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

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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

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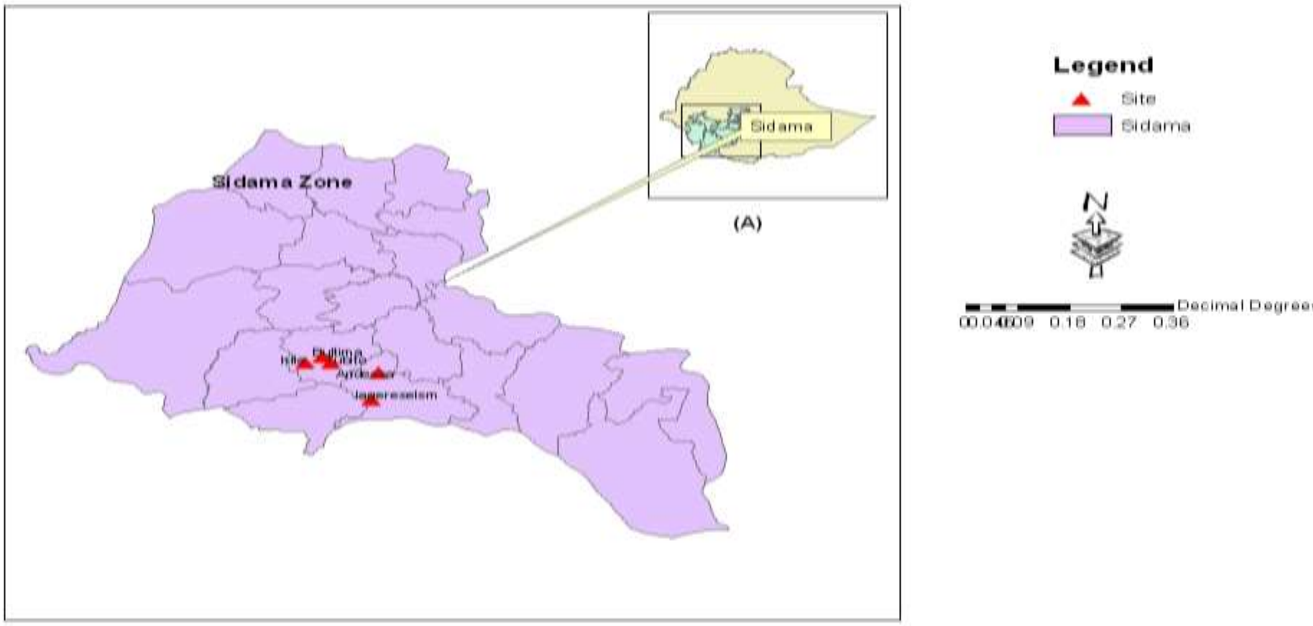

Figure 1. Sampling sites in Sidama.

ornamental tree (http://database.prota.org//Erythrina%20 abyssinica_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

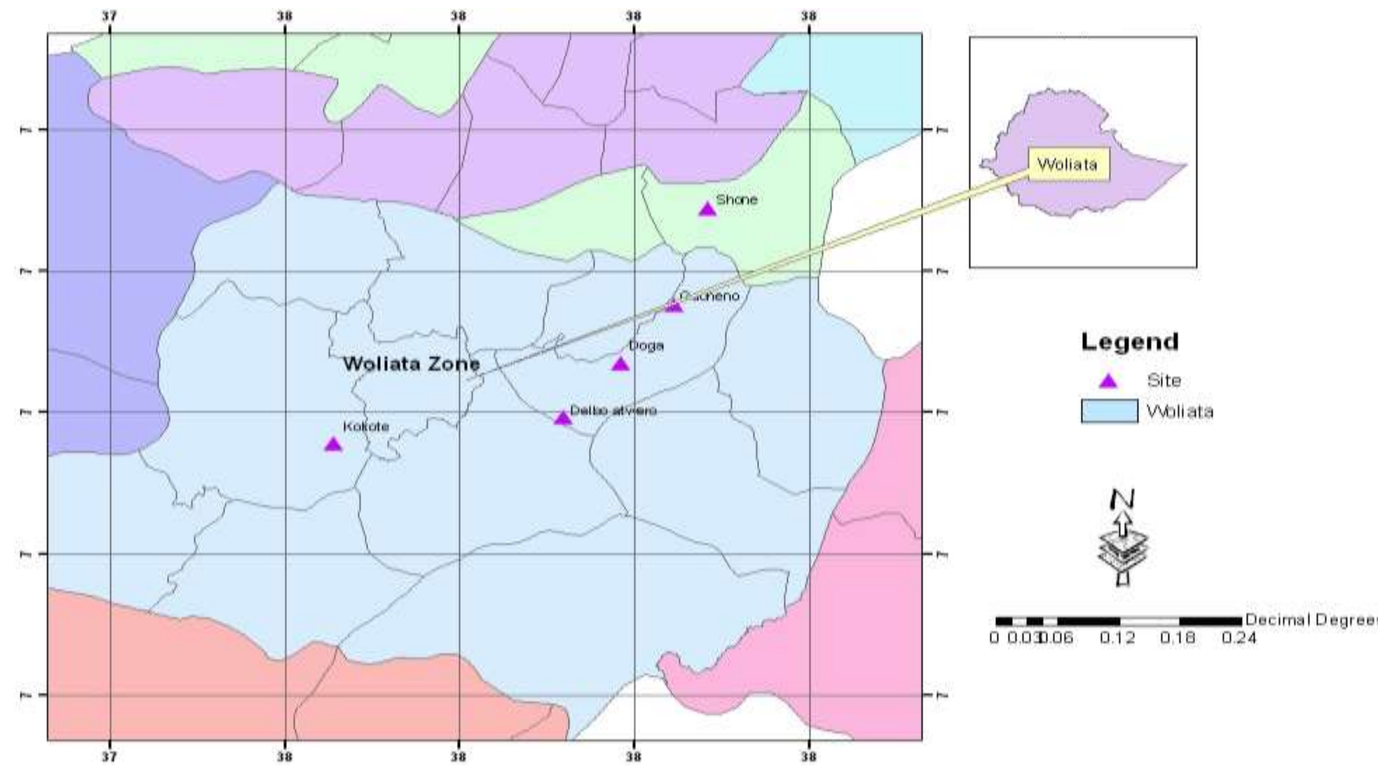

Figure 2. Sampling sites in Wolaita.

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.

