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Effects of litter quality and decomposition rate of some agroforestry species on soil properties in Rivers State Nigeria

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ABSTRACT

Effect of litter quality and decomposition rate of some agro-forestry species on soil properties found in the main campus of Rivers State University, Port Harcourt, Nigeria was investigated. Litters from Masquerade tree, gmelina and teak were collected and their chemical composition determined. Twenty-five grams (25 g) of each leaf litter was placed in a nylon litter bag and buried shallowly within 687 g soil in a container. At the end of the research, findings revealed that teak litter (C:N ratio = 23.14) was fairly of higher quality because the C:N ratio was the narrowest whereas masquerade tree (C:N ratio = 25.39) had the lowest quality. Teak litter decomposed significantly higher than those of gmelina and masquerade tree. The decomposition of the different litters in the soil had no significant effect on soil texture, pH, available P, base saturation, exchangeable acidity, ECEC, Na and K but, soil organic matter, total N, Ca, Mg, K and electrical conductivity were significantly affected by decomposition of the agro-forestry species in the soil. Building in agro-forestry into farming systems, particularly in the tropics is necessary in order to ensure land use sustainability.

1.0 Introduction

Soil organic matter has been described as the nerve center of soil fertility sustenance in Nigeria as well as similar tropical environments (Osiname, 2000). Organic matter in soil actually includes plant and animal tissues at various stages of decomposition as well as organisms in the soil that participate in soil formation. Ideally, organic matter in soil has often been related to the contribution of vegetation to the soil in the form of litter fall and dead roots, branches and tree trunks, and differentiating it from the living organisms in the soil (Mgbonu *et al.*, 2009). Organic matter management is viewed as central to the finest scale approaches used to assess the sustainability of soil systems (Swift and Woomer, 1993).

Secondary reasons often given for the increased use of organic materials are the need to improve environmental condition and public health, and to reduce the costs of fertilizing crops. This is in agreement with the holistic concept of agricultural sustainability (Swift and Woomer, 1993; Sanchez *et al.,* 2003). In line with these and for the numerous roles of organic matter in the soil, integrated approaches based on agro-forestry are aimed at increasing soil organic matter by leaf fall and periodical pruning of tree species for use as mulch or green manure (Mulongoy and Sanginga, 1990; Akobundu, 1993). Soil organic matter status has been identified as one of the most important indicators of soil fertility (Agboola and Obatolu, 1989), and thus, it is imperative that agricultural practices being developed should guarantee stable soil organic matter levels.

Quality of litter such as concentrations of cellulose, hemicelluloses and lignin, and nitrogen (N), phosphorus (P) and potassium (K) have been found to play a major role in litter decomposition in different ecosystems (Tripathi and Singh, 1992a, b; Osono and Takeda, 2001, 2004). According to Sanchez and Miller (1986), the C/N and lignin/N ratios are estimates of the ease or otherwise of the decomposition of an organic material. In most tropical environments, the conversion of forested vegetation to agricultural land results in a decline of the soil organic matter content to a newer, lower equilibrium (Lal, 1991; Woomer and Ingram, 1990). Organic matter decomposition rate can vary considerably (up to four times) due to temperature difference of 36^0C between the humid tropical environment and temperate zone (Jenkinson and Ayanaba, 1977; Mgbonu *et al.*, 2009).

One of the challenges faced by soil scientists is how to conserve organic matter in soils under cultivation. It is therefore pertinent that techniques which restore soil organic matter status and ensure its sustainability be adopted in tropical agriculture, and agro-forestry techniques are in this direction. The use of the inorganic fertilizers has shown some depletion of the secondary plant nutrients in soils (Kang, 1993; Saker *et al.,* (1998). This is due to the consideration of N, P and K as the fertilizer nutrients and most fertilizers productions have been based on varying the proportion of these nutrients. The use of organic material could be a means of solving such depletion and this could be the reason for the good yield obtained with organic manure application and evidence abounds for the quality of produces from organically manured crop (Omueti *et al.,* 2000).

The implementation of agro-forestry techniques is aimed at regenerating the productivity of the soil, mainly, through the addition of organic matter to the soil by periodically pruning of the tree leaves and applying such to the soil (Hulugalle and Kang, 1991; Akobundu, 1993; Mgbonu *et al.*, 2009). It is well known fact that the addition of organic matter to the soil improves both the physical, chemical and biological properties of the soil. Determining liter quality, decomposition rate and effect on soil physical and chemical properties of agro-forestry species common in Rivers State University campus will be very useful in recommending if these species can be used for restoring degraded soil within the campus and similar environments. Hence, the objectives of the study are to:

i. Determine the litter quality of the agro-forestry species

ii. Examine decomposition rate of litter from the agro-forestry species

iii. Evaluate relative effect of litter from different agro-forestry species on some soil physical and chemical properties.

2. Materials and Methods

2.1 Description of Experimental Site

The experiment was conducted in the Green-House of the Department of Crop/Soil Science of the Rivers State University, Port Harcourt, Nigeria. Rivers State University is located in the heart of Port Harcourt, the state capital. The site is located on Latitude $4^0$45' N and longitude $6^0$50' E within the land area of 1,077 km^2 of the state. The soils here are the 'acid sands' Ultisols with the characteristic poor chemical properties (Hulugalle *et al.,* 1989; Mgbonu *et al*., 2009). Several Agro-forestry species such as *Alchornea cordifolia, Gmelina arborea, Tectona grandis, Tithonia grandiflora, Dactyledania barteri, Chromolaena odorata, Leucaena leucocephala, Acacia* spp., *Azadirachta indica*, *Terminalia catapp*a, *Derris indica,* amongst others can survive favorably.

2.2 Experimental Design

The experiment was laid out as completely randomized design (CRD) with four replicates. The three agro-forestry species' litters served as the treatments.

2.3 Collection of Litter

Freshly abscised litter of Gmelina (*Gmelina arborea*), teak (*Tectona grandis*) and Masquerade tree (*Polyalthia longifolia*) were collected from different locations in Rivers State University that the species were found to ensure that enough litter was made available for the experiment. The litter samples were air dried to a constant weight.

2.4 Litter Quality and Decomposition Rate Determination

Litter quality is expressed in terms of the C:N ratio sequel to the determination of total C and total N contents of the litter. The decomposition pattern of the agro-forestry species' litter was determined by the nylon net bag technique of Bocock *et al*. (1960) at Rivers state university, Nigeria. Twenty-five grams (25 g) of air dried litter was placed in nylon net bag of 15 cm X 15 cm with about 2 mm mesh. Four replicates of the bag were prepared for each agro-forestry species, giving rise to twelve (12) experimental units. The nylon-net bags containing the litter were shallowly buried in plastic bucket filled with equal quantity of soil (that is, 687g soil) taken from the same site in the University teaching and research farm.

The quantity of soil added to the bucket was based on litter yield of 4.82 t/ha obtained from *Dactyledania barteri* fallow for a comparable site around the area of study (Mgbonu *et al*., 2009). The plastic buckets were firmly anchored with pegs and thread. At end of the research period (that was, 50 days), the nylon net bags were collected for each agro-forestry species, air dried and brushed to remove adhering soil off. Then, the litter was air-dried to a constant weight and weighed. Litter decomposition rate was determined with the formula:

$$\text{D.R.} = \frac{W1 - W2}{T2 - T1}$$

Where D.R. is the decomposition rate of litter; W1 and W2 are initial and final weights of litter; T1 and T2 are initial and final time respectively.

2.5 Chemical Analysis of Litter

Air-dried samples of the fresh litter of the three species were finely ground, and total nitrogen (N), potassium (K), calcium (Ca) and organic carbon contents were estimated following standard procedures (Piper, 1966). N content of litter was determined by micro Kjeldhal method using nitrogen analyzer (Kjeltec 2300- FOSS Tecator, Sweden). K and Ca contents in litter samples were extracted by dry ashing followed by digestion with 1:1HCl; K content was estimated flame photometrically using auto analyzer; Ca content was determined using atomic absorption spectrophotometer after treating residue with concentrated H_2SO_4 followed by ashing (Van Soest, 1963).

2.6 Soil Sample Collection

Soil samples from the site were initially collected at random from five points, bulked from which composite sample was collected and taken to the laboratory for analysis. Also, after the removal of the litter bags at the end of the experiment, soil sample from each plastic container was collected and equally analyzed for the same properties.

2.7 Soil Physical and Chemical Properties

Particle size analysis (Texture) of the soil was determined by Bouyoucos (hydrometer) method' for soil pH, soil was equilibrated with water (1:2.5 soil solvent ratio). The pH of the suspension was determined electrometrically on a direct reading pH meter with combined calomel –glass electrode; cation exchange capacity (CEC) was estimated using neutral normal ammonium acetate (Black, 1965); total carbon by wet oxidation method (Walkley and Black, 1934) and nitrogen was estimated by dry combustion method using Macro-Kjeldahl method; available phosphorus was extracted using Bray II extractant and estimated by chloromolybdic stannