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# Effect of Soil Factors on Net N-Mineralization and Decomposition Rate of Organic Nutrient Sources

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### ABSTRACT

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 randomly collected from Sidama and Wolaita zones of southern Ethiopia. Surface soil samples (0-20 cm) depths were also collected from Cambisols of Wolaita and Luvisol of Sidama areas. Physicochemical properties of the composite 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 Luvisol 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. Based on the TN contents, the amount of ONS equivalent to 100 kg urea + 100 kg DAP ha<sup>-1</sup>, was calculated and incorporated into 200g of each soil type separately. The pots were watered to field capacity every day or two. In general, the study was conducted to investigate the effect of soil chemical and physical properties such as pH, particle size, organic carbon and total nitrogen content on rate of mineralization of these ONS. 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 these ONS can be used as alternative or supportive fast decomposing organic sources of fertilizers.

**Keywords:** C/ N ratio, Incubation, Total Nitrogen, Organic Carbon, Organic Nutrient Sources

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## 1.0 INTRODUCTION

Addition of organic materials to agricultural soil (with or without chemical fertilizers) is important for replenishing the annual C losses and for improving both the biological and physico-chemical properties of the soils (Goyalet *et al.* 1999).

Multipurpose trees (MPT) such as *Erythrina abyssinica* (EA), *Erythrina brucei* (EB) and *Ensete ventricosum* (EV) are environment friendly organic fertilizers and found in the homestead of most farmers, in 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 have adapted to grow in areas with altitude ranging from 1400 to 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 live fence around homesteads, and is also planted as an ornamental tree

([http://database.prota.org/Erythrina%20abyssinica\\_En.htm](http://database.prota.org/Erythrina%20abyssinica_En.htm)).

The nutrient cycles in soil are driven by the activities of different microbial communities, cultivation system and climatic conditions which continuously influence physical structure, nutrient availability and organic matter turnover. Therefore soil shall be assessed to effectively evaluate these

## 2.0 MATERIALS AND METHODS

Sidama covers 6972.1 km<sup>2</sup> and lies between 6°14' to 7°18' N and 37°02' to 39°19' E, with an elevation ranging from 501 to 3000 m.a.s.l. The annual mean temperature of the zone ranges between 10.1 to 27° C and the annual mean rainfall ranges from 801 to 1600 mm (SNNPR, 2012). Samples of EA, and EV were collected from Sidama zone (fig.1)

practices (Bandick and Dick, 1999; Hall, 1999; Sasaki *et al.*, 2009).

To support the nutrient demand of the crops the use of ONS would be an inevitable practice (Satyanarayana *et al.*, 2002). But it is particularly challenging when ONS are applied in to 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 properties (pH, texture, organic matter content) and organic matter characteristics like the C:N ratio, residue quality like lignin content, polyphenol content and particle size, environmental variables (Van Kessel and Reeves, 2002; Stadler *et al.*, 2006; Schomberger *et al.*, 1994; Trinsoutrot *et al.*, 2000).

However, Net N-Mineralization and decomposition rate of EA, EB and EV in Cambisols and Luvisol have not been investigated so far. Therefore, further investigation on these plant species for improvements of soil fertility is a crucial step for low-income farmers, organic manure advocates to synchronization nutrients released with crop demand which ultimately helps to when and how much ONS to be applied under specific soil conditions. Thus, this experiment was conducted to determine and relate the rates of Net N-Mineralization and decomposition to these ONS in Cambisols and Luvisol.

## 2.1 Description of ONS Sampling Sites

Wolaita covers an area of 4471.3 km<sup>2</sup> and having an elevation ranging from 1200 to 2950 m.a.s.l. with annual average temperature of 15.1°C and The area has a bimodal rainfall pattern, with an average annual rainfall of 1300 to 2000 mm distributed over 8 to 9 months. (SNNPR, 2012). Samples of EB and EV were collected from Wolaita (fig. 2)

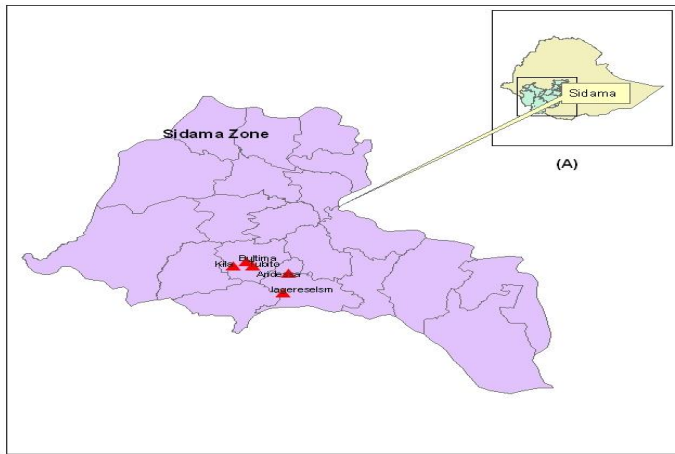


Fig 1. Sampling sites in Sidama

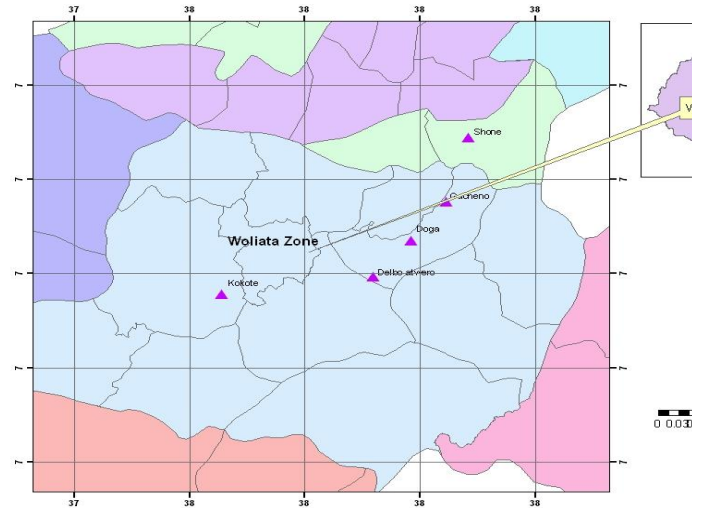


Fig. 2 sampling sites in Wolaita

Hawassa is situated at  $07^{\circ} 03'$  North and  $38^{\circ} 29'$  East with an average altitude of 1750 m.a.s.l. According to the National Meteorological Agency, Hawassa Branch Directorate (NMAHBD) (2009), the climate is warm with mean temperature varying between

### 2.3 Sampling and Sample Preparation

Representative, about 50 kg surface soils (0-20 cm), were collected using auger from 30 different randomly selected spots surface soils, from Cambisolsof Wolaita (Ashenafiet *al.*, 2010)  $06^{\circ} 52' 37.7''$  N and  $37^{\circ} 35' 33''$  E and DystricLuvisol of Sidamafound at  $06^{\circ} 29' 26.1''$  N and  $038^{\circ} 30' 45.3''$  E (Abayneh *et al.*, 2006,

### 2.4 Incubation of Soil Samples

The incubation experiment was conducted at Hawassa University, College of Agriculture. For the experiment 0.127, 0.169 and 0.215g of ground EA, EB and EV were incorporated into 200g of each soil type separately by converting the TN content of the plants to the local recommendation of urea and DAP. Then it was transferred into 300 mL wide mouth polyethylene bottle. The soil and ONS mixture was watered to field capacity and was left in the greenhouse. However, watering to field

### 2.5 ONS Total Nitrogen Content Analysis

Total nitrogen content of the plant material was analyzed by wet oxidation of the modified Kjeldahl procedure that involves digestion of

$10^{\circ}\text{C}$  in the winter and  $30^{\circ}\text{C}$  during the summer months. The area receives the mean annual precipitation of 956 mm, with monthly mean minimum rainfall of 17 mm in December (dry season) and mean maximum of 126 mm in September (main rainy season).

unpublished) areas for this study. The plant materials were cleaned and freed of extraneous substances including soil and dust washed thoroughly with tap water and rinsed with distilled water, followed by first air-drying and then oven drying at  $65^{\circ}\text{C}$  for 24 hrs.

capacity was made every day or two until the end of the experiment monitoring by Moisture Meter (Delta, model HH2). Then, the samples which were ready (mature for the test) for analyses were collected and transferred to chemical laboratory for further analysis. The treatments for each experiment were commenced the same day but with separate polyethylene bottles. Each pot was sampled separately at 1, 2, 3, 4, and 5 week stages.

sample with sulphuric acid salicylic acid mixture and catalyst followed by distillation and titrimetric quantification in the digest (Kim,

1996).

## 2.6 Selected Soil chemical and physical analysis

Soil pH and electrical conductivity were measured using soil: water (1:2.5) by shaking in 100 ml polyethylene bottle for two hours at 150 rpm, and measuring 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. Then 10 ml of 1 N  $K_2Cr_2O_7$  solution was added, two blanks were included. Then 20 ml (98%)  $H_2SO_4$  was carefully added followed by swirling. Then flask was allowed to cool. Then 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. Then it was titrated with

## 2.7 Statistical Analysis

The data obtained from the analysis of soils, plants and mineralization were subjected to analysis of variance (ANOVA) using statistical analysis software version 9.3 (SAS Institute, 2003). The least significant difference (LSD) was worked to separate means at  $p \leq 0.05$

## 3.0 RESULTS AND DISCUSSION

The soil texture of the Cambisols and Luvisol were found to be clayey. The critical bulk density value for agricultural use according to Hillel (1980) is  $1.4 \text{ g cm}^{-3}$ . Thus, the Cambisols and Luvisol have lower value than the critical value; implying that there is no

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 Stokes' 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).

using Duncan Multiple Range Test. To measure release of nutrients (Organic Carbon, Total Nitrogen and C/N ratio) in soil, simple correlation analysis (at  $p \leq 0.05$ ) was carried out.

## 3.1 Soil Physical Properties

excessive compaction and restriction to root development (Werner, 1997) i.e. Both soil types possess good porosity for activities of aerobic microorganisms.

Table 1: Selected soil physical characteristics of Luvisol/ Sidama and Cambisols/Wolaita

Site	Depth (cm)	Particle Size (%)			Textural Class	FC PWP		BD (Mgm <sup>-3</sup> )
		Sand	Silt	Clay		(V %)	(V %)	
Luvisol/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

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 percent < 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 Luvisol 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.

### 3.2 Soil Chemical Properties

The pH-H<sub>2</sub>O 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.

Table 2: Some chemical characteristics of Cambisols and Luvisol

Site	pH-H <sub>2</sub> O	EC	OC	TN	C/N
Luvisol/Sidama	4.98	0.014	1.76	0.16	11
Cambisols/Wolaita	6.27	0.064	1.52	0.13	12

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,

### 3.3 Organic Carbon (OC) and Total Nitrogen

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

and they become progressively more abundant as soil pH increases to neutrality (Edwards and Bohlen, 1996). Thus, the Luvisols less favorable for these organisms as compared to Cambisols; a result slow decomposition is expected in Luvisol than in Cambisols.

### (TN) Contents of the Study Area

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 percent TN content of soils as: < 0.1% as very low, 0.1 - 0.2 % as low, 0.2- 0.5 % as medium, 0.5-1.0 % as high and > 1% as very high. Based on the data, the nutrient statuses of Luvisol and Cambisols are in suitable range to stimulate mineralization.

### 3.4 Changes in Organic Carbon, Total Nitrogen and C:N Ratio, During

There was significant difference ( $p \leq 0.001$ ) in OC content of EA, EB and EV incorporated soils during the course of mineralization influenced by ONS quality and duration (weeks)

### Mineralization of EA, EB And EV in Luvisol and Cambisols

of incorporation in both soil types. The interaction between ONS, and week (duration) in the two soil type were also significant ( $p \leq 0.001$ ).

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.

Table 3: Interaction effect of Cambisols, Luvisol, EA, EB, EV and weeks on OC

Luvisol					Cambisols			
WEEK	Control	EA	EB	EV	Control	EA	EB	EV
1	1.720 <sup>n</sup>	4.617 <sup>a</sup>	3.747 <sup>c</sup>	2.523 <sup>h</sup>	1.500 <sup>rqs</sup>	4.137 <sup>b</sup>	3.430 <sup>d</sup>	2.233 <sup>j</sup>
2	1.580 <sup>po</sup>	4.123 <sup>b</sup>	3.137 <sup>f</sup>	2.330 <sup>i</sup>	1.533 <sup>pq</sup>	3.320 <sup>e</sup>	3.163 <sup>f</sup>	2.117 <sup>k</sup>
3	1.540 <sup>pq</sup>	2.580 <sup>g</sup>	1.923 <sup>l</sup>	1.473 <sup>rts</sup>	1.520 <sup>rq</sup>	2.240 <sup>j</sup>	1.750 <sup>n</sup>	1.440 <sup>t</sup>
4	1.500 <sup>rqs</sup>	1.907 <sup>l</sup>	1.837 <sup>m</sup>	1.213 <sup>u</sup>	1.500 <sup>rqs</sup>	1.533 <sup>pq</sup>	1.723 <sup>n</sup>	1.117 <sup>v</sup>
5	1.500 <sup>rqs</sup>	1.840 <sup>m</sup>	1.503 <sup>rqs</sup>	1.200 <sup>u</sup>	1.520 <sup>rq</sup>	1.607 <sup>o</sup>	1.470 <sup>ts</sup>	1.067 <sup>w</sup>
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							

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

In the first week mineralization stage, the percent OC content in Cambisols and Luvisolincorporated with EA showed the highest accumulation (4.6%) in Luvisoland

(4.1%) in Cambisol, followed by EB (3.7%) in Luvisoland (3.4%) Cambisol and EV (3.36 %) in Luvisoland (2.2%) Cambisol

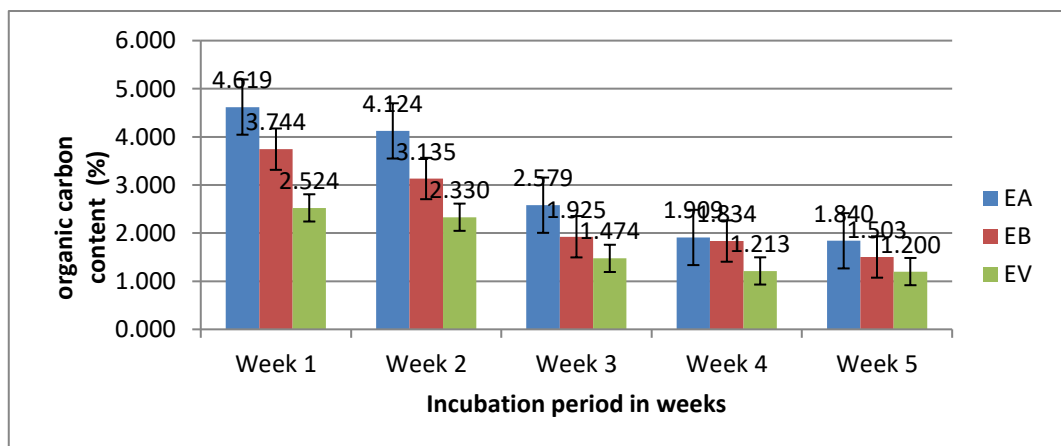


Figure 3: OC content of EA, EB and EV in Luvisolduring five weeks' Incubation period

There were also significant differences in each incubation period (week), and soil type (Fig 3, Table 3). The OC content of Luvisol 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 fifth week of the experiment in this soil as compared to Cambisols. (Fig, 4).

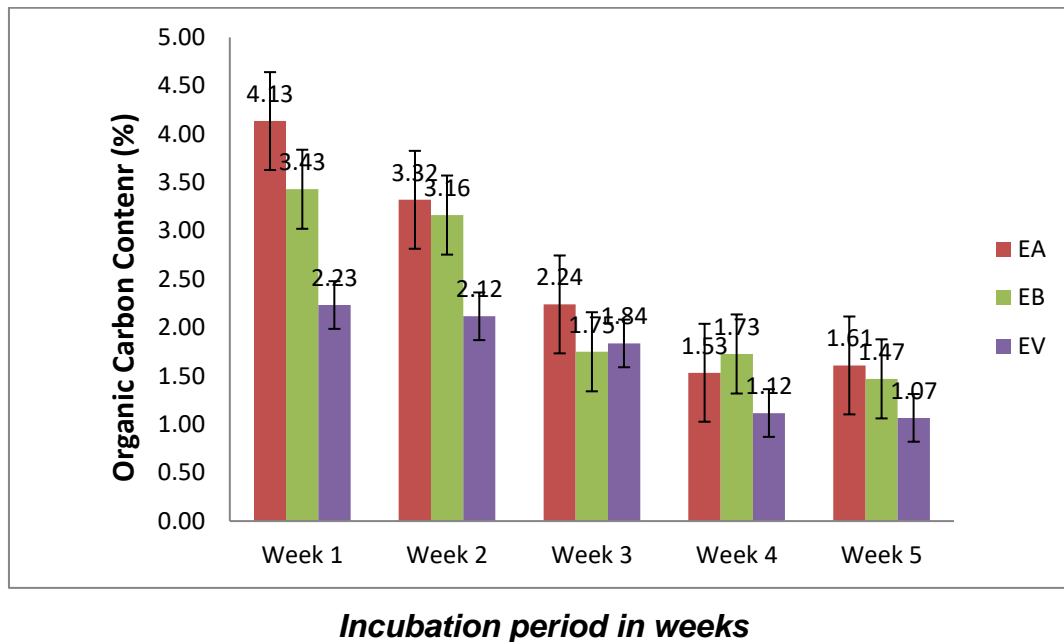


Figure 4: Decomposition of EA, EB and EV in Cambisols and the status of OC in five weeks' incubation

Similarly, high OC content may be due to the initial high C:N ratio and the difference in TN content of each ONS. In line with these, Stemmer *et al.* (1999) reported that when stabilized organic products with adequate C:N ratio (<20) are added to the soil, the mineralization process is enhanced, while products with high C:N ratio promote immobilization. Consequently, the low C:N ratio may have assisted fast mineralization of the three ONS in both soil types. However, initially the OC content in Luvisol was higher than that of Cambisol, 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.

Similarly, the TN content followed a decreasing trend in both soil types Fig (5,6). 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 ( $r = 0.766$ ,  $P \leq 0.01$ ) in Cambisol and ( $r = 0.689$ ,  $P < 0.01$ ) in Luvisol 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 ( $p \leq 0.001$ ) due to plant type, soil type, and length of time of incorporation. The interaction among ONS, and weeks were also significant. In line to 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

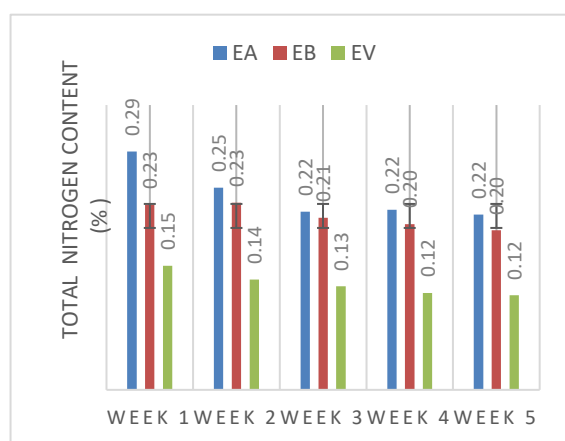
Table 4: Interaction effect of Cambisol, Luvisol, EA, EB, EV and incubation weeks on TN

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

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

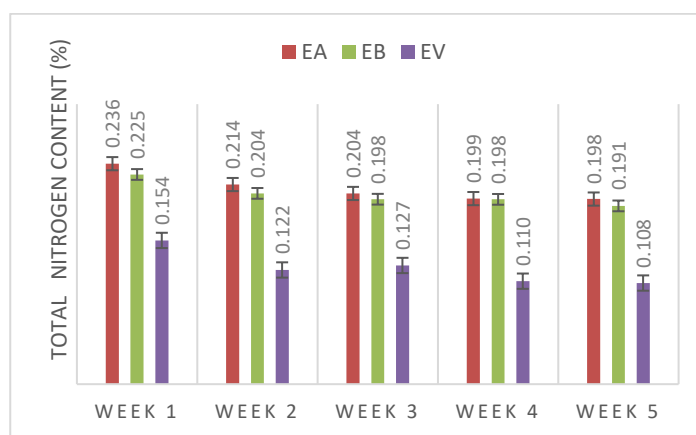
During the incubation experiment of the three ONS, the mineralization processes might have also been affected /enhanced by the high temperature of Hawassa during the experiment. In line to this a study conducted by Eghball (2000) indicated that Nitrogen (N) mineralization increases with increasing temperature in agricultural soils. The study conducted by Schomberger *et al.* (1994) also confirms that the ONS mineralization depends on, environmental variables (e.g. water and temperature). Huang *et al.* (2004) described

that manure applied to soils, increases the energy or food supplies available to the soil microbial population. This energy supply stimulates soil microbial activity, 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.



Incubation period in weeks

Figure 5



Incubation period in weeks

Figure 6

Decomposition of EA, EB and EV in Luvisol (fig 5) and Cambisol (fig 6) the status of TN during five weeks' incubation period



The decrease in TN content was significantly different at each sampling week (Table 4, Figure 5 and 6) and similar trend was observed in both soil types. Consequently, the C:N ratio had shown a decreasing trend in the mineralization processes.

Harguindeguy *et al.* (2000) found that the C:N ratio was also found to be a good predictor of decomposition rate, due largely to the fact that higher C:N values are often associated with compounds showing higher C enrichment, particularly lignin.

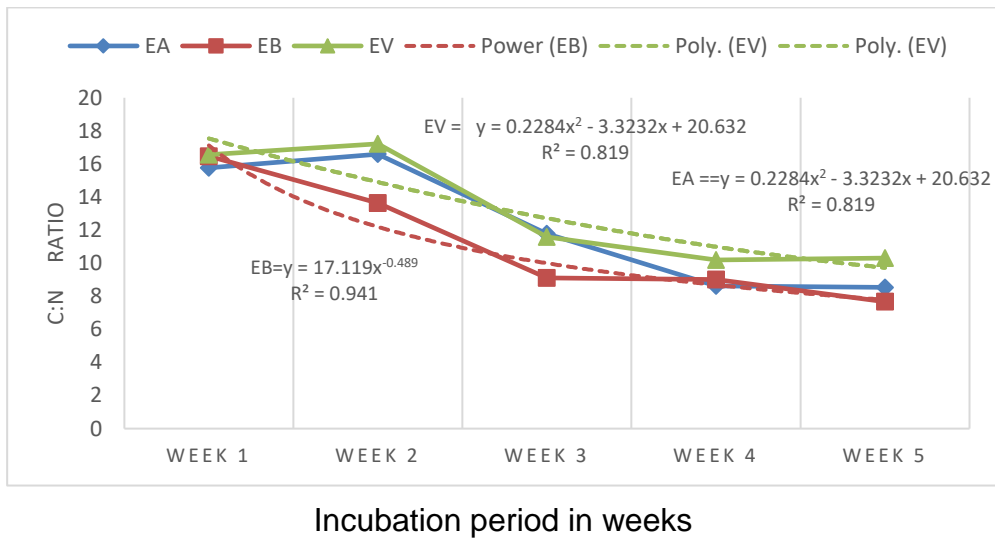


Figure 7: Decomposition of EA, EB and EV in Luvisol and the C:N ratio during five weeks' of incubation.

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 (fig 7,8). In line to 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 Luvisol, the difference might be due to: the difference in holding precipitation, the inherent soil properties, and microbial factors of the both sites.

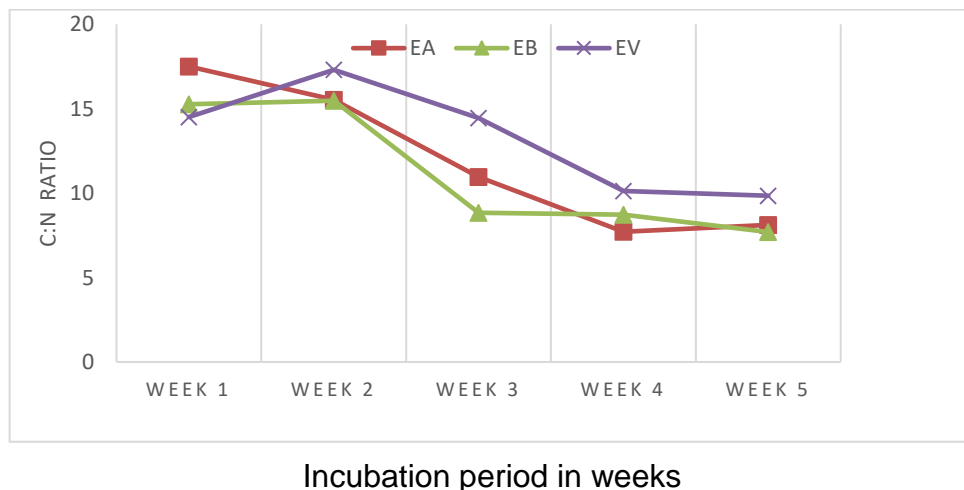


Figure 8: Decomposition of EA, EB and EV in Cambisol soils and the status of C:N ratio in five weeks' time

## CONCLUSION AND RECOMMENDATION

Incorporating EA, EB and EV to Cambisols and Luvisol showed an increase in TN and OC content of the soil as compared to their respective controls. However, Ensete 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. It followed the same trend in Luvisol. These species are categorized as the fast decomposing organic materials with medium to highest TN content regardless of the site of sampling. The fact that these materials are high quality, it is expected that they decompose faster and release N.

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 conditions is questioned and therefore, field experiments are encouraged.

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