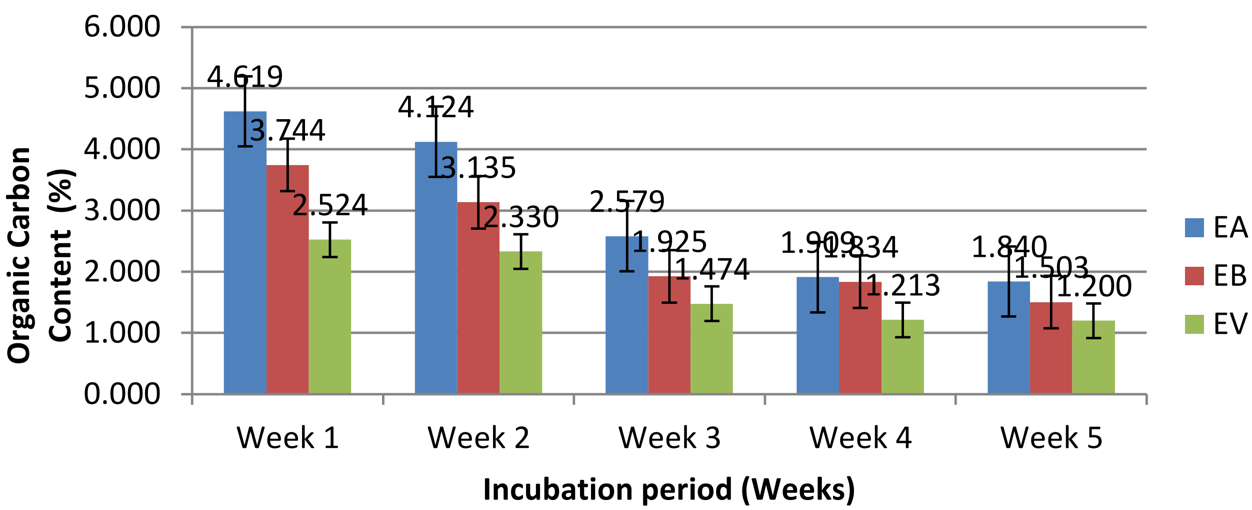

Figure 3. Status of OC in Luvisols during decomposition of *EA, EB* and *EV.*

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

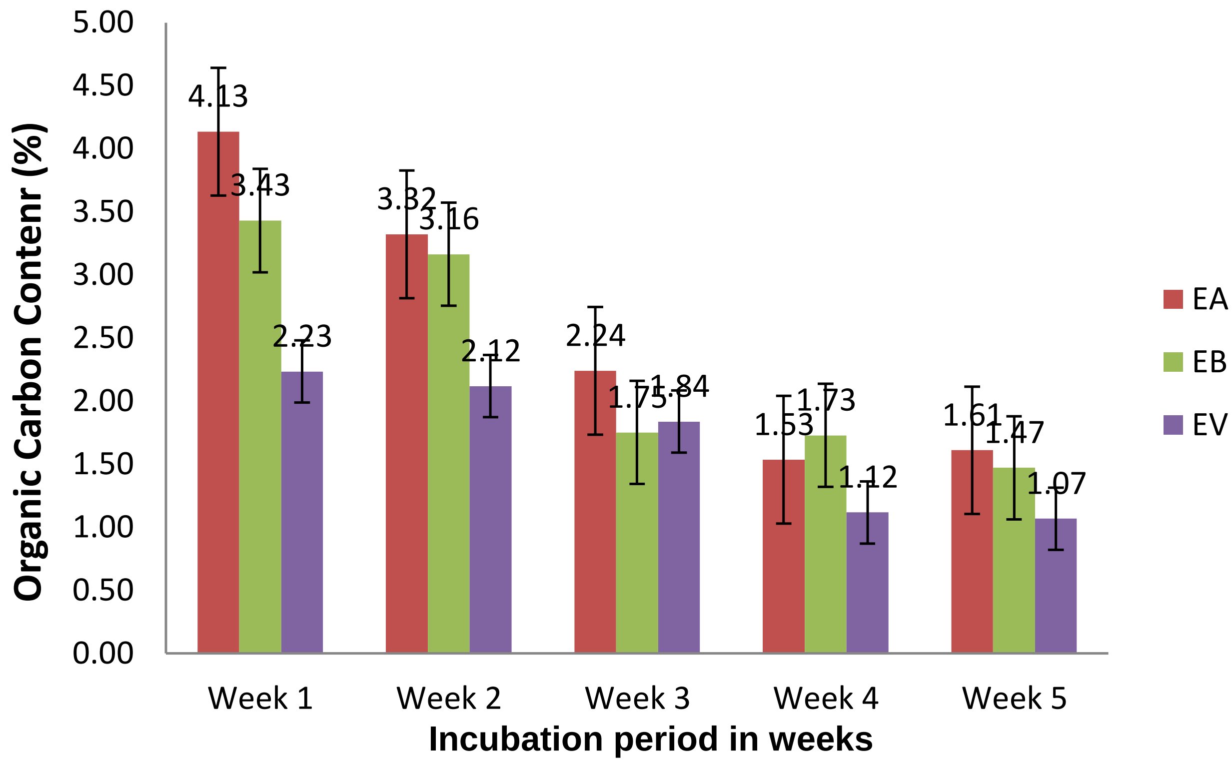

Figure 4. Status of OC in decomposition of EA, EB and EV in Cambisols.

