering and fruiting mainly determines the phenological behaviour of tropical trees, and directly or indirectly their population dynamics.

The forest cover of Ethiopia is declining at an alarming rate. This problem influences country and people in many ways. To reduce this problem expansion of plantation forestry is very important. For several species shortage of seed, difficulties in collection, short viability and / or problems of extraction, dormancy or other handling difficulties limit their use in plantation programs (Schidt, 2000). Moreover, according to Asare and Pedersen (2004) insufficient tree seed supply was a major bottleneck problem in tree planting activity.

This is particularly true for indigenous forest development of Guji Zone. This can be attributed to the inherent characteristics of seeds and lack of proper planning for seed collection. This shortage is not only because of lack of seed source, but also shortage of knowledge about the seed collection time. This gap also includes lack of information about the flowering, fruiting and seed maturity time of the different tree species. In order to fill this gap detailed information about the flowering time, fruiting time, seed maturity and seed collection time of every species must be known for a specific area.

In order to fill the above problem, this study focused on flowering time, fruiting time, Seed maturity and seed collection time reproductive phenology of selected indigenous tree species of Anferara forest. This phonological study was aimed to document the reproductive phenology of indigenous tree species including the timing of flowering and fruiting as well as studying the collection calendar of selected tree species. Information on the calendar of flowering, fruiting and other parameters gathered through this study can then be used to anticipate the timing for seed collection and seedling propagation for reforestation with native trees in the study area. Therefore, the objectives of the assessment were to assess the reproductive phenological pattern of most usable indigenous tree species of Anferera forest, and to assess flowering, fruiting pattern, fruiting duration and seed collection calendar of the selected indigenous tree species.

Materials and Methods

Prior to the study of reproductive phenology of indigenous tree species of Anferara forests carried out, by using key informant interview and focus group discussion the most usable indigenous tree species were identified from Anferara natural forests. Based on the preferences of the community of the study area, the following ten indigenous tree species *Cordia africana*, *Croton macrostachyus*, *Albizia gumifera*, *Podocarpus falcutus*, *Prunus africana*, *Ekerbergia capensis*, *Milletia ferrugenia*, *Polysias ferrugenia*, *Strichynos spinosa* and *Aningeria adolffriedrin* were selected for this phenological study for three years, 2015-2017.

From each indigenous tree species selected from Anferara forests, five mother trees were selected and a total of fifty (50) mother trees were tagged for data collection. Those selected mother trees were marked by red colour and their geographical positions were taken. Up to the end of this phonological study, each month necessary data such as flowering, fruiting and seed maturity and seed collection time of each selected tree species was recorded. In addition, the slope, altitude, and position (Geographic coordinates) of the area were recorded by using clinometers, altimeter, and Geographical Positing System (GPS), respectively.

For phenological study of selected indigenous tree species, several methods were applied to identify their reproduction phenology. Those are by climbing trees, observation from natural or artificial high point (hill, by using binoculars) and inspecting their fallen flowers or fruits. Flowering rate of selected indigenous tree species was done according to flowering scale procedure of Tadele (2009) lecture note:

4 = Very good, most of the trees in the stand have abundant flowers,

3 = Good, most of the trees have flowers, some abundant,

2 = Intermediate, <40% of the trees bear flowers, few have many flowers

1 = Poor, most of the trees in the stand have few flowers, edge and exposed tree may flower prolifically

0 = Very poor, flowering poor and only an edge trees or isolated exposed trees

In the survey scales 2-4 was selected that is potential sources for further evaluation. In case of fruiting, fruits of some species grow quickly into mature size, in other it may take several months. Therefore fruiting assessment was conducted only when the fruits have enlarged.

Results and Discussion

Flowering time

It was observed that from selected indigenous tree species their phonological study were studied for three years in Anferara natural forests, *Cordia africana* and *Croton macrostachyus* tree species were flowered in September, *Albizia gumifera* was flowered in October and *Podocarpus falcutus* and *Prunus africana* tree species were flowered in November. This indicated that these five indigenous tree species were flowered during main rainy season (Genna season) of the study area. In support of this study, many research findings indicated that, there are a number of factors, which may influence the timing of flowering including rainfall, moisture, temperature and photoperiod (Anderson *et al*. 2005 and Kikim & Yadava, 2001). In general, their onset and peak flowering time of these five indigenous tree species coincided with the rainy season.

Based on the findings of this phonological study, *Ekerbergia capensis* was flowered in January, *Milletia ferugenia* and *Polysias ferrugenia* were flowered in February and *Strichynos spinosa* and *Aningeria adolffriedrin* were flowered in March. This showed that, their flowering time was during dry season of the study area and their onset and peak of flowering periods coincided with the long dry season. In line with the present study result, a study in Northern Thailand tropical dry forest also showed that peak of flowering of tree species coincided with the beginning of dry season or wet season (Elliott *et al.* 1994). Furthermore, Elliott *et al*. (1994) stated that this phenomenon may be due to different species reproduction strategy. Generally, as the finding of flowering phonology of this study indicated that, in most indigenous tree species selected for this study their flowering time varied between months of the year (Table 1).

Table 1. Flowering, fruiting, seed maturity and seed collection phenological pattern of selected indigenous tree species of Anferara forest, Guji Zone, South Oromia, Ethiopia

No.	Indigenous tree species	Phenological parameters			
		Flowering time	**Fruiting time**	**Seed maturity time**	**Seed collection time**
1	*Cordia africana*	September	October	November	November
2	*Aningeria adolffriedrin*	March	March	March-April	April -May
3	*Prunus africana*	November	December-January	January-February	February
4	*Croton macrostachyus*	September	September-October	October	October
5	*Albizia gumifera*	October	November	December	December
6	*Milletia ferrugenia*	February	February	March-May	May
7	*Strichynos spinosa*	March	March	April-May	May
8	*Ekerbegia capenis*	January	February	March	March
9	*Podocarpus falcutus*	November	December	January-April	April
10	*Polysias ferrugenia*	February	February	March-June	June

Fruiting time

As indicated in Table 1 above, in most indigenous tree species their fruiting time only lasted for one month. For instance, from selected indigenous tree species: *Cordia africana*, *Albizia gumifera*, *Podocarpus falcutus*, *Buddleja polystachya*, *Aningeria adlffriedrin* and *Strichynos spinosa* fruiting time lasted for one month and their month of fruiting time were in October, November, December, February and March respectively. However, from indigenous tree species selected for this study from Anferara forests: fruiting time of *Croton macrostachyus* and *Prunus africana* lasted for two months and their months of fruiting time were in September to October and December to January respectively (Table 1).

Based on the finding of this study, fruiting time of *Cordia africana*, *Croton macrostachyus* and *Albizia gumifera* related with main rainy season (Gena season) of the study site. In support of this study, Gunter *et al*. (2008) indicated that there are a number of factors, which may influence the fruiting time of tree species including rainfall. Therefore, the fruiting pattern of the above three indigenous tree species coincided with the rainfall. However, fruiting time of the remaining indigenous tree species such as: *Albizia gumifera*, *Podocarpus falcutus*, *Buddleja polystachya*, *Aningeria adlffriedrin, Strichynos spinosa* and *Prunus africna* were during dry season of the study area.

Seed maturity time

Based on the findings of this study, most of indigenous tree species selected for this study were showed rapid seed maturity time. For example, rapid seed maturity for *Cordia africana*, *Croton macrostachyus*, *Albizia gumifera*, *Milletia ferugenia*, *Strichynos spinosa* and *Polysias ferrugenia* was recorded during November, October, December, March-May, April-May and March respectively. On the other hand, for the rest of indigenous tree species such as *Podocarpus falcutus*, *Aningeria adolffriedrin*, *Polysias ferrugenia* and *Ekerbegia capenis* lengthy fruit maturation period up to three months was recorded. The recorded seed maturity months for *Podocarpus falcutus* was from January-March and for *Aningeria adolffriedrin*, *Polysias ferrugenia* and *Ekerbegia capenis* tree species the recorded seed maturity period was from March-May.

Seed collection time

As it is indicated in Table 1 above, seed maturity and seed collection time of indigenous tree species selected for this study from Anferara forest is relatively similar. The finding of this study indicated that seed collection time for *Croton macrostachyus* and *Cordia africana* was in October and November respectively. This showed that seed collection time of both indigenous tree species depends on climatic parameters like rain fall, due to their seed maturity time and collection was observed during main rainy season of the study site. Seed collection time for *Albizia gumifera* was from December- January, *Prunus africana* and *Ekerbergia capensis* was in March and for both *Milletia ferugenia* and *Aningeria adolffriedrin* their seed collection time was in May. However, for *Podocarpus falcutus* and *Polysias ferrugenia* tree species their seed collection time was in April and June, respectively.

Conclusion and Recommendations

Based on this phenological study, ten most usable indigenous tree species were selected from Anferara forests and their reproductive phenological study was done for three years. The findings showed that the timing of flowering, fruiting, seed maturity and seed collection of selected indigenous tree species were concentrated in long dry season and during rainy season of the study area. From indigenous tree species studied for reproductive phenology, majority of the tree species were flowered during main rainy season (Genna season). However, the rest of the indigenous tree species were flowered during long dry season. In fruiting time phenology, only three species *Cordia africana*, *Croton macrostachyus* and *Albizia gumifera* were bearing fruits during main rainy season (Genna season); but the findings of the remaining indigenous tree species showed fruit bearing during long dry season. Seed maturity and seed collection time of the indigenous tree species selected for this study were more or less similar and after maturity time of their seed, close supervision is very important to collect their matured seed at proper time.

References

Elliott, S., P. J. Baker & R. Borchert. 2006. Leaf flushing during the dry season: the paradox of Asian mon-soon forests. *Global Ecology and Biogeography* **15:** 248-257.

Kikim, A. & P. S. Yadava. 2001. Phenology of tree species in subtropical forests of Manipur in north eastern India. *Tropical Ecology* **42:** 269-276.

Moza, M. K. & A. K. Bhatnagar. 2005. Phenology and climate change. *Current Science* **89:** 243-244.

Sakai, S. 2001. Phenological diversity in tropical forests. *Population Ecology* **43:** 77-86.

Tesfaye, G., D. Teketay, M. Fetene & E. Beck. 2011. Phenology of seven indigenous tree species in a dry Afromontane forest, southern Ethiopia. *Tropical Ecology* **52:** 229-241.

Yadav, R. K. & A. S. Yadav. 2008. Phenology of selected woody species in a tropical dry deciduous forest in Rajasthan, India. *Tropical Ecology* **49:** 25-34.