OPEN ACCESS

Journal of Soil Science and Environmental Management

April 2018
ISSN 2141-2391
DOI: 10.5897/JSSEM
www.academicjournals.org

ACADEMIC JOURNALS
expand your knowledge

ABOUT JSSEM

The **Journal of Soil Science and Environmental Management (JSSEM)** is published monthly (one volume per year) by Academic Journals.

Journal of Soil Science and Environmental Management (JSSEM) is an open access journal that provides rapid publication (monthly) of articles in all areas of the subject such as Biological control of rot-inducing fungi, Post harvest losses of rice from harvesting to milling, Genetic variability studies between released varieties of cassava, Seed borne pathogens on farmer-saved sorghum etc..

The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in JSSEM are peer-reviewed.

Contact Us

Editorial Office:	jssem@academicjournals.org
Help Desk:	helpdesk@academicjournals.org
Website:	http://www.academicjournals.org/journal/JSSEM
Submit manuscript online	http://ms.academicjournals.me/

Editors

Dr. Geoffrey Kironchi
Department of Land Resource Management &
Agricultural Technology
University of Nairobi,
Kenya.

Prof. Gamal Abdel-Nasser Khalil
Soil Science Dept.
College of Food and Agricultural Sciences - King
Saud
University
P.O. BOX 2460 - Riyadh 11451,
Saudi Arabia.

Dr. Anil vyas
Department of Botany,
J.N.V. University
A-282, Shastri Nagar.

Editorial Board

Dr. Elijah Ohimain
North Carolina A & T State University, Greensboro
Carver Hall Room 207,
Department of Natural Resources and Environmental Design,
School of Agriculture and Environmental Science,
USA.

Dr. Mohamed Rashad Abd El-Fattah
Arid Lands Cultivation and Development Research Institute,
Mubarak City for Scientific Research and Technology Applications,
Egypt.

Dr. Gamal Abdel-Nasser Khalil
King Saud University P.O. BOX 2460 – Riyadh 11451,
Saudi Arabia.

Dr. V. Krishna Murthy
Pes Institute of Technology,
Ring Road, BSK III Stage, Bangalore-560 085,
Karnataka State,
India.

Dr. ANIL VYAS
Department of Botany,
J. N. V. University, A-282, Shastrinagar,
India.

Dr. Anthony O. Ano
National Roots and Tubers Research Institute
Umudike, Umuahia, Abia State,
Nigeria.

Dr Moacir de Souza Dias Junior
Universidade Federal de Lavras (Federal University of Lavras)
Departamento de Ciência do Solo (Soil Science Department)
Brazil.

Dr. Luki Subehi
Ndonesian Institute of Sciences,
Research Centre for Limnology
Cibinong Science Centre 16911 -
Indonesia.

Dr. Goswami Shreerup
P.G. Department of Environmental Science,
F.M. University , Gyana Vigyana Vihar,
Balasore-756020, Orissa,
India.

Dr. Tanushree Bhattacharya
Institute of Science and Technology for Advanced Studies & Research
ISTAR, Near V.P. Science College, Motabazar, Vallabh Vidyanagar,
Anand, Gujarat 388120"
India.

Dr. Suklayan Chakraborty
V. Patel College of Pure and Applied Scienes,
India.

Dr. Ulviyya Samadova
Institute of Soil science and Agrochemistry of Azerbaijan National,
Azerbaijan.

Dr. Luís Carlos Timm
Federal University of Pelotas
Address Campus Universitário s/n – Capão do Leão-RS,
Brazil.

Dr. Willie Peijnenburg
RIVM – Laboratory for Ecological Risk assessment
Leiden University, Centre for Environmental sciences
Bilthoven,
The Netherlands.

Dr. Dedeke Gabriel Adewumi
University of Agriculture, Abeokuta, Ogun State,
Nigeria.

Dr. M J Singh
Punjab Agricultural University, Punjab
India.

Mr. Willis
University of Western Australia
Australia.

Journal of Soil Science and Environmental Management

Table of Contents: Volume 9 Number 4 April 2018

ARTICLES

Potassium dynamics under enset (*Ensete ventricosom cheesman*) farming systems of Sidama zone, Southern Ethiopia **47**
Kibreselassie Daniel Auge, Tekalign Mamo Assefa, Wassie Haile Woldeyohannes and Bizuayehu Tesfaye Asfaw

Effect of soil factors on net N-mineralization and decomposition rate of organic nutrient sources **59**
Abebe Abay

academicJournals

Vol. 9(4), pp. 47-58, April 2018
DOI: 10.5897/JSSEM2018.0679
Articles Number: 504481D56581
ISSN 2141-2391

http://www.academicjournals.org/JSSEM

Journal of Soil Science and Environmental Management

Full Length Research Paper

Potassium dynamics under enset (*Ensete ventricosom cheesman)* farming systems of Sidama zone, Southern Ethiopia

Kibreselassie Daniel Auge[1*], Tekalign Mamo Assefa[2], Wassie Haile Woldeyohannes[1] and Bizuayehu Tesfaye Asfaw[1]

[1]School of Plant and Horticulture Science, Hawassa University, Ethiopia.
[2]Ministry of Agriculture, Ethiopia.

Received 22 October, 2017; Accepted 21 December, 2017

Potassium dynamics of soils is constituted by constantly changing relationship between soil K forms, and this relation is affected by some soil physical and chemical properties. Most Sidama (south Ethiopia) farmers grow enset crops which have high K requirements. The soils were collected from Awassa-Zuriya and Dale districts; 'Woinadega' (warm subtropical climate) and Hula district 'Dega' (wet, cool temperate climate). Overview of K dynamics in soils via Quantity-Intensity (Q/I) curves was used to evaluate the dynamics of K in fifteen soil samples representing the enset farming systems of Sidama. All of the Hula district soils and half of the Dale district soils had low percent K saturation. There were significant correlations between some soil properties and Q/I parameters and among equilibrium solution parameters and Q/I parameters. Variations among the mean quantity (±∆K) values of the soils were not significant. The Dale and Hula district soils had higher K intensity than the Awassa-Zuriya district soils; where the Hula (Adola kura kebele) soil had the highest value. Therefore, the Dale and Hula district soils will require frequent and split K applications since they have lower capacity to maintain long-term supply of K. On the other hand, Awassa-Zuriya district soils had high K quantity than the Dale and Hula district soils. This shows that the Awassa-Zuriya district soils have a higher potential to supply K for a longer period of time from the exchangeable pool. However, the Awassa-Zuriya district soils require less frequent and higher K fertilization to saturate the exchangeable pool to meet immediate potassium requirement of crops. The low equilibrium activity ratio of potassium and low potassium replenishing capacity of nearly all of the soils studied also indicated the need for K application.

Key words: Dynamics of potassium, potential buffering capacity, activity ratio, quantity-intensity isotherms, potassium saturation.

INTRODUCTION

Enset (*Enseteventricosum Cheesman*) is a part of sustainable production system and has been cultivated in Ethiopia since ancient times (Garedew et al., 2017). It is most commonly grown in home-gardens, frequently intercropped with peas or beans, which is suitable to compensate the low protein level in enset foods (Abebe et al., 2010). It is also intercropped with cereal crops (maize, sorghum), root crop (sweet potato), coffee, cabbage, papaya and avocado.

Forms of soil potassium are partitioned into four different pools on the bases of the degree of availability to plants (Romheld and Kirkby, 2010). Among the pools the labile, soil solution and exchangeable K meet the immediate requirements of growing plants while the non-labile, non-exchangeable and mineral K are responsible for the long-term supply of K to plants (Askegaard et al., 2003).

Potassium dynamics in soils is described as the constantly changing relationship between labile and non-labile forms of K (Yawson et al., 2011). It helps to explain the movement of K in soil-solution-plant systems in relation to driving forces. Potassium dynamics depends on the magnitude of equilibrium among the K forms and it is mainly governed by the physicochemical properties of soils, mineral make up, exchange properties and rate of weathering (Lalitha and Dhakshinamoorthy, 2013). Constant change of K in soils is derived by gravitational and diffusion forces (Frissel, 1978). These forces cause dynamic equilibrium of K in soils and the dynamic equilibrium in turn distributes K into different forms. However, soil K forms and other soil properties are not homogeneously distributed in soils since the parent material, degree of weathering, K gains through manures and fertilizers and losses due to crop removal, erosion and leaching differs for different soils (Bogunovic et al., 2017; Rodrigo-Comino et al., 2017). In spite of this, farmers lack sufficient knowledge on soil conservation techniques and the importance of the soils in the bio-geological cycles (Biratu and Asmamaw, 2016; Cerdà et al., 2017).

So far, concentration of exchangeable K has been determined by traditional method that employs chemical extractants. However, Bansal et al. (2002) reported the insufficiency of exchangeable K alone for evaluating K availability under intensive cropping. This could be mainly due to the fact that dynamic interactions among different K pools control plant availability of soil potassium. As of late, new techniques that use adsorption isotherms and thermodynamic parameters such as ionic activity, activity coefficient, ionic strength, free energy of replacement, activity ratio and buffering capacity are considered by several researchers as accurate methods for evaluating potassium status and its availability in soils (Al-Zubaidi et al., 2008). These can be partly achieved through the study of the relationship that exists between changes in concentration of adsorbed K to changes in concentration of solution K; that is, Quantity/Intensity (Q/I) relationship (Uddin et al., 2011).

Both intensity and soils inherent capacity to buffer K against changes are important parameters which determine availability of K to plants (Raheb and Heidari, 2012). Hence, misunderstanding of these dynamics leads to mismanagement of soil fertility. However, to assess the conditions of potassium uptake by plants, the extensive parameters such as potassium, calcium and magnesium contents of soils are also required (Yong-Hong, 2010). In this case, the activity ratio (AReK) described by Beckett (1964) is one of the satisfactory measures of the K dynamics and its availability, because it measures the chemical potential of labile K present to the chemical potential of labile calcium plus magnesium in the same soil.

To date, no research has been conducted and published on potassium dynamics in Sidama soils (south Ethiopia). The objective of this study was therefore to evaluate the dynamics of potassium under enset farming systems of Sidama, Southern Ethiopia and hence it was expected that the research will provide detailed information on the status of potassium.

MATERIALS AND METHODS

Study area

This study was conducted in Awassa-Zuriya, Dale and Hula districts of Sidama zone, Southern Ethiopia (Figure 1) in 2016. Sidama administrative zone is located within 5°45’- 6°45’N latitude and 38°-39°E longitude covering a total area of 6,538.17 square kilometers (SZPEDD, 2010). It lies in the area varying from flat land (warm to hot) to highland (warm to cold). The regional and zonal capital, Hawassa, which is located in the northern tip of Sidama zone, has a distance of 275 km from Addis Ababa (capital city of Ethiopia). Sample study areas (districts) from the zone were randomly selected because nearly all areas in the zone have good potential for *enset* production irrespective of productivity variation due to rainfall and altitude discrepancy. The selected districts are located between 38°20'7.8" - 38°32'36.5"E and 06°28'15.5" - 07°04'50.3"N. Awassa-Zuriya and Dale districts have moist to humid, warm subtropical climate with a mean annual precipitation of 1000 to 1800 mm, and have a mean annual temperature of 15 to 20°C. In these districts, perennial crops such as ‘enset’, ‘chat’ (catha edulis), coffee (*Coffea arabica), Avocado (Persea americana) and annual crops such as* maize (*Zea mays* L.*),* tomato (*Solanum lycopersicum*), sweet potato (*Ipomea batatas*) and haricot bean (*Phaseolus vulgaris* L.) are widely grown. The Hula district has wet, cool temperate climate and receives an annual rainfall of 1200 to 1800 mm, and has the mean annual temperature of 10 to 15°C. In this district, enset (*Ensete ventricosum*), barley (*Hordeum vulgare*), bread wheat (*Triticum aestivum* L.), cabbage (*Brassica carinata*), and potato (*Solanum tuberosum*) are widely grown (SZPEDD, 2010).