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

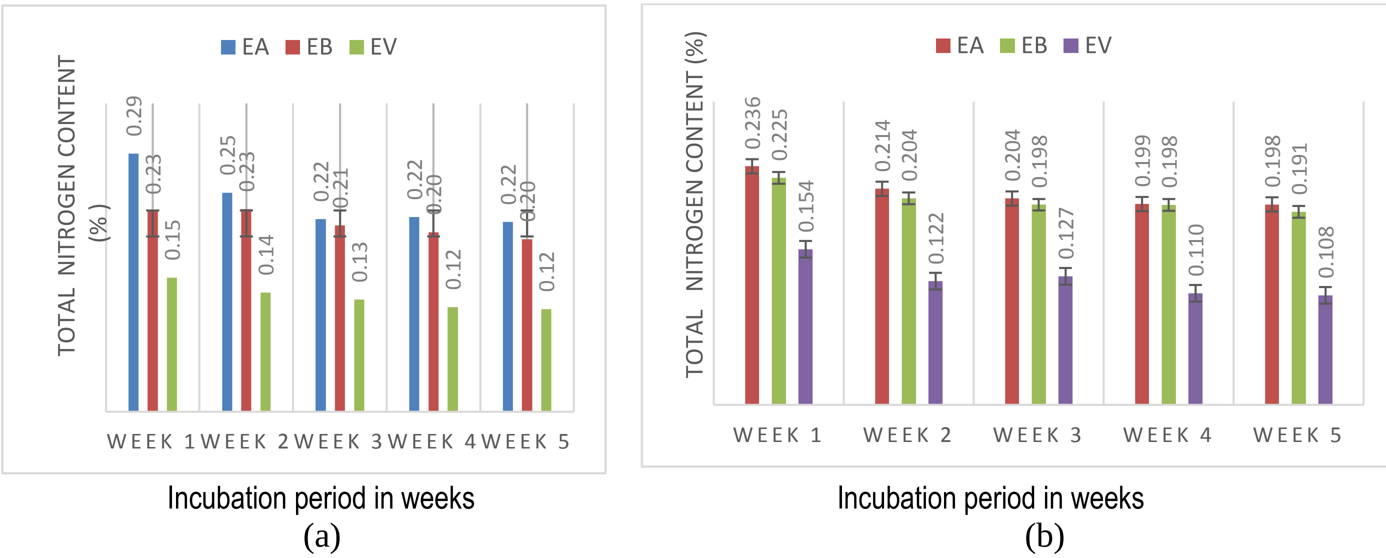

Figure 5. The status of TN in decomposition of EA, EB and EV in a) Luvisols and b) Cambisols.

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

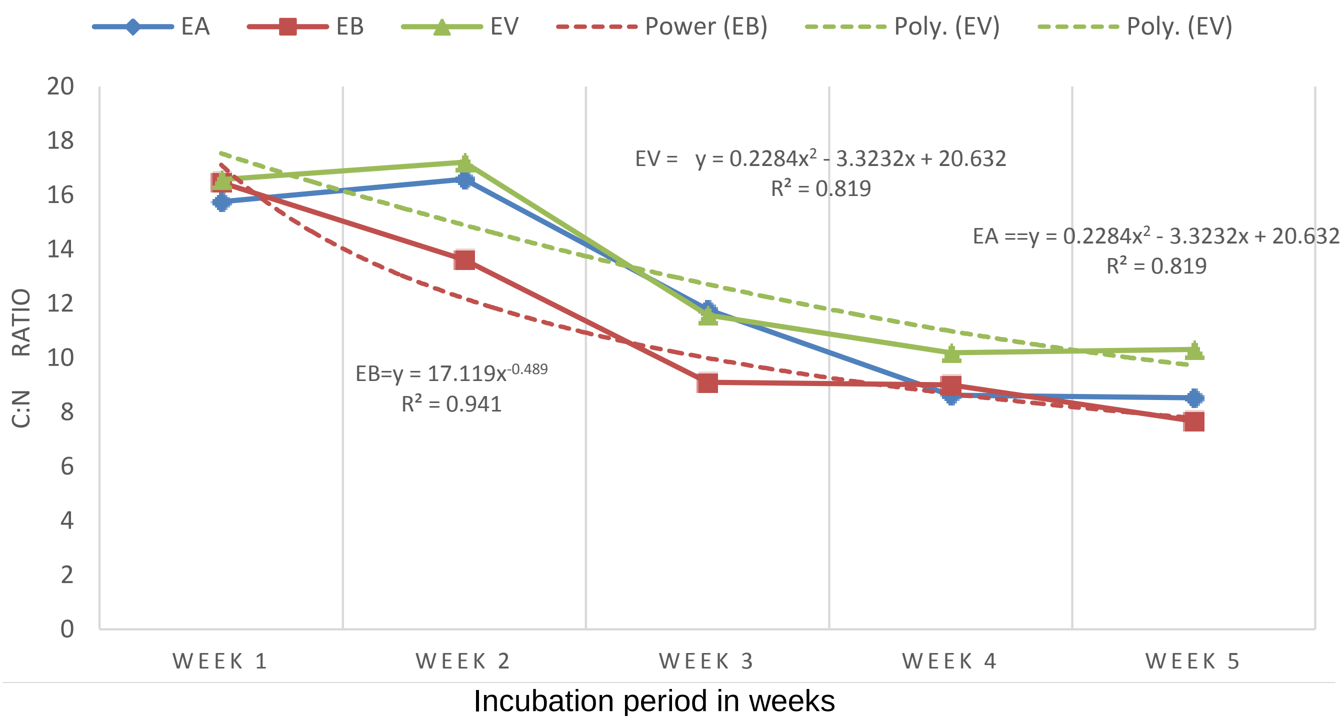

Figure 6. Decomposition of EA, EB and EV in Luvisols and the C:N ratio.

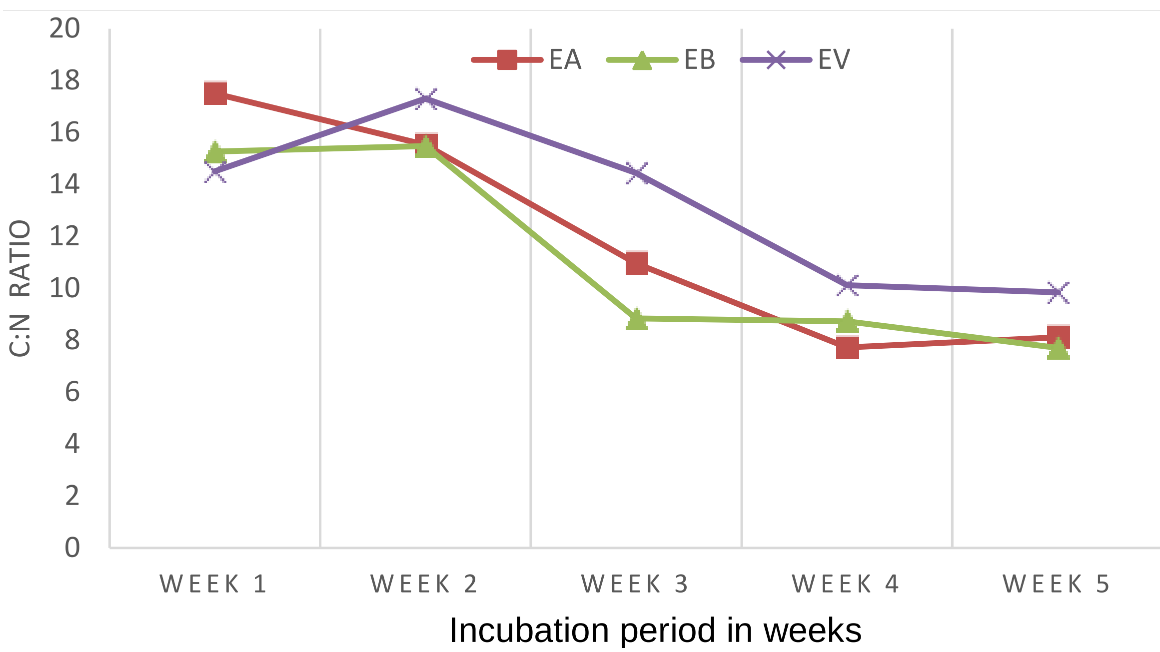

Figure 7. Decomposition of EA, EB and EV in Cambisols soils and the status of C:N ratio.

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.

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