*Corresponding author. E-mail: kibreselasiedaniel@yahoo.com

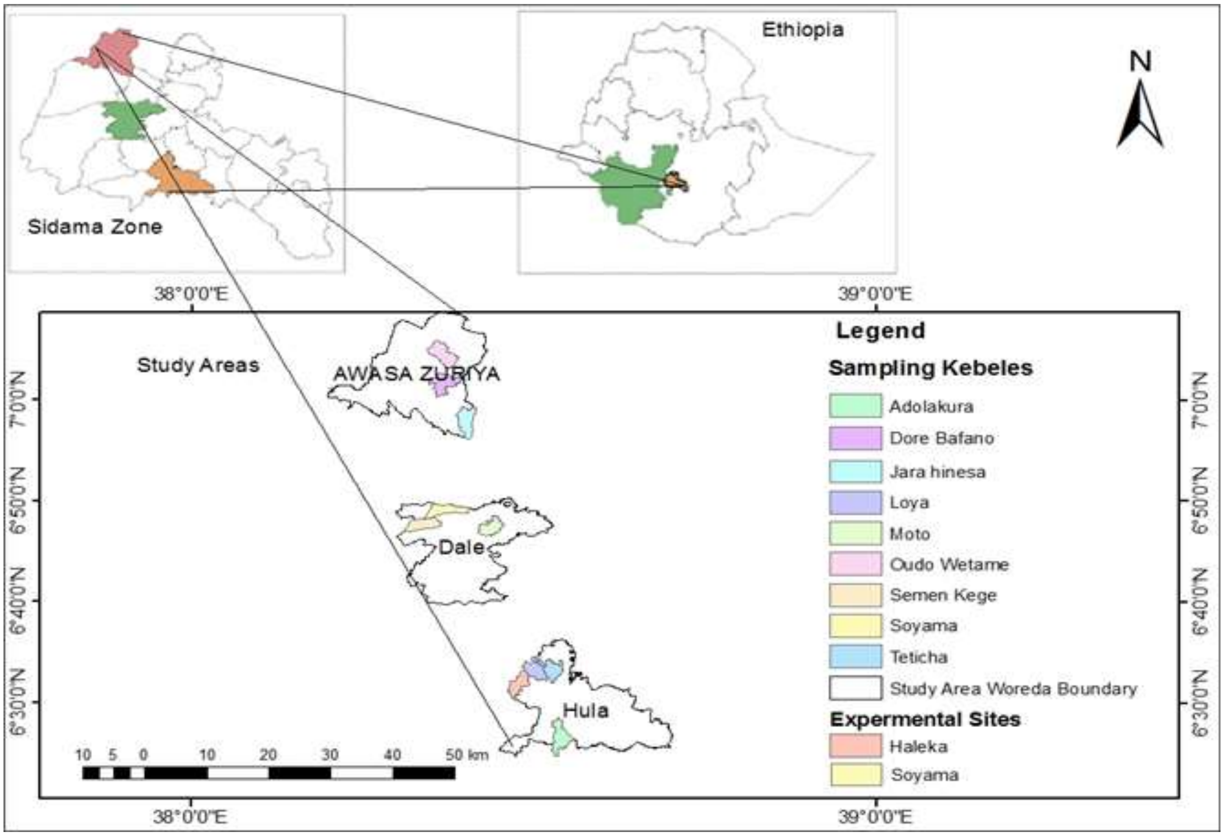


Figure 1. Location map of Sidama zone in Southern Ethiopia, study districts in Sidama zone and soil sampling kebeles in the study districts

Soil sampling

Forty five composite samples were collected in November, 2015 from the three randomly selected districts in Sidama zone where animal dung and manures fertilizers have been applied. After selecting representative farmers' *enset* farms in the farmer associations (kebeles), each field was divided into three stratum with 12 m long in the direction from home vicinity to far located fields. Composite soil sample (12 cores) from 50 cm depth was collected in a plastic pail from each stratum based on the method outlined in Hussen (2007) using auger. The soils were placed on a plastic sheet with an area of 3 m^2 and thoroughly mixed. About 1 kg sample was taken and kept in a polyethylene plastic bag and labeled. Before laboratory analysis, samples were air-dried at room temperature, ground using mortar and pestle, homogenized, and passed through a 2 mm sieve. Finally, samples were stored in clean and dry area at room temperature until the time of use.

Soil physical and chemical analysis

Selected physical and chemical properties of the soils were determined using standard procedures. The pH value was determined by 1:2.5 soil-water suspensions by a glass electrode (Jackson, 1973). Electrical conductivity was determined in supernatant solutions by electro conductivity meter. Organic carbon was determined by the wet oxidation method of Walkley-Black (1934). Cation exchange capacity (CEC) was determined by the 1N NH_4OAc extraction method; and exchange acidity by the 1N KCl extraction method. Soil texture was determined by the hydrometer method (Bouyoucos, 1951) and the textural classes were determined using United State Department of Agriculture (USDA) soil textural triangle. Effective cation exchange capacity (ECEC) was determined by summation method. Lastly, the exchangeable potassium was determined using Mehlich III extractant (Mehlich, 1984).

Equilibration procedure

Soil samples selected were analyzed by the Quantity/Intensity procedure based on the method outlined in Beckett (1964). A stock solution of potassium chloride, 10 mmole/L KCl and Calcium chloride, 10 mmole/L $CaCl_2$ were prepared separately. From these separate solutions, graded concentrations of potassium (0.0, 0.2, 0.4, 1.0, and 2.0 mmol/L in 10 mmole/L $CaCl_2$) were prepared and used for equilibration study. From each soil samples, duplicates of 5 g soils were weighed and quantitatively transferred into each of five plastic tubes. Then, 50 ml of the graded concentration solutions from each was added to the correspondingly labeled plastic tubes. The suspensions were then shaken with a horizontal flask shaker for half an hour and allowed to equilibrate overnight. After equilibration, suspensions were filtered using Whatman No. 42 filter paper, and the equilibrium solutions were analyzed for potassium by Flame Photometer (BWB, 2012); for Electrical conductivity (EC)

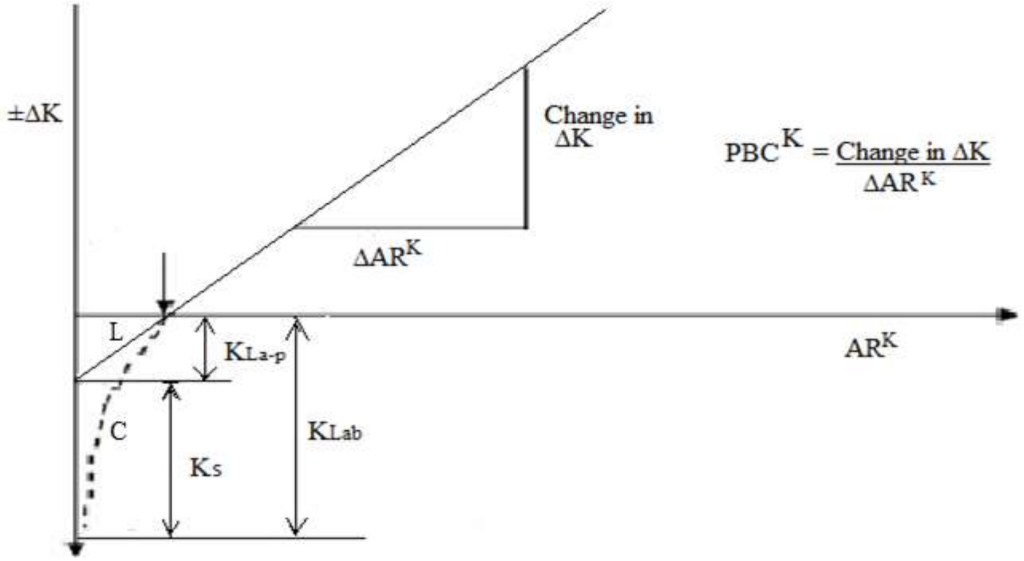


Figure 2. Typical Quantity/ Intensity plot.

by EC meter and for Ca and Mg by EDTA titration (Tucker and Kurtz, 1961).

Equations used to determine thermodynamic parameters and graphical analysis of Quantity/Intensity plots

Ionic strength (μ) mol/L in equilibrium solutions was calculated from the electrical conductivity (EC) using the equation.

$$\mu = 0.0129 * EC, \text{ (Lindsay, 1979).} \qquad (1)$$

Activities (a) of potassium, calcium and magnesium in equilibrium solutions were calculated as product of concentration of ions by their activity coefficient (γ) values. Activity coefficient of ions was calculated using extended Debye-Hückel equation:

$$\text{Log}\gamma = -\text{AZi}^2 \frac{\sqrt{\mu}}{1+\text{Bdi}\sqrt{\mu}} \qquad (2)$$

Where:
Zi: valency of ion
A: 0.508 for water at 25°C
B: 0.328 ×10^8 for water at 25°C
d: is the effective distance of closest approach measured in centimeter and corresponds roughly to the effective size of hydrated ions (d values for different ions are tabulated in Lindsay (1979)).

The gain (loss) of potassium in relation to the adsorbed phase (±ΔK) was calculated by measuring the corresponding increase or decrease in the concentration of potassium in the equilibrium solution, compared to the original solution using the following equation:

$$\Delta K = \text{Initial conc.} - \text{Final conc.} \qquad (3)$$

Where Initial conc. is K added and Final conc. is K in equilibrium solution.
The intensity (I) of labile K in the soil was determined by employing the formula of activity ratio of potassium to the sum of activities of calcium and magnesium in equilibrium solutions as:

$$AR^K = {}^aK\sqrt{a(Ca+Mg)} \text{ (Davis, 1962)} \qquad (4)$$

Where: a is activity

A graph of increase or decrease of K (on the y-axis) and the activity ratio of potassium (on the x-axis) were plotted. On this graph, the equilibrium activity ratio (AReK) was obtained by reading the value on the abscissa where increase or decrease of K (±ΔK) = 0 (Figure 2). 'L' and 'C' denote linear and curvilinear portions of the Q/I lines respectively. These were obtained by extrapolating from the lower x, y coordinate points to the y-axis. Non-specific K ($K_{La\text{-}p}$) was obtained from y-intercept of linear portion of the curve where AR^K = 0. Specific K (Ks) was obtained by extrapolating the linear portion of the curve to the ordinate, by drawing a tangent from the point of abscissa where ±ΔK = 0 and by measuring from the point of labile K (planar and non-specific K) to the end of tangent line on ordinate.
Potential buffering capacity was determined by calculating the slope of the linear portion of the curve. K-potential was determined by multiplying the non-specific potassium by the buffering capacity of potassium (PBC^K). The free energy or the potential of the soil for K-(Ca + Mg) replenishment was determined using the equation reported by woodruff (1955):

$$\Delta F = -2.303RT \log {}^aK\sqrt{a(Ca+Mg)} \qquad (5)$$

Where, T = Absolute temperature at 25°C (298K), R (universal gas constant), constant = 1.987 Cal/mol and a = activity of metal ions. Labile K ($-K_{lab}$) released by the soil was obtained graphically by extrapolating the linear portion of the Q/I plot to its y-intercept (Figure 2). Potassium saturation percentage was calculated using:

$$\%K = \frac{K_{ads}}{CEC} \times 100 \quad \text{(Mutscher, 1995)} \qquad (6)$$

Lastly, Potassium equilibrium parameters were computed with

Excel sheet facilities.

Statistical data analysis

Correlation analysis between soil properties and Quantity/Intensity parameters, between equilibrium solution parameters and Quantity/Intensity parameters were performed with the statistical analysis system (SAS Institute, 2012)

RESULTS AND DISCUSSION

Soil properties

The selected soils physico-chemical properties are presented in Table 1. The pHs of the soils were interpreted as per the ratings of EthioSIS (2014) and it ranged from 4.7 to 7.6, where neutral soils prevail. All of the Hula district soils were strongly acidic while 25% of the Dale district soils had moderately acidic reaction. The Awassa-Zuriya district soils were dominated with neutral and moderately alkaline pH ranges. These results are in line with the findings of David (2015) who suggested the effect of high exchangeable cations on the pH of soils. Organic carbon (OC) ranged from 1.2 to 4.1%. Based on Landon (2014), all soils of Awassa-Zuriya district were categorized as very low in OC while nearly all soils of the Dale and Hula districts had low level of OC. The result is in agreement with the findings of Laekemariam (2015) who reported low levels of OC in enset fields.

The mean particle size distribution in Awassa-Zuriya district is in the order of clay (35.67) > silt (34.67) > sand (29.33), whilst the distributions in Dale and Hula districts are in the order of clay (42) > sand (30.75) > silt (27.25) and sand (39.2) > clay (33.6) > silt (27.2), respectively. These values indicated that the Dale and Awassa-Zuriya district soils had relatively high clay fraction suggesting their ability to retain K than its loss through leaching. However, more K could be fixed in these areas. The Hula district soils, on the other hand, had relatively high sand fraction which aids leaching and the likelihood of acidic conditions than retention of K.

Based on Landon (2014), soils in all studied districts were sufficient in exchangeable Ca while closer values of exchangeable Mg content were found for all districts. Soils of Dale and Awassa-Zuriya districts had high amounts of soil exchangeable K while soils of Hula district had low amount (EthioSIS, 2014). There is a positive correlation between pH and ECEC and an inverse relation between pH and exchange acidity (Evangelou and Blevins, 1998). Consequently, considering the pH and the exchange acidity of Dale district Motto dorsiso. village, the high ECEC can be expected.

Potassium saturation percentage (%K) was found to range from 0.97 to 10.38 and had a mean of 4.28±3.0. Although the mean is above the critical, all soils of Hula district along with 50% of Dale district were found far below critical value of 2.3 (FAO-UNESCO, 1997). This indicated the saturation of CEC with other cations in these areas while on the contrary, all soils of Awassa-Zuriya district and half of the Dale district had potassium proportion of above the critical level.

Evaluation of equilibrium solution parameters

The mean values of parameters in the equilibrium solutions are presented in Table 2. In the table, the mean K^+ concentration in moles/L ranged from 1.06×10^{-4} (Awassa-Zuriya district, Oudo wetame village) to 6.41×10^{-4} (Hula district, Adola kura village). The Hula district, Adola kura, Teticha and Loya diko village soils had high K^+ concentrations and K activity. The Ca and Mg concentrations ranged from 0.644×10^{-2} to 2.073×10^{-2} moles/L and in the range, Awassa-Zuriya district, Oudo Wetame mote, Hula district Adola holo, Dale district, Soyama Bochesa, Moto gadelo and Moto gowe village soils had high values. On the contrary, the Hula district, Teticha and Adola kura village soils had low values. However, the activity coefficients for both $[K^+]$ and $[Ca^{2+}\text{-}Mg^{2+}]$ did not vary significantly; while the opposite can be said of the activity of both K and Ca-Mg. According to Affinnih et al. (2014), soil K^+ concentration can be used to assess the K status of soils.

K intensity

The availability of potassium is satisfactorily estimated from the activity ratio of K (AR^K) in a solution in equilibrium with a soil. Activity ratio (AR^K) is a measure of the intensity (I) of labile K in the soil and represents the K that is immediately available to crop roots. From Table 2, the mean values of AR^K ranged from 0.0008 to 0.0115 moles/L and increased with increasing concentrations of the equilibrating solutions. The range reported here is lower than those reported for some soils: 0.2231 to 0.5394 for Ghana soils (Yawson et al., 2011), 0.00174 to 0.0199 for Iran soils (Abaslou and Abtahi, 2008) and 0.0071 to 0.0320 for Egypt soils (Mahdy and Abu El-Eyuoon, 2017). Reason for these variations could be due to differences in the concentration of equilibrating solutions, equilibration time, the Ca and/or Mg contents and the differences in the mineralogy of the soils. Quantity/Intensity plots are presented in Table 4. In Table 4, Awassa-Zuriya district, Oudo Wetame mote village soil showed high value ($-0.095\ (mol/L)^{1/2}$) of Planar K (easily exchangeable K or non-specific K) indicating the high release of K into soil solution. The lowest value, -0.0025.

K quantity

The quantity factor or gain/loss of K (±ΔK) indicates

Table 1. Selected physical and chemical properties of the soils.

District	Village /Kebele/	pH	Organic Carbon (%)	Particle Size (%)				Exchangeable bases ($cmolkg^{-1}$)				Exchange Acidity ($cmolkg^{-1}$)	ECEC ($cmolkg^{-1}$)	%K
				Clay	Silt	Sand	Textural Class	Ca	Mg	K	Na			
Awassa Z.	Jara hinesa	7.3	1.50	39	35	26	Clay loam	12.65	1.67	2.91	0.38	0.03	17.64	7.96
Awassa Z.	Oudo Wetame	7.5	1.92	39	45	14	Silty clay loam	20.44	3.34	1.75	0.45	0.02	26	6.45
Awassa Z.	Dore Bafano, diko	6.7	1.22	22	32	46	Loam	13.3	3.5	1.36	0.27	0.07	18.5	7.51
Awassa Z	Oudo Wetame, mote	7.0	1.71	46	34	20	Clay	20.34	5.26	1.07	0.27	0.06	27	6.69
Awassa Z.	Dore Bafano, dogo	6.2	1.37	48	32	20	Clay	15.08	4.93	1.60	0.29	0.10	22	10.38
Dale	Soyama, bochesa	7.1	1.69	20	30	50	Loam	22.16	7.06	1.56	0.18	0.04	31	5.50
Dale	Moto, dorsiso.	7.1	3.11	42	39	19	Clay	12.8	2.59	1.05	0.10	0.04	16.84	3.29
Dale	Moto, gadelo.	7.6	3.81	46	24	30	Clay	21.81	5.64	2.4	0.14	0.01	30	5.33
Dale	Moto, gowe	6.3	3.07	50	20	30	Clay	17.72	2.96	0.62	0.10	0.10	22.5	2.24
Dale	Semen Kege	7.2	2.20	30	26	44	Clay loam	17.27	3.17	1.66	0.12	0.05	22.27	2.28
Hula	Teticha	4.8	2.81	23	26	51	Sandy clay loam	17.08	5.09	0.34	0.15	0.12	22.72	0.97
Hula	Adola kura	4.9	4.12	19	40	41	Loam	11.4	4.49	0.37	0.11	0.17	16.54	1.26
Hula	Adola, holo	4.9	3.60	34	18	48	Sandy clay loam	18.78	4.99	0.47	0.14	0.11	24.49	1.47
Hula	Loya, diko	5.0	2.68	46	24	30	Clay	19	4.89	0.49	0.23	0.07	24.68	1.54
Hula	Loya	5.3	3.03	46	28	26	Clay	16.09	3.11	0.56	0.14	0.10	25	1.37

Awassa Z. = Awassa Zuriya

$$\%K \quad \frac{K_{ads}}{CEC} \quad X\ 100$$

Table 2. Mean values of thermodynamic parameters of the equilibrium solutions.

District	Kebele	$[K^+]$ ($\times 10^{-4}$) (mol/L)	[Ca + Mg] ($\times 10^{-2}$) (mol/L)	EC (dSm^{-1})	I ($x\ 10^{-2}$) (mol/L)	γK	γ(Ca+ Mg)	$^{a}K^{+}$ ($\times 10^{-4}$)	$^{a}(Ca^{2+} + Mg^{2+})$ ($\times 10^{-2}$)	AR^K (mol/L)	±ΔK ($\times 10^{-4}$) (mol/L)	ΔF ($kj.\ mol^{-1}$)
Awassa Z.	Jara hinesa	3.42	1.50	0.097	0.1246	0.959	0.825	3.28	1.2334	0.0031	5.583	-15.72
Awassa Z.	Oudo Wetame	2.86	1.190	0.087	0.1117	0.962	0.833	2.75	0.9635	0.0029	6.141	-15.46
Awassa Z.	Dore Bafano, diko	1.40	1.992	0.062	0.0794	0.967	0.857	1.35	1.7078	0.0011	7.603	-18.20
Awassa Z	Oudo Wetame, mote	1.06	2.073	0.087	0.1117	0.962	0.820	1.02	1.7277	0.0008	7.936	-17.96
Awassa Z.	Dore Bafano, dogo	1.51	1.930	0.068	0.0880	0.966	0.830	1.45	1.6444	0.0012	7.494	-17.61
Dale	Soyama, bochesa	2.83	2.071	0.102	0.1313	0.958	0.850	2.72	1.6994	0.0021	6.167	-15.93
Dale	Moto, dorsiso	2.97	1.092	0.073	0.0945	0.965	0.846	2.86	0.9230	0.0031	6.032	-14.49

Table 2. Contd

Dale	Moto, gadelo	2.88	2.025	0.102	0.1313	0.958	0.821	2.76	1.6617	0.0022	6.115	-15.46
Dale	Moto, gowe	3.75	2.025	0.057	0.0730	0.970	0.869	3.65	1.7609	0.0028	5.252	-15.51
Dale	Semen Kege	3.95	1.400	0.067	0.0859	0.966	0.852	3.82	1.1931	0.0036	5.049	-14.96
Hula	Teticha	5.96	0.920	0.088	0.1138	0.961	0.832	5.73	0.7620	0.0062	3.038	-13.26
Hula	Adola kura	6.41	0.644	0.082	0.1052	0.963	0.838	6.17	0.5399	0.0115	2.590	-12.61
Hula	Adola, holo	3.55	2.033	0.057	0.0730	0.969	0.863	3.44	1.7547	0.0026	5.449	-15.47
Hula	Loya, diko	5.67	1.913	0.102	0.1313	0.958	0.821	5.44	1.5694	0.0044	3.327	-15.22
Hula	Loya	3.84	1.983	0.077	0.0988	0.964	0.842	3.70	1.6708	0.0030	5.160	-15.37

Awassa-Z = Awassa-Zuriya
$[K^+]$ = K concentration
AR^K = activity ratio of K
γK = activity coefficient of K
[Ca + Mg] = Ca + Mg concentration
EC = Electrical conductivity
$^a(Ca^{2+} + Mg^{2+})$ = activity of Ca + Mg
±ΔK = gain/loss of K
$^aK^+$ = activity of K
I = Ionic Strength
γ[Ca + Mg] = activity coefficient of Ca + Mg
ΔF = Free energy of replacement

the non-exchangeable and total elemental K reserves. It ranged from 0.000259 (Hula district Adola kura village) to 0.000794 moles/L (Awassa-Zuriya Oudo Wetame mote village). It was observed during the equilibration analysis that these values also increased with increasing concentrations of the equilibration solutions. Obviously, unlike the variation in intensity values (0.00329 ± 0.00265), the variation in the quantity values for the soils is not wide (0.000562 ± 0.000163). However, the range is lower than those reported for some soils: 1.3302 to 1.3327 for Ghana soils (Yawson et al., 2011), 0.001 to 0.0025 for Indian soils (Lalitha and Dhakshinamoorthy, 2015), and 0.00005 to 0.0031 for Poland soils (Bernard et al., 2006).

The free energy of replacement (ΔF)

The free energy of replacement that is used to determine the soils K supplying power was determined based on the method in Woodruff (1995) as shown in Table 4. In the table, soils whose ΔF value is lower than -14.7 kj.mol^{-1} are classified to have poor supplying power of potassium while soils whose ΔF ranges from -14.7 to -8.4 kj.mol^{-1} have medium supplying power. Lastly, soils whose ΔF value is less than –8.4 kj.mol^{-1} are classified as poor in replenishing potassium. Values obtained ranged from -18.2 to -12.61 kj.mol^{-1} and averaged to -15.55 ± 1.53 kj.mol^{-1}. This indicated that soils had poor supplying power of potassium and supplying power varied from soil to soil due to variations in soils' mineralogical properties.

Parameters obtained from Graphical analysis of Q/I plots and their evaluation

The parameters obtained from evaluations of the(mol/L)$^{1/2}$ was determined in Dale district Moto dorsiso and Awassa-Zuriya district Oudo wetame villages indicating the soils' strong ability to absorb K. Moreover, examination of Quantity/ Intensity plots showed that soils of Awassa-Zuriya district, Jara hinesa, Dore Bafano and Dore Bafano diko; soil of Dale district, Semen Kege and soil of Hula district, Adola kura village have

Table 3. Classification of free energy of replacement (Source: Woodruff, 1995).

ΔF(kj.mol^{-1})	Interpretation
Less than -14.7	Low supplying power of potassium
-14.7 to -8.4	Medium/marginal supplying power of potassium
Greater than -8.4	High supplying power of potassium

positive values (positive y-intercepts). The positive y-intercepts indicate the lack of planar K and strong ability of soils to absorb K. Due to this, K was not desorbed from the non-specific binding sites of these soils. Apart from these values, the rest soils have negative values of planar K indicating more K release into soil solution (Jalali, 2007).

Specific potassium (Ks) is the quantity of potassium held on specific edges or peripheral interstices of stacks of clay plates (Holzmueller et al., 2007). This potassium was determined by extrapolating quantity-intensity (Q/I) curves to the ordinates (Figure 2). Values of Ks ranged from -0.0005 to -0.044 (mol/L)$^{1/2}$ (Table 3). In the range, the lowest value was determined in Hula district Adola kura village soil, and Awassa-Zuriya district, Oudo Wetame mote village soil showed the highest. The highest Ks value in Awassa-Zuriya district could be due to high clay content (46%). On the contrary, the lowest Ks value of Hula district soil might be due to low clay content and high acidic reaction pH (4.7). Moreover, somewhat less from the highest Ks values were obtained in soils of Hula district Loya diko and Adola holo; in soils of Dale district Moto gadelo, Moto gowe and Moto dorsiso and in soils of Awassa-Zuriya district Dore Bafano diko and Oudo wetame mote villages. The Ks values of these soils also indicate high K fixing capacity that demands plants to apply more energy to take up potassium. On the other hand, the inverse can be said for soils with low Ks values in Awassa-Zuriya district Dore dogo and Jara hinessa, and in Dale district Semen Kege and in Hula district Adola kura villages.

Potential buffering capacity (PBC^{K}) expresses the ability of a soil to maintain a supply of K as crop use or leaching decreases the content of K in solution and is proportional to CEC. Although PBC^{K} often leads to low K intensity, a high value is indicative of greater capacity of the soil to maintain K for longer periods. On the other hand, soils having low PBC^{K} require frequent K fertilization since such soils fail to maintain a given supply of K for a considerable period of time (Wang et al., 2004).

The PBC^{K} values varied from 50 (Hula district Loya village) to 211 (Awassa-Zuriya district Oudo Wetame M. village (Table 4). According to Zharikova (2004), the values of PBC^{K} in cmol (p+) kg^{-1} were rated as very low (<20), low (21 to 50), medium (51 to 100), elevated (101 to 200) and high (> 200). Based on the rate, the Awassa-Zuriya district, Oudo Wetame, Dore Bafano diko, Dore dogo, the Hula district, Adola holo, Teticha and the Dale district, Moto gadelo village soils had elevated buffering potential. On the other hand, soils of the Awassa-Zuriya district, Jara hinessa, the Hula district, Adola kura and Loya and the Dale district, Moto dorsiso, Moto gowe, Soyama bochessa and Semen Kege villages indicated medium buffering potential. On the contrary, soils of the Hula district, Loya diko and Awassa-Zuriya district, Oudo Wetame M. villages had low and high PBC^{K}, respectively. Soils PBC^{K} values of greater than 200 cmol(p+) kg^{-1} indicates the lowest percent K saturation (Zharikova, 2001).

According to Adinarayana et al. (1987), PBC^{K} correlates positively with ECEC. Hence, the high PBC^{K} of the Awassa-Zuriya Oudo Wetame mote village soil can be attributed to its high ECEC (Table 1) and a low activity coefficient of Ca-Mg (Table 2). Moreover, the elevated PBC^{K} of the Awassa-Zuriya district, Audo Wetame, Dore diko and Dore Bafano dogo, the Dale district, Moto gadelo, the Hula district, Adola holo and Teticha village soils could be attributed to their ECEC, high clay and Ca-Mg contents (Table 1). This suggests a preference for Ca-Mg over K adsorption (Schneider, 1997).

The equilibrium activity ratio (AReK) in (mol/L)$^{1/2}$, derived from the Q/I plots, ranged between 0.00001 (Awassa-Zuriya district Dore diko village) and 0.0013 (Dale district Moto gadelo village and Hula district Teticha village). This range is by far lower than the range obtained by Sharma et al. (2009), 0.00046 to 0.0213 (mol/L)$^{1/2}$ and the range obtained by Samadi (2012) for two different soil types, 0.0047 to 0.012 and 0.008 to 0.013 (mol/L)$^{1/2}$, which were reported as declined. However, the range of AReK in the present study is higher than the suggested minimum range 0.0005 (mol/L)$^{1/2}$ by Beckett and Webster (1971). Soils of Dale district, Moto gadelo, the Hula district, Loya and Teticha, the Awassa-Zuriya district, Oudo Wetame mote villages had relatively high AR_eK values and it could be attributed to their high percent organic carbon (Table 1). On the other hand, these soils had low percent K saturation since Ca_{ex} and Mg_{ex} concentrations influenced the overall potassium activity ratios (McLean and Watson, 1985). According to Fergus et al. (2005), in soil having low exchangeable K pool, the intensity (AReK) was reduced by the exhaustive cropping to 0.00047 (mol/L)$^{1/2}$. In the present study, about 73% of soils indicated AReK values of lower than this minimum. On the contrary, soils of Dale

Table 4. Parameters determined by evaluating Q/I plots.

District	Kebele	AReK	K_{La-p}	$-K_S$	PBC^K	K- Potential
Awassa-Zuriya	Jara hinesa	0.00007	+0.022	-0.004	57	-----
Awassa-Zuriya	Oudo wetame	0.00010	-0.0025	-0.019	111	-0.28
Awassa-Zuriya	Dore Bafano, diko	0.00001	+0.009	-0.002	157	-----
Awassa-Zuriya	Oudo Wetame, mote	0.00042	-0.095	-0.044	211	-20.1
Awassa-Zuriya	Dore Bafano, dogo	0.00015	+0.0003	-0.037	157	-----
Dale	Soyama, bochesa	0.00053	-0.021	-0.029	100	-2.10
Dale	Moto, dorsiso.	0.00020	-0.0025	-0.034	73	-0.18
Dale	Moto, gadelo.	0.00130	-0.093	-0.038	180	-16.7
Dale	Moto, gowe	0.00012	-0.0029	-0.036	100	-0.29
Dale	Semen Kege	0.00010	+0.008	-0.004	60	------
Hula	Teticha	0.00126	-0.0083	-0.016	125	-1.04
Hula	Adola kura	0.00025	+0.0048	-0.0005	92	------
Hula	Adola, holo	0.00020	-0.0051	-0.033	114	-0.58
Hula	Loya, diko	0.00030	-0.0068	-0.035	100	-0.68
Hula	Loya	0.00080	-0.0085	-0.021	50	-0.43

+ = Positive y-intercepts,
AR_eK = equilibrium activity ratio of K $(mol/L)^{1/2}$,
K_{Lab} = Labile K (cmol (P+) Kg^{-1}),
PBC^K = Potential buffering capacity (cmol(P+) Kg^{-1} $mol^{1/2}/L^{1/2}$,
K_{La-p} = Non-specific K (cmol (P+) kg^{-1}
K-Potential = [(cmol (P+) kg^{-1})$mol^{-1/2}L^{1/2}$]
$-K_s$ = Specific K (cmol (P+) kg^{-1}).

district, Moto gadelo, Hula district, Teticha and Loya and Awassa-Zuriya district, Oudo wetame mote had high values of K intensity. This shows greater tendency to maintain K supply to crops though K could be lost through leaching.

The K-potential is the product of non-specific K and PBC^K and it indicates K availability in soil solution. From Table 4, the Awassa-Zuriya district Oudo Wetame mote village soil had the highest K-potential and Ks while the Dale district Moto dorsiso village soil showed the lowest K-potential. This confirmed the soil's lower preference for specific adsorption of K. Soils of Hula district, Adola kura, Dale district, Semen Kege and Awassa-Zuriya district, Jarra hinesa, Dore Bafano diko and Dore Bafano dogo villages, had no K-potential but low Ks values. In these soils, more K may be fixed at specific adsorption sites and creates a lower PBC^K on equilibration (Abaslou and Abtahi, 2008). On the other hand, soils of Awassa-Zuriya district, Audo Wetame mote and Dale district, Moto gadelo villages had high K-potential and Ks. These soils release more K from non-specific (planar) sites, leading to higher PBC^K on equilibration. A cross-correlations between the soil properties and the Q/I parameters are presented in Table 5.

From Table 5, AReK shows intermediate positive correlation with ECEC. This is expected since ECEC of soils plays a positive role on the availability of plant nutrients. Potential buffering capacity indicates intermediate positive correlation only with Mg_{ex}. K-potential shows intermediate negative relationships with Ca_{ex} and ECEC while intermediate positive relationships existed with pH. This could be due to high concentration of Ca in solution which prevented K from desorbing into soil solution and the same explanation can be given for the relation with ECEC (Diatta et al., 2006). Non-specific K shows intermediate negative correlations with Ca_{ex} and ECEC. Since non-specific K represents K desorbed from the exchangeable pool, high concentration of Ca_{ex} in soil solution and high ECEC might reduce the extent of K desorption. Specific K shows intermediate negative correlations with Clay, Ca_{ex} and ECEC. This is very convincing that K desorption from specific sites is lowered as clay percent increases and the same can be suggested for Ca_{ex} and ECEC. Finally, free energy shows an intermediate positive relationship with only organic carbon. This indirectly agrees with Talibudeen (1972) who pointed out the dependence of free energy on CEC which in turn depends on soil organic matter. Lastly, no significant relationships were found among the rest of the soil properties and the Q/I parameters.

In Table 6, the results of cross-correlation among equilibrium solution parameters and Q/I parameters are presented. In the table, strong positive correlations were found among $[K^+]$, ${}^aK$, AR^K and ΔF. Such associations existed because these parameters explain K status in equilibrium solution. On the other hand, PBC^K shows

Table 5. Cross-correlation among soil properties and Q/I parameters.

Parameter	**AR_eK**	**$K_{La\text{-}p}$**	**Ks**	**PBC^K**	**K-Potential**	**ΔF**
Ph	-0.0605	-0.4613	-0.1502	0.0670	-0.4355	-0.3952
Organic Carbon	0.3943	-0.0950	-0.1198	-0.1774	-0.0569	0.7174***
Clay	0.0885	-0.2279	-0.6583**	0.1271	-0.2685	-0.3168
Silt	-0.3165	0.0015	0.0818	0.0255	-0.0312	-0.2914
Sand	0.2284	-0.3200	0.4609	-0.1449	-0.4601	0.2514
Ca_{ex}	0.4808	-0.5655*	-0.5391*	0.2369	-0.5135*	-0.1994
Mg_{ex}	0.4553	-0.4696	-0.4337	0.5501*	-0.4502	-0.0722
K_{ex}	-0.1001	-0.2345	0.1397	0.0707	-0.2231	-0.3565
Exchange acidity	-0.0050	0.4341	0.1904	-0.0843	0.3999	0.3689
ECEC	0.5010*	-0.5959*	-0.5596*	0.3737	-0.5286*	-0.2356

* Significant at $P < 0.05$; ** at $P < 0.01$; *** at $P < 0.005$.

intermediate negative associations with ^{a}K and $[K^+]$. This indicates that soils K buffering capacity declines as exchangeable K desorbs while equilibrium K content increases. In agreement to this, ±ΔK correlated positively and intermediately with PBC^K. Equilibrium K $[K^+]$ indicates perfect negative correlation with ±ΔK. This shows inverse relation since complete increase in the amount of adsorbed K is accompanied by complete decrease in equilibrium K concentration. Moreover, intermediate positive correlations occurred between Ks and $K_{La\text{-}p}$, and K-potential and Ks. From this it can be said that Ks is directly proportionate to $K_{La\text{-}p}$ and the same can be said for K-potential and Ks. Furthermore, K-potential shows intermediate negative correlation with PBC^K. This indicates the decrease of soils K buffering potential as crop available K increases. Lastly, AR_eK shows intermediate negative correlation with $K_{La\text{-}p}$ though unexpected.

Conclusion

So far, the evaluation of soil potassium in terms of its availability to crops has been based on the figure obtained using chemical extractants. The problems are however weak correlations found between this K-pool and crop yields. Therefore, identifying, quantifying and monitoring soil properties and K changes are necessary to prevent soil degradation. Supporting this fact, growing researches on this issue are indicating that Quantity-Intensity (Q/I) isotherms provide a better estimation of plant available potassium. Due to this, Quantity/Intensity isotherms were used to evaluate the K dynamics in fifteen selected soils with varying properties representing the enset farm systems of Sidama, south Ethiopia.

It was believed that high silt proportion at Awassa-Zuriya district could increased the K adsorption capacity of soils. The higher K ratio (intensity) at Dale and Hula districts obtained while high quantity is measured at Awassa-Zuriya district soils shows that, Awassa-Zuriya district soils have a higher potential to supply K for a longer period of time from the exchangeable pool. On the other hand, the Dale and Hula soils will have high K concentration in solution immediately after K fertilization. Nevertheless, this high K intensity can be rapidly depleted through leaching and/or plant uptake. Moreover, According to the results of previous findings, higher K^+ intensity and activity lead to a lower PBC^K which is a better indicator of the ability of soil to maintain K intensity. Consequently, the Dale and Hula district soils which had higher K intensity will have lower PBC^K. Moreover, the Hula and Dale district soils had low potassium saturation. Therefore, the Dale and Hula district soils will require split and frequent K fertilization. On the other hand, the low free energy of replacement values determined indicated poor capacity of soils to supply K with minor exception. This also pointed out that the studied areas require K fertilization to boost crop production.

From the graphical analysis of Quantity/intensity plots, nil K-potential was determined for half of the Awassa-Zuriya district samples while low AReK values obtained nearly for all samples. This also pointed out the need for K application in Awassa-Zuriya district. Furthermore, indirect and direct associations existed between soil physico-chemical properties and the Q/I parameters further illuminated light on the behavior of K in soils and simplified the evaluation of its dynamics.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

Authors are very indebted to International Potash Institute (IPI) for covering all research expenses and their

Table 6. Cross-correlation among the equilibrium solution parameters and Q/I parameters.

Parameter	**$[K^+]$**	**$^aK^+$**	**AR^K**	**$\pm\Delta K$**	**AReK**	**$K_{La\text{-}p}$**	**Ks**	**PBC^K**	**K-Potential**	**ΔF**
$[K^+]$	1									
$^aK^+$	0.9999*****	1								
AR^K	0.8575*****	0.8571*****	1							
$\pm\Delta K$	-1*****	-0.9999*****	-0.8573*****	1						
AR_eK	0.2572	0.2540	0.1101	-0.2582	1					
$K_{La\text{-}p}$	0.3651	0.3677	0.3073	-0.3637	-0.5276*	1				
Ks	0.3346	0.3342	0.4845	-0.3338	-0.2186	0.5205*	1			
PBC^K	- 0.5124*	-0.5144*	-0.3586	0.5117*	0.2261	-0.7041***	-0.4593	1		
K-Potential	0.3908	0.3932	0.3048	-0.3896	-0.4558	0.9921*****	0.5021*	-0.7306***	1	
ΔF	0.8915*****	0.8919*****	0.8461*****	-0.8915*****	0.3068	0.2957	0.3062	-0.5467*	0.3281	1

*Significant at $P < 0.05$; ** at $P < 0.01$; *** at $P < 0.005$; ****at $P < 0.001$; ***** at $P < 0.0001$.

devotion to support food insecure society through very indispensible and timely researches on potassium status of soils.

REFERENCES

Abaslou H, Abtahi A (2008). Potassium quantity intensity parameters and it with selected soil properties in some soils of Iran. J. Appl. Sci. 8(10):1875-1882.

Abebe T, Wiersum KF, Bongers E (2010). Spatial and temporal variation in crop diversity in agroforestry homegardens of southern Ethiopia. Agrofor. Syst. 78:309-322.

Adinarayana V, Subba Rao A, Krishna Reddy B, Subba Rao IV (1987). Relationships between Q/I parameters of potassium and some characteristics of soils of Nellore district, Andhra Pradesh. The Andhra Agric. J. 34:128-131.

Affinnih KO, Salaw IS, Isah AS (2014). Methods of Available Potassium Assessment in Selected Soils of Kwara State, Nigeria. 14:1.

Al-Zubaidi A, Yanni S, Bashour I (2008). Potassium status in some Lebanese soils. Lebanese Sci. J. 9(1):81-97.

Askegaard M, Eriksen J, Olesen JE (2003). Exchangeable potassium and potassium balances in organic crop rotations on a coarse sand. Soil Use Manage. 19:96-103.

Bansal SK, Rao CS, Pasricha NS, Imas P (2002). Potassium dynamics in major benchmark soil series of India under long - term cropping. 17th World Congress of Soil Science, Bangkok, Thailand.

Beckett PHT (1964). Studies on soil potassium. I. Confirmation of ratio law: Measurement of labile potassium in the soil. J. Soil. Sci. 15:9-23.

Beckett PHT, Webster R (1971). Soil variability: A review. Soil Fert. 34:1-15.

Bernard JD, Kociałkowski ZW, Grzebisz W (2006). Evaluation of potassium quantity-intensity parameters of selected polish agricultural soils. Electronic J. Pol. Agric. Univ. Agron. 9:4.

Biratu AA, Asmamaw DK (2016). Farmers' perception of soil erosion and participation in and water conservation activities in the Gusha Temela watershed, Arsi, Ethiopia. Int. J. River Basin Manage. 14:329-336.

Bogunovic I, Bilandzija D, Andabaka Z, Stupic D, Comino JR, Cacic M, Brezinscak L, Maletic E, Pereira P (2017). Soil compaction under different management practices in a Croatian vineyard. Arab. J. Geosci. 10:1-9.

Bouyoucos GJ (1951). Recalibration of hydrometer method of mechanical analysis of soil. Agron. J. 43(2):434-435.

BWB (2012). A guide to flame photometer analysis. Version 1.0 – 16, BWB Technologies UK Ltd. www.gbcpolska.pl/bwb/pdfy/flame_photometery_guide.pdf

Cerdà A, Rodrigo-Comino J, Giménez Morera A, Keesstra SD (2017). An economic, perception and biophysical approach to the use of oat straw as mulch in Mediterranean rainfed agriculture land. Ecol. Eng. 108PA:162-171.

Davis CW (1962). Ion Association. Butterworths, London, England.

David C (2015). Soils and Plant Nutrients Extension Gardener Handbook Retrieved from: https://content.ces.ncsu.edu/extension-gardener-handbook/1-soils-and-plant-nutrients.

Diatta JZ, Waclaw M, Grezebisz W (2006). Evaluation of potassium quantity- parameters of selected Polish agricultural soils. Agronomy 9:4-15.

EthioSIS (Ethiopia Soil Information System) (2014). Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Addis Ababa, Ethiopia

Evangelou VP, Blevins RL (1998). Effect of longterm tillage systems and nitrogen addition on K quantity-intensity relationships. Soil Sci. Soc. Am. J. 52:1047-1054.

Food and Agriculture Organization (FAO) United Nations Educational, Scientific and Cultural Organization (UNESCO) (FAO-UNESCO) (1997). FAO-UNESCO soil map of the world. Revised legend with correction and updates. Technical paper 20, ISRIC Wageningen. http://www.fao.org/soils-portal/soil-survey/soil-maps-anddatabases/faounesco-soil-map-of-the-world/en/

Fergus IF, Martin EA, Little IP, Haydock KP (2005). Studies on soil potassium: II. The Q/I relation and other parameters compared with plant uptake of potassium. Aust. J. Soil Res. 10(1):95-111.

Frissel MJ (1978). Cycling of mineral nutrients in agricultural ecosystems. Elsevier B.V., Amsterdam, Netherlands.

Garedew B, Ayiza A, Haile B, Kasaye H (2017). Indigenous Knowledge of Enset (*Ensete ventricosum* Cheesman) Cultivation and Management Practice by Shekicho People, Southwest Ethiopia. J. Plant Sci. 5(1):6-18.

Hussen A (2007). PhD Thesis, Addis Ababa University, Addis Ababa.

Holzmueller EJ, Jose S, Jenkins MA (2007). Influence of calcium, potassium, and magnesium on *Cornus florida* L. density and resistance to dogwood anthracnose. Plant Soil 290:189-199.

Jackson ML (1973). Soil chemical analysis. Prentice Hall of India (P) Ltd., New Delhi.

Jalali M (2007). A study of the Quantiti/Intensity relationships of potassium in some calcareous soils of Iran. Arid Land Res. Manage. 21(2):133-141.

Laekemariam F (2015). Soil spatial variability analysis, fertility mapping and soil plant nutrient relations in wolaita zone, Southern Ethiopia. Ph.D Thesis. Haromaya University Ethiopia.

Lalitha M, Dhakshinamoorthy M (2015). Quantity-intensity characteristics of Potassium (K) in relation to potassium availability under different cropping system in alluvial soils. Afr. J. Agric. Res. 10(19):2097-2103.

Lalitha M, Dhakshinamoorthy M (2013). Forms of soil potassium-a review. Afr. J. Agric. Res. 35(1):64-68.

Landon JR (2014). Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Routledge, Abingdon, UK 532p.

Lindsay WL (1979). Chemical Equilibria in Soils. Join Wiley, New York.

Mahdy HH, Abu El-Eyuoon AZA (2017). Evaluation of Potassium Quantity- Intensity in some Soils of El-Dakhla Oasis, New Valley, Egypt. http://asejaiqjsae.journals.ekb.eg/article_2367_b749c2b3c7e3c3ac88c73e14d6cd3b07.pdf

McLean ED, Watson ME (1985). Soil measurements of plant available potassium. In: R.D. Munson (Ed.). Potassium in Agriculture. ASA-CSSA-SSSA, Madison, WI., USA. pp. 277-308.

Mehlich A (1984). Mehlich III soil test extractant: A modification of Mehlich II extractant. Comm. Soil Sci. Plant Anal. 15:1409-1416.

Mutscher H (1995). Measurement and Assessment of Soil Potassium. Inter. Potash Inst., Basel/Switzerland. IPI Research Topics, No. 4.

Raheb A, Heidari A (2012). Effects of clay mineralogy and physicochemical properties on potassium availability under soil aquic conditions. J. Soil Sci. Plant Nutr. 12(4):747-776.

Rodrigo-Comino J, Senciales González JM, Ramos MC, Martínez-Casasnovas JA, Lasanta Martínez T, Brevik EC, Ries JB, Ruiz-Sinoga JD (2017). Understanding soil erosion processes in Mediterranean sloping vineyards (Montes de Málaga, Spain). Geoderma 296:47-59.

Romheld V, Kirkby EA (2010). Research on potassium in agriculture; needs and prospects. Plant Soil 335:155-180.

SAS institute (2012). User's Guide. SAS/STAT® 9.3. Statistical Procedures, Second edition. SAS institute inc, Cary, NC, USA.Schneider A (1997). Influence of soil solution Ca concentration on short-term K release and fixation of a loamy soil. Eur. J. Soil Sci. 48:513-522.

Sharma A, Jalali VK, Vivak M, Arya, Pradeep R (2009). Distribution of various forms of Potassium in soils representing intermediate zone of Jammu region. J. Indian Soc. Soil Sci. 57(2):205-207.

Sidama Zone Planning and Economic Development Department (SZPEDD) (2010). Sidama Administrative zone: A socio-economic profile. Awassa, Ethiopia.

Talibudeen O (1972). Exchange of potassium in soils in relation to other cations. 9th Colloq. of the International Potash Institute, Berne, Switzerland pp. 97-110.

Tucker BB, Kurtz LT (1961). Calcium and Magnesium Determinations by EDTA Titrations1. Soil Sci. Soc. Am. J. 25:27-29.

Uddin MS, Abedin MMJ, Islam MR, Saleque MA, Islam MS (2011). Potassium status of four rice growing soils of Bangladesh. Bangl. J. Agric. Res. 36(4):633-646.

Walkley A, Black IA (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29-38.

Wang JJ, Dustin LH, Paul FB (2004). Potassium buffering characteristics of three soils low in exchangeable potassium. Soil Sci. Soc. Am. J. 68:654-661.

Woodruff CM (1995).The energy of replacement of calcium by potassium in soils. Soil Sci. Soc. Am. Proceed. 19:167-171.

Woodruff CM (1955). Ionic Equilibria Between Clay and Dilute Salt Solutions. Soil Sci. Soc. Am. Proc. 19:36.

Yawson DO, Kwakye PK, Armah FA, Frimpong KA (2011). The dynamics of potassium (k) in representative soil series of Ghana. ARPN J. Agric. Biol. Sci. 6(1):1990-6145.

Yong-Hong L (2010). Effects of potassium behaviour in soils on crop absorption. Afr. J. Biotechnol. 9(30):4638-4643.

Zharikova EA (2004). Potential Buffer Capacity of Soils with Respect to Potassium (by the Example of the Amur River Region). Euro. Soil Sci. 37(7):710-717.

Zharikova EA (2001). In Ecological Risk: Proceedings of the 2nd All-Russia Conference P 166.

academicJournals

Vol. 9(4), pp. 59-67, April 2018
DOI: 10.5897/JSSEM2017.0655
Articles Number: 53E559C56585
ISSN 2141-2391

http://www.academicjournals.org/JSSEM

Journal of Soil Science and Environmental Management

Full Length Research Paper

Effect of soil factors on net N-mineralization and decomposition rate of organic nutrient sources

Abebe Abay

Ethiopian Environment and Forest Research Institute, P. O. Box 31037, Addis Ababa, Ethiopia.

Received 25 August, 2017; Accepted 3 October, 2017

Rate of mineralization for organic nutrient sources (ONS) depends on temperature, soil moisture, soil chemical, physical, biological properties as well as the chemical composition of the ONS. *Erythrina abyssinica* (EA), *Erythrina brucei* (EB) and *Ensete ventricosum* (EV) (ONS) were collected from Sidama and Wolaita, southern Ethiopia. Soil samples (0-20 cm) depths were collected from Cambisols and Luvisols areas. Physicochemical properties of the two soils were analyzed following standard analytical methods. For the greenhouse mineralization pot experiment, 21 treatments for each week were designed for *EA*, *EB* and *EV* in Luvisols and Cambisols. The treatments were arranged in a completely randomized design (CRD) with three replications. The incubation was carried out in green house for five consecutive weeks, the average TN contents of *EA*, *EB* and *EV* were 4.05, 3.35 and 2.56%, respectively. The pots were watered to field capacity every day or two. Each week, determination of OC and TN contents were conducted. The results of mineralization revealed that the TN concentration was highest in the first week and became low and constant at the third to fifth week. The same trend was followed by OC constant declining in both soil types. There was a reduction of C/N ratio in both soil types. The ONS had medium to high TN content and they decompose easily. Thus, the study reveals that these ONS can be used as alternative or supportive fast decomposing organic sources of fertilizers.

Key words: C/N ratio, incubation, total nitrogen, organic carbon, organic nutrient sources.

INTRODUCTION

Incorporating of organic nutrient sources (ONS) to agricultural soil with/without inorganic fertilizers is important for refilling the annual Carbon uptake by plants and for improving fertility of the soils (Goyal et al*.*, 1999). Trees which have versatile uses, such as *EA, EB* and EV are cultivated in farmstead of most growers of Southern Ethiopia. *EA* and EB *are* endemic to Ethiopia and they are N-fixing trees, thus, they are organic nutrient sources (Thulin, 1989; Fassil, 1993). These trees grow in areas with altitude starting from 1400 to as high as 2600 m.a.s.l. The *Ensete ventricosum* is wild and grows across many regions of Africa (Kippie, 2002). *Erythrina abyssinica*, besides its medical application, the tree is recommended for soil conservation programmes, and used as green manure. It is extensively used as a residence boundary marker and is also planted as an

*Corresponding author. abebeabayt@yahoo.com Tel: +25191146 7175.

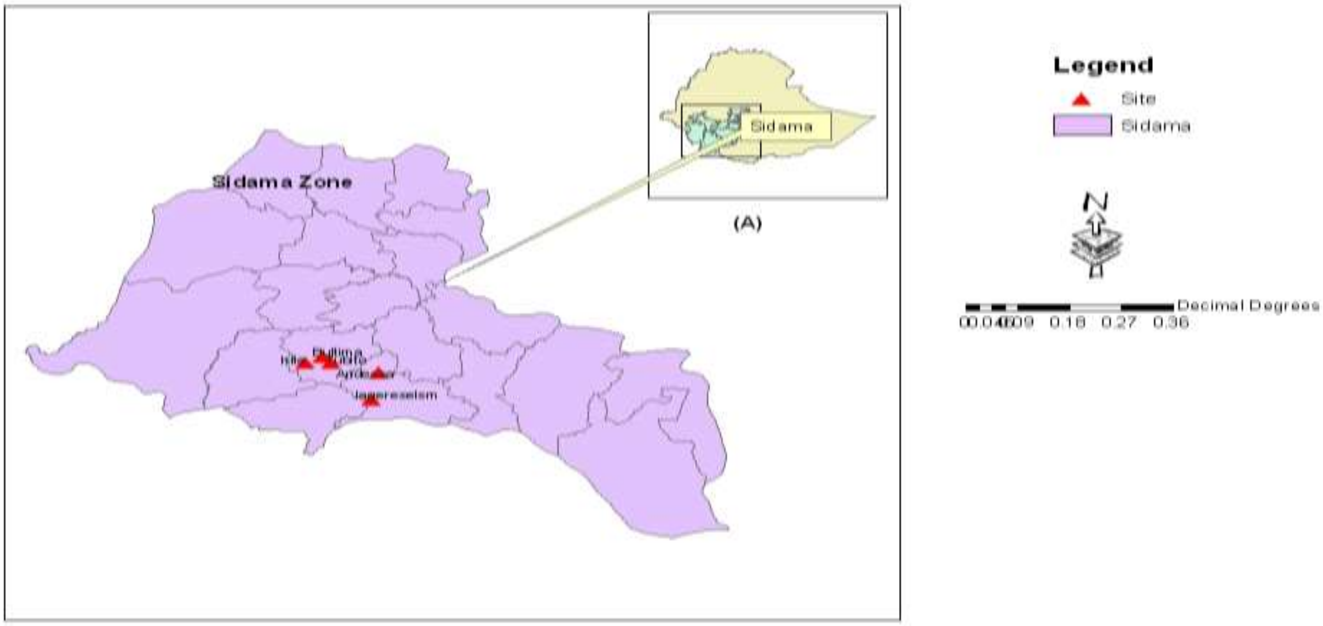


Figure 1. Sampling sites in Sidama.

ornamental tree (http://database.prota.org//Erythrina%20abyssinica_En.htm).

The nutrient rotations in soil are managed by the active role of many verities of microbial colonies, cultivation system and climatic conditions which continuously influence physical structure, chemical properties, nutrient availability and organic matter return to the soil. Henceforth, soil shall be studied to effectively and efficiently addressee these potential (Bandick and Dick, 1999; Hall, 1999; Sasaki et al*.,* 2009).

It shall be an inevitable practice to maintain the nutrient requirements of crops by application of ONS as described by Satyanarayana et al*.* (2002). However, it is challenging to predict the releasing rate of the ONS when applied into different agro-climatic zones and different soil types. This is because the N release from such materials depends on the microbially-mediated processes of N mineralization and nitrification, soil chemical and physical properties, organic matter characteristics like the C:N ratio, residue quality like lignin content, polyphenol content and environmental variables (Van Kessel and Reeves, 2002; Stadler et al., 2006; Schomberg et al., 1994; Trinsoutrot et al., 2000).

However, Net N-Mineralization and decomposition rate of *EA, EB* and *EV* in Cambisols and Luvisols have not been investigated so far. Therefore, further investigation and knowledge on the decomposition rate of these ONS assists to answer when and how much nutrients are released under specific soil conditions. Moreover, it also helps to synchronize crop demand with the released nutrients. Thus, this experiment was conducted to determine and relate the rates of Net N-Mineralization and decomposition of these ONS in Cambisols and Luvisols.

MATERIALS AND METHODS

Description of ONS sampling sites

Sidama covers 6972.1 km^2 and lies between 6°14' to 7°18' N and 37°92' to 39°19'' E, with an elevation 501 to 3000 m.a.s.l. The annual mean temperature of the zone ranges 10.1 to 27°C and the annual mean rainfall ranges 801 to 1600 mm (National Meteorological Agency, Hawassa Branch Directorate (NMAHBD), 2012).

Wolaita covers an area of 4471.3 km^2 and having an elevation ranging from 1200 to 2950 m.a.s.l. with annual average temperature of 15.1°C. The area has a bimodal rainfall pattern, with an average annual rainfall of 1300 to 2000 mm distributed over 8 to 9 months (NMAHBD, 2012). Samples of *EA*, and *EV were* collected from Sidama (Figure 1) and *EB* and *EV* were collected from Wolaita (Figure 2).

Description of experiment site

The experiment site (Hawassa) is located at 07° 03' N and 38° 29' E with an average altitude of 1750 m.a.s.l. The data obtained from NMAHBD (2012), showed the mean temperature ranges from 10°C in the winter to 30°C in the summer months. The area also receives mean annual precipitation of 956 mm with monthly mean ranging between 17 mm in December (dry season) to 126 mm in September (main rainy season).

Sampling and sample preparation

Representative, about 50 kg surface soils (0-20 cm), were collected

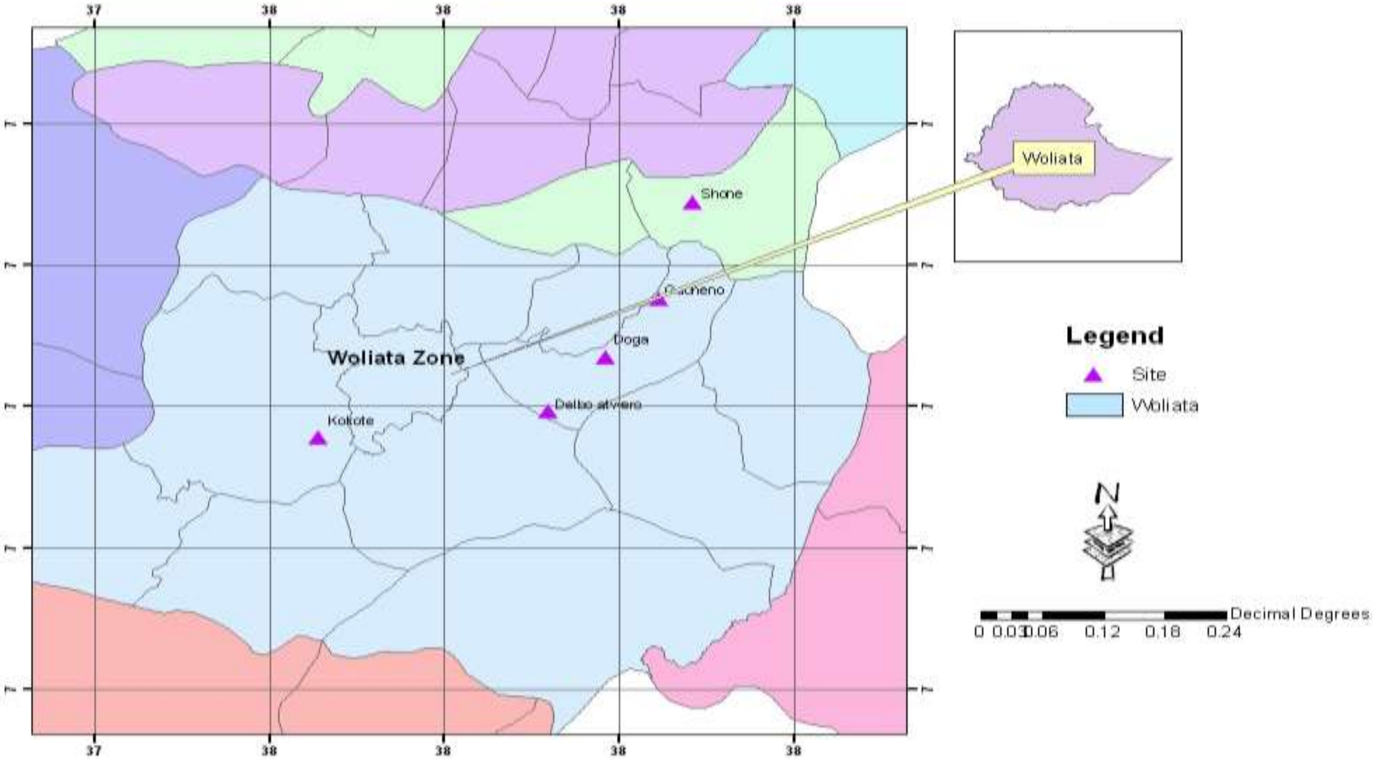


Figure 2. Sampling sites in Wolaita.

using Edelman auger from 30 randomly selected spots from Cambisols of Wolaita (Ashenafi et al*.,* 2010) located at 06° 52' 37.7'' N and 37° 35' 33'' E (Figure 2) and Dystric Luvisols of Sidama found at 06° 29' 26.1'' N and 038° 30'45.3'' E (Abayneh et al., 2006, Unpublished) areas for this study (Figure 1). The plant materials were cleaned, freed of extraneous substances including soil and dust, washed carefully with water jet and rinsed with deionized water, followed by first open air-drying and then drying in an oven at 65°C for 24 h.

Incubation experiment

The incubation greenhouse experiment was done at Hawassa University, School of Agriculture and Horticultural Sciences. For the experiment 0.127, 0.169 and 0.215 g of ground EA, EB and EV were incorporated into 200 g of each soil type separately by converting the TN content of the plants to the local recommendation of urea and DAP. Thereafter, it was transferred into plastic cup. The mixture, soil and ONS, was watered to field capacity until the completion of the experiment by monitoring using Moisture Meter (Delta, model HH2). The samples which were ready (mature for the test) for analyses were then collected and transferred to chemical laboratory for further analysis. The treatments for each experiment were commenced the same day but with separate polyethylene bottles. Every cup was sampled independently at 1, 2, 3, 4, and 5 week stages.

ONS total nitrogen content analysis

The total nitrogen content of the ONS was analyzed by the modified Kjeldahl procedure that involves digestion of sample with sulphuric-salicylic acid mixture and catalyst followed by distillation and titrimetric quantification in the digest (Kim, 1996).

Selected soil chemical and physical analysis

The pH and electrical conductivity of the soils were measured in the ratio 1:2.5 (soil: water) followed by shaking for two hours at 150 rpm, and measured in the suspension using pH meter and Electrical Conductivity meter, respectively (Reeuwijk, 2002). Organic carbon content was determined after weighing 1.0 g air-dry soil and transferred to a 300-ml Erlenmeyer flask. Thereafter, 10 ml of 1 N $K_2Cr_2O_7$ solution was added, with two blanks included. Also, 2 0 ml (98%) H_2SO_4 was carefully added followed by swirling. The flask was allowed to cool, 200 ml distilled water and 10 ml H_3PO_4) (Sp. gr. 1.75) were added and just before titration, 0.5 ml of barium diphenylamine sulphonate was added. It was then titrated with 0.5 N ferrous sulphate solutions until the color changes to light green as described in Walkley and Black (1934) method. The total N content in soils was determined using the modified Kjeldahl procedure (Nelson and Sommers, 1980). For soil particle size analysis, hydrometer method which is based on Stock's law (Bouyoucos, 1951) was employed. The soil moisture contents at field capacity (FC, -0.3 bars) and at permanent wilting point (PWP,-15 bars) were measured by the pressure plate apparatus. Finally, the plant available soil water holding capacity was determined from the difference between water content at FC and PWP (Hillel, 1980).

Statistical analysis

Data collected from the analysis of soils, ONS and mineralization were subjected to analysis of variance software version 9.3 (SAS

Table 1. Some physical characteristics of Luvisols/ Sidama and Cambisols/Wolaita.

Soil type	Depth (cm)	PS (%)			Class	FC	P.P	BD (Mgm^{-3})
		Sand	Silt	Clay		(V %)		
Luvisols/Sidama	0-20	14	32	54	Clay	46.20	31.55	1.23
Cambisols/Wolaita	0-20	16	36	48	Clay	42.74	27.57	1.23

Where FC is field capacity, PWP is permanent wilting point, BD is bulk density and PS is particle size.

Table 2. Selected chemical characteristics of Cambisols and Luvisols.

Site	pH-H_2O	EC (dSm^{-1})	OC	TN	C/N
			(%)		
Luvisols/Sidama	4.98	0.014	1.76	0.16	11
Cambisols/Wolaita	6.27	0.064	1.52	0 .13	12

Institute, 2003). To separate means at $p \leq 0.05$, Duncan Multiple Range Test was worked to obtain the least significant difference of the means. To measure release of nutrients (Total Nitrogen, Organic Carbon, and C/N ratio) in both soil types, simple correlation analysis (at $p \leq 0.05$) was carried out.

RESULTS AND DISCUSSION

Soil physical properties

The soil texture of the Cambisols and Luvisols were found to be clayey. The critical bulk density value for agricultural use according to Hillel (1980) is 1.4 g cm^{-3}. Thus, the Cambisols and Luvisols have lower value than the critical value; implying that there is no excessive compaction and restriction to root development (Werner, 1997), that is, both soil types possess good porosity for activities of aerobic microorganisms.

The gravimetric water contents of the soils at field capacity (33 kPa) were 46.20 and 42.74%, while the amount at permanent wilting point (1500 kPa) were 31.55 and 27.57% for Sidama and Wolaita, respectively (Table 1). According to Beernaert (1990), AWC % < 8 are rated as very low, 8-12 as low, 12-19 as medium, 19-21 as high and >21 as very high. The volumetric plant available water contents (AWC) of these soils were in medium range with 14.65 and 15.17% for Luvisols and Cambisols respectively. The optimal microbial activity occurs at near “field capacity” (Linn and Doran, 1984), and thus both soils are in suitable range for aerobic microorganisms’ activity.

Soil chemical properties

The pH-H_2O value of Wolaita soil was 6.2 (Table 2). According to the rating of Kim (1996), the pH range of the soils was slightly acidic this is preferred range for most crops. The soil of Sidama is categorized in slightly acidic range, unlike strongly acid or highly alkaline soils, which forms poor growing conditions for microorganisms, resulting in low levels of biological oxidation of organic matter.

According to Havlin et al. (2010), the electrical conductivity (EC) of these soils are categorized in very low range. This implies that the soils are normal. Soil fauna are also very sensitive to acidic conditions in soil. For example, earthworms occur in very low numbers, with the exception of few species, in most acidic soils, and they become progressively more abundant as soil pH increases to neutrality (Edwards and Bohlen, 1996). Thus, the Luvisols is less favorable for these organisms as compared to Cambisols; a resulting slow decomposition is expected in Luvisols than in Cambisols.

Organic Carbon (OC) and Total Nitrogen (TN) contents of the study area

The OC contents of both soils fall in the “very low” range according to Landon (1996) rating, who categorized the OC content as, very low (< 2%), low (2-4%), medium (4–10%), high (10-20%) and very high (>20%). Decomposition is greatest near the soil surface where the highest concentration of plant residues occur. At greater depths there is less SOM decomposition, which matches to drop in OC levels due to less plant residues. Small particle sizes are more readily degraded by soil microbes than large particles: Because the overall surface area is larger with small particles, as a result the small size residues are exposed to be attacked by microbes (James and Rafiq, 2010).

According to Landon (1996) rating, the TN content of these soils are categorized under the “low” category, which categorized the %TN content of soils as: < 0.1% as very low, 0.1 - 0.2% as low, 0.2- 0.5% as medium, 0.5-

Table 3. Interaction effect of Cambisols, Luvisols, *EA, EB, EV* and weeks on OC.

	Luvisols				Cambisols			
Week	**Control**	**EA**	**EB**	**EV**	**Control**	**EA**	**EB**	**EV**
1	1.720^{n}	4.617^{a}	3.747^{c}	2.523^{h}	1.500^{rqs}	4.137^{b}	3.430^{d}	2.233^{j}
2	1.580^{po}	4.123^{b}	3.137^{f}	2.330^{i}	1.533^{pq}	3.320^{e}	3.163^{f}	2.117^{k}
3	1.540^{pq}	2.580^{g}	1.923^{l}	1.473^{rts}	1.520^{rq}	2.240^{j}	1.750^{n}	1.440^{t}
4	1.500^{rqs}	1.907^{l}	1.837^{m}	1.213^{u}	1.500^{rqs}	1.533^{pq}	1.723^{n}	1.117^{v}
5	1.500^{rqs}	1.840^{m}	1.503^{rqs}	1.200^{u}	1.520^{rq}	1.607^{o}	1.470^{ts}	1.067^{w}
Mean	1.568	3.013	2.429	1.748	1.515	2.567	2.307	1.595
LSD(0.05)	0.011							
CV (%)	1.464							

Means in a column followed by the same superscript letters are not significantly different.

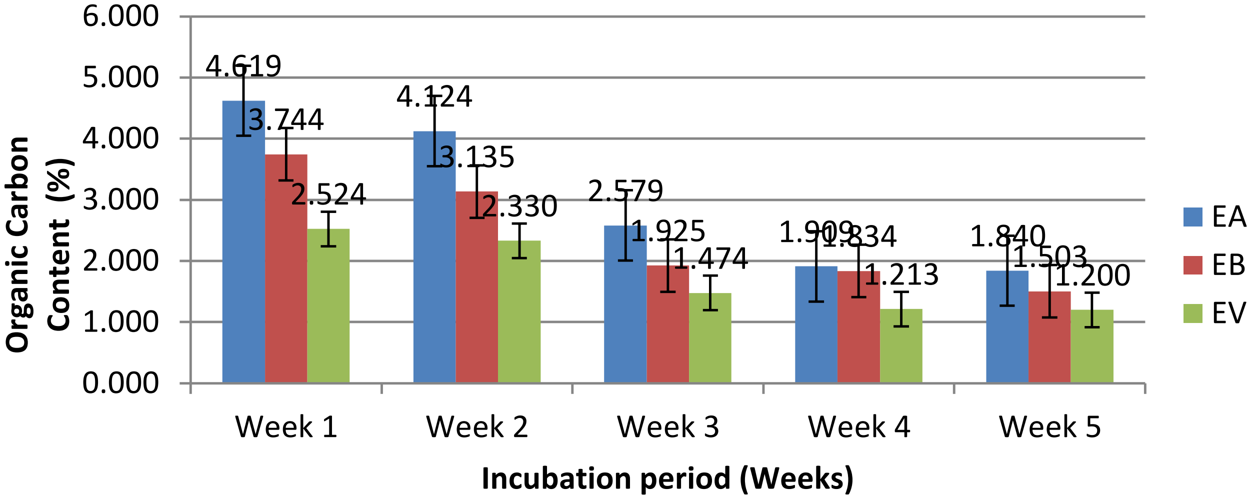


Figure 3. Status of OC in Luvisols during decomposition of *EA, EB* and *EV.*

1.0% as high and > 1% as very high. Based on the data, the nutrient statuses of Luvisols and Cambisols are in suitable range to stimulate mineralization.

Changes in Organic Carbon, Total Nitrogen and C:N ratio, during mineralization of *EA*, *EB* and *EV* in Luvisols and Cambisols

There was significant difference (p≤0.001) in OC content of EA, EB and EV incorporated soils during the course of mineralization influenced by ONS quality and duration (weeks) of incorporation in both soil types. The interaction between ONS, and week (duration) in the two soil type were also significant (p≤0.001).

The pattern of the release of nutrients in the greenhouse incubation experiments and the soil analyses results showed an observable decreasing trend (Table 3). In this study negative high correlations in Luvisol (r = -0.655) and in Cambisols (r = -0.649) was found between incubation period (week) and OC content, implying that as the time went on in the mineralization process, the amount of OC had decreased with time. In both soil types, the control had lower OC content than the amended ones.

In the first week mineralization stage, the percent OC content in Cambisols and Luvisols incorporated with EA showed the highest accumulation (4.6%) in Luvisols and (4.1%) in Cambisols, followed by EB (3.7%) in Luvisols and (3.4%) Cambisols and EV (3.36%) in Luvisols and (2.2%) Cambisols.

There were also significant differences in each incubation period (week), and soil type (Figure 3 and Table 3). The OC content of Luvisols was higher than Cambisols, which could be due to low activity and low concentration of microorganisms at lower pH. As a result, relatively higher accumulation or non-decomposition of the incorporated ONS was obtained from first week to

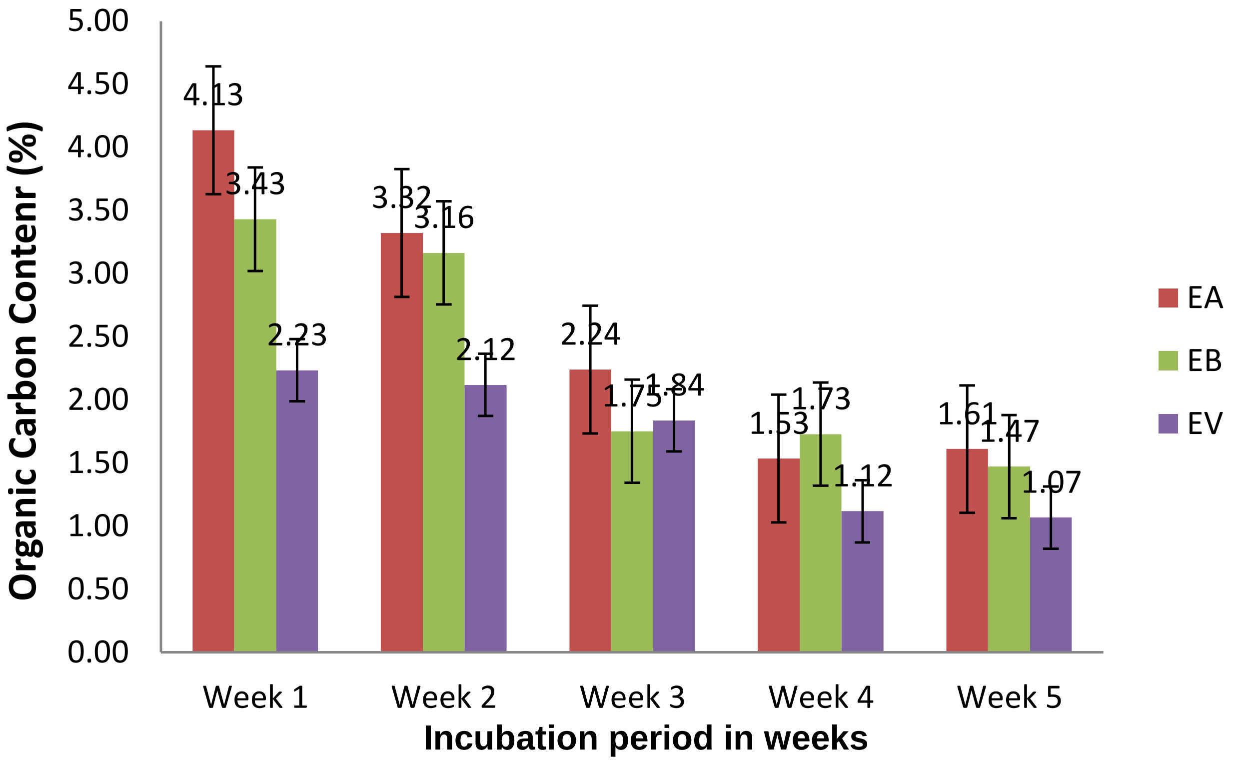


Figure 4. Status of OC in decomposition of EA, EB and EV in Cambisols.

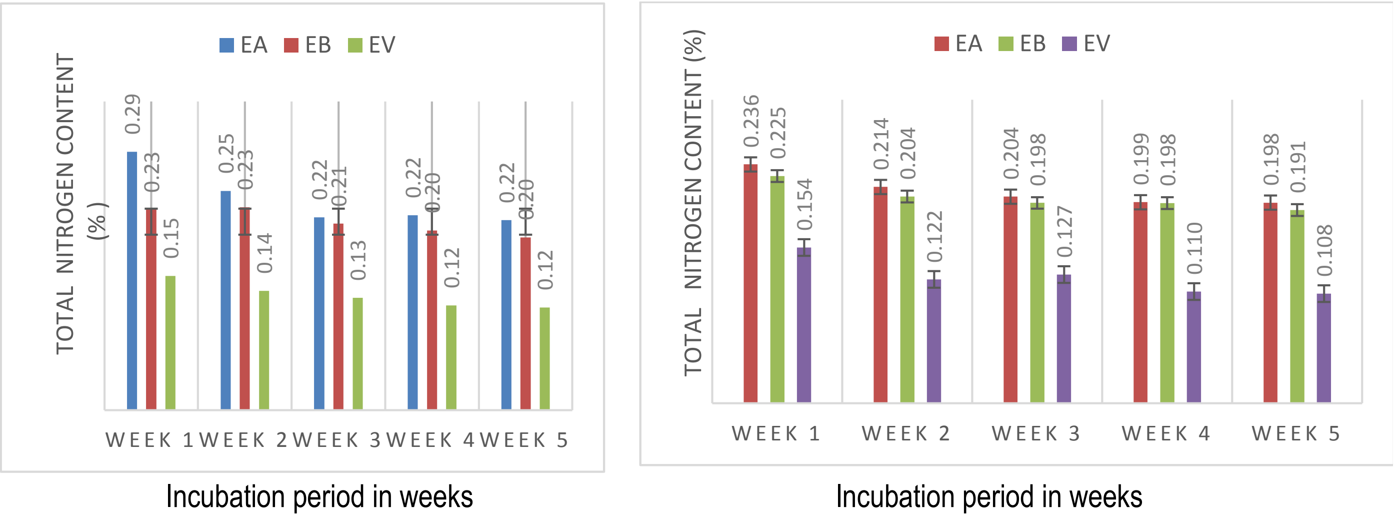
fifth week of the experiment in this soil as compared to Cambisols (Figure 4).

Likewise, high OC content may be due to the initial high C:N ratio and the variation in TN fixation capacity of each ONS. In line with these, Stemmer et al. (1999) emphasized that when stabilized organic products with sufficient C:N ratio (<20) are incorporated to the soil, the mineralization process is enhanced; while ONS with wide C:N ratio promote immobilization. Accordingly, the low C:N ratio may have facilitated fast mineralization of the three ONS in both soil types. However, at first week, the OC content in Luvisols was higher than that of Cambisols, as a result of which higher mineralization products can be recorded in Cambisols. In support of these results, the study conducted by Fu et al. (1987) showed that the mineralization process was influenced by N supplying capacity that depends mostly on the initial soil organic matter, the addition of organic residues, and the various soil environmental factors.

In the same way, the TN content followed a decreasing trend in both soil types Figure 5a and b. Moreover, there were significant differences in TN content of each of the organic nutrient sources applied. In the study of mineralization of EA, EB, and EV, high and positive correlations (r = 0.766, P≤0.01) in Cambisols and (r = 0.689, P<0.01) in Luvisols were found between OC and TN, indicating that there was strong association of OC and TN in the mineralization processes (Table 4). TN content also significantly varied (p≤0.001) due to plant type, soil type, and length of time of incorporation. The interaction among ONS, and weeks were also significant. In line with this, Palm and Sanchez (1990) also reported that both the decomposition rate and the N release of three tropical legumes (*Inga edulis, Cajanuscajan, and Erythrina* spp.) were fast.

During the incubation experiment of the three ONS, the mineralization processes might have also been affected/ enhanced by the high temperature of Hawassa during the experiment. In line with this, a study conducted by Eghball (2000) indicated that Nitrogen (N) mineralization increases with increasing temperature in agricultural soils. The study conducted by Schomberg et al. (1994) also confirmed that the ONS mineralization depends on environmental variables (e.g. water and temperature). Huang et al. (2004) described that manure applied to soils; enhance the energy or food supplies available to the soil microbial population. This energy supply activates soil micro-organisms, which consumes more available N than the mineralization processes release. Thus, high microbial activity and temperature during initial manure mineralization can cause a reduction of available N below that needed for plant growth. Hence, N mineralization and transformation are intimately linked to organic C decomposition.

The decrease in TN content was significantly different at each sampling week (Table 4, Figure 5a and b) and



(a) (b)

Figure 5. The status of TN in decomposition of EA, EB and EV in a) Luvisols and b) Cambisols.

Table 4. Interaction effect of Cambisols, Luvisols, and EA, EB, EV and incubation weeks on TN.

	Luvisols				**Cambisols**			
Week	**Control**	**EA**	**EB**	**EV**	**Control**	**EA**	**EB**	**EV**
1	0.100^{nm}	0.293^{a}	0.227^{cde}	0.150^{ih}	0.127^{kj}	0.237^{cb}	0.227^{cde}	0.153^{h}
2	0.100^{nm}	0.247^{b}	0.230^{cd}	0.137^{ij}	0.117^{kml}	0.213^{fe}	0.203^{gf}	0.123^{kjl}
3	0.120^{kl}	0.220^{de}	0.213^{fe}	0.127^{kj}	0.113^{kml}	0.203^{gf}	0.200^{gf}	0.120^{kl}
4	0.110^{ml}	0.220^{de}	0.203^{gf}	0.120^{kl}	0.093^{n}	0.200^{gf}	0.200^{gf}	0.110^{ml}
5	0.100^{nm}	0.213^{fe}	0.200^{gf}	0.120^{kl}	0.0867^{n}	0.197^{g}	0.190^{g}	0.110^{ml}
Mean	**0.106**	**0.239**	**0.215**	**0.131**	**0.107**	**0.210**	**0.204**	**0.123**
LSD(0.05)	0.0049							
CV (%)	5.103							

Means in a column followed by the same superscript letters are not significantly different at p<0.05.

similar trend was observed in both soil types. Consequently, the C:N ratio had shown a decreasing trend in the mineralization processes. Perez-Harguindeguy et al*.* (2000) found that the C:N ratio was also a good predictor of mineralization rate, due to the fact that higher C:N values are often associated with compounds showing higher C enrichment, particularly lignin.

In the first week of mineralization, relatively wide C:N ratio (16-17) was observed, followed by the second (14-16) and the third (9-13) week. C:N ratio was narrowing and then became almost constant (8-9) commencing the third week to fifth week (Figures 6 and 7) In line with this, Mary et al. (1996) had also confirmed that organic residues having low C/N ratios show N mineralization more than those with wide C:N ratios, with the latter mostly causing N immobilization during decomposition. In the course of mineralization, C:N ratio in Cambisols was higher than that of Luvisols, with a difference that might be due to the difference in holding precipitation, the inherent soil properties, and microbial factors of the both sites.

CONCLUSION AND RECOMMENDATIONS

Incorporating EA, EB and EV to Cambisols and Luvisols showed gradual raise in TN and OC content of both soils as compared to their own controls. However, EV contained relatively low amount of TN and OC content. Based on the pattern of release TN and OC content, the species showed the order: EA > EB > EV. Except in the magnitude, both Luvisols and Cambisols created favorable ground for nutrient release. These species are categorized as the fast decomposing organic materials with medium to highest TN content regardless of the site

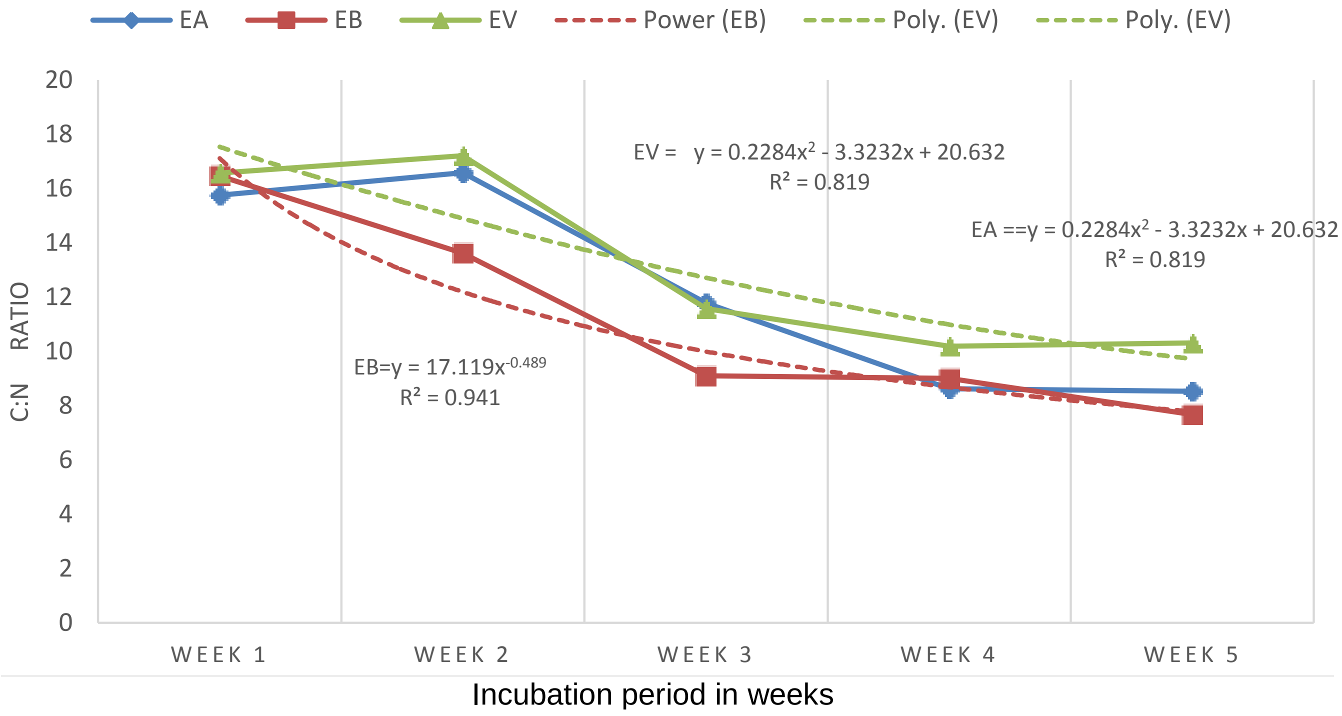


Figure 6. Decomposition of EA, EB and EV in Luvisols and the C:N ratio.

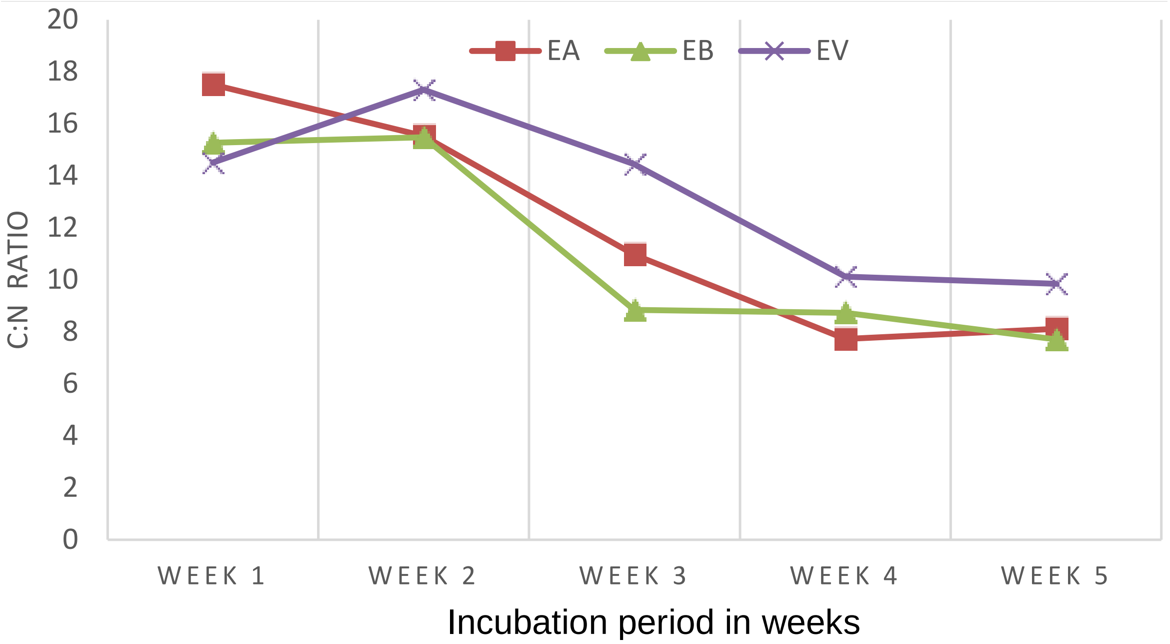


Figure 7. Decomposition of EA, EB and EV in Cambisols soils and the status of C:N ratio.

of sampling. The fact that these materials are high quality, it is expected that they decompose faster and release N faster than those with high retarding constituents.

The end users should synchronize the maximum crop requirement with inorganic nitrogen release from EA, EB and EV. However, more detailed research to synchronize laboratory results and field experimentation are needed on EA, EB and EV in both soils types to draw sound conclusion.

As described by Stanford and Epstein (1974), laboratory incubations have been invaluable in describing the relationship of N mineralization to temperature and moisture. Accordingly, their applicability to field condition is questioned and therefore, field experiments are encouraged.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

REFERENCES

Abayneh E, Demeke T, Asahneafi A (2006). Soils of the testing site of Hagereselam Agricultural Research Center. Technical Paper. National Soil Research Center, Ethiopian Agric. Res. Org, Addis Ababa, Ethiopia. Unpublished.

Ashenafi A, Abayneh E, Sheleme B (2010). Characterizing Soils of DelboWegene watershed, Wolaita Zone, southern Ethiopia for planning appropriate land management. J. Soil Sci. Environ. Manage. 1(8):184-199.

Bandick AK, Dick RP (1999). Field management effects on soil enzyme activities. Soil Biol. Biochem. 31:1471-1479.

Beernaert F (1990). Simple and practical methods to evaluate analytical data of soil profiles. Maputo, Mozambique. pp. 145-150.

Bouyoucos GH (1951). A Reclamation of the Hydrometer for Making Mechanical Analy. Soil Agro. J. 43:434-438.

Edwards CA, Bohlen PJ (1996). Biology and ecology of earthworms. 3rd ed. Chapman and Hall, London, UK.

Eghball B (2000). Nitrogen mineralization from field-applied beef cattle feedlot manure or compost. Soil Sci. Soc. Am. 64:2024-2030.

Fassil A (1993). Nodulation Nitrogen Fixation by Rhizobium and Brady rhizobium Species of Some Indigenous Tree Legumes of Ethiopia. Dissertation, University of Bayreuth, Germany.

Fu MH, Xu XC, Tabatabai MA (1987). Effect of pH on nitrogen mineralization in crop residue treated soils. Biology and Fertility of Soils. 5:115-119.

Goyal S, Chander K, Mundra MC, Kapoor KK (1999). Influence of inorganic fertilizers and organic amendments on soil organic matter and soil microbial properties under tropical conditions. Biol. Fert. Soils. 29:196-200.

Hall JE (1999). Nutrient Recycling. The European Experience (A Review), Asian-Aust. J. Anim. Sci. 12: 667-674.

Havlin JL, Beaton JD, Tisdale SL, Nelson WL (2010). Soil Fertility and Fertilizers. An Introduction to Nutrient Management.7th ed. PHI Pvt. Ltd, New Delhi.

Hillel D (1980). Fundamentals of Soil Physics. New York: Academic press. P 413. http://database.prota.org/ PROTA html /Erythrina % 20 abyssinica_En.htm

Huang Y, Zou J, Zheng X, Wang Y, Xu X (2004). Nitrous oxide emissions as influenced by amendment of plant residues with different C:N ratios. Soil Biol. Biochem. 36:973-981.

James JH, Rafiq I (2010). Fact sheet, Agriculture and Natural Resources., the Ohio State University.

Kim HT (1996). Soil sampling, preparation and analysis. Marcel Dekker, Inc. New York, USA. pp.139-145.

Kippie KT (2002). "Five Thousand Years of Sustainability? A Case Study on Gedeo Land Use" Ph.D Dissertation. Treemail publishers, Heelsum. The Netherlands.

Landon JR (1996). Booker tropical soil manual. A handbook for soil survey and agricultural land evaluation in the tropics and sub tropics. John Wiley and Sons, New York. pp. 94-95.

Linn DM, Doran JW (1984). Effect of water-filled pore space carbon dioxide and nitrous oxide production in tilled and non-tilled soils. Soil Sci. Soc. Am. 48:1267-1272.

Mary B, Recous S, Darwis D, Robin D (1996). Interactions between decomposition of plant residues and nitrogen cycling in soil. Plant Soil. 181:71-82.

National Meteorological Agency, Hawassa Branch Directorate (NMAHBD)(2012). National Meteorological Agency, Hawassa Branch Directorate, Ethiopia.

Nelson DW, Sommers LE (1980). Total nitrogen analysis for soil and plant tissues. J. Asso. Offic. Anal. Chem. 63:770-775.

Palm CA, Sanchez PA (1990). Decomposition and nutrient release patterns of the leaves of three tropical legumes. *Biotropica*. 22:330-338.

Perez-Harguindeguy N, Diaz S, Cornelissen JHC, Vendramini F, Cabido M, Castellanos A (2000). Chemistry and toughness predict leaf litter decomposition rates over a wide spectrum of functional types and taxa in central Argentina. Plant Soil. 218:30.

Reeuwijk LP (2002). Procedures for Soil Analysis.6th Edition. Technical Paper/International Soil Reference and Information Centre, Wageningen, The Netherlands. SAS® (Statistical Analysis Software) Institute Inc. 2002-2003. SAS 9.1 for Windows, Version 9.1.3: Cary, NC, USA.

Sasaki H, Nonaka J, Otawa K, Kitazume O, Asano R, Sasaki T, Nakai Y (2009). Analysis of the structure of the bacterial community in the livestock manure-based composting Process. Asian-Aust. J. Anim. Sci. 22:113-118.

Satyanarayana V, Prasad PV, Vara Murthy VRK, Boote, KJ (2002). Influence of integrated use of farmyard manure and inorganic fertilizers on yield and yield components of irrigated lowland rice. J. Plant Nut. 25: 2081-2090.

Schomberg HH, Steiner JL, Unger PW (1994). Decomposition and nitrogen dynamics of crop residues-residue quality and water effects. Soil Sci. Soc. Am. 58:372-381.

Stadler C, Von Tucher S, Schimidhalter U, Gutser R, Heuwinkle H (2006). Nitrogen release from plant-derived and industrially processed organic fertilizers used in organic horticulture. J. Plat. Nutr. Soil Sci. 169:549.

Stanford G, Epstein E (1974). Nitrogen mineralization-water relations in soils.Soil Sci. Soc. Am. 38:103-107.

Stemmer M, von Lützow M, Kandeler E, Pichlmayer F, Gerzabek MH (1999). The effect of maize straw placement on mineralization of C and N in soil particle size fractions. Euro. J. Soil Sci. 50:73-85.

Thulin M (1989). Fabaceae (Leguminosae). *Flora of Ethiopia*, Pittosporaceae to Aralliaceae. Hedberg, I. and Edwards, S. (eds). Addis Ababa and Uppsala. **3**:49-51.

Trinsoutrot I, Nicolardot B, Justes E, Recous S (2000). Decomposition in the field of residues of oilseed rape grown at two levels of nitrogen fertilization. Effects on the dynamics of soil mineral nitrogen between successive crops. Nutr. Cycl. Agroecosyst. 56:125-137.

Van Kessel JS, Reeves J (2002). Nitrogen mineralization potential of dairy manures and its relationship to composition. Bio. Fert. Soils 36:118-123.

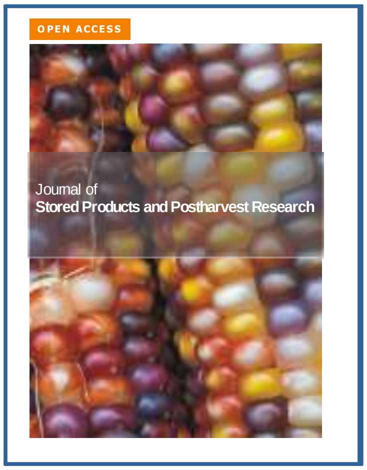
Walkley A, Black IA (1934). An examination of the digestion method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 34:29-38.

Werner MR (1997). Soil Quality characteristics during conversion to organic orchard management. Appl. Soil Ecol. 5:151-167.

Related Journals:

OPEN ACCESS

Journal of
Plant Breeding and Crop Science



OPEN ACCESS

Journal of
Stored Products and Postharvest Research

OPEN ACCESS

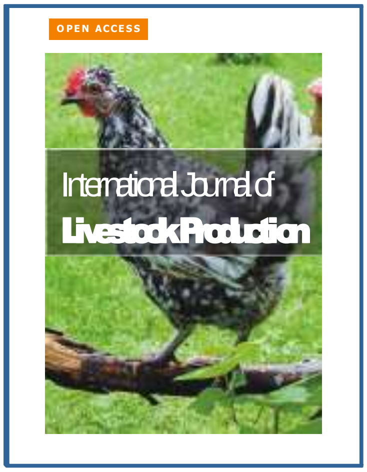
Journal of
Soil Science and
Environmental Management

OPEN ACCESS

African Journal of
Agricultural Research

OPEN ACCESS

International Journal of
Fisheries and Aquaculture



OPEN ACCESS

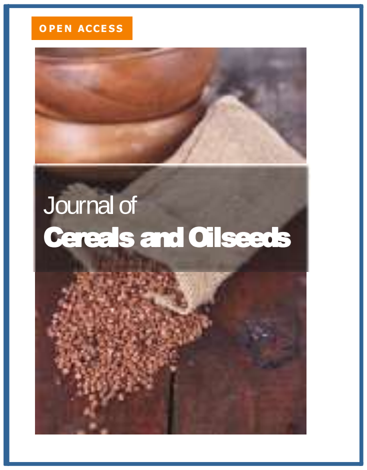
International Journal of
Livestock Production

OPEN ACCESS

Journal of
Agricultural
Biotechnology and
Sustainable Development

OPEN ACCESS

Journal of
Agricultural Extension
and Rural Development



OPEN ACCESS

Journal of
Cereals and Oilseeds

www.academicjournals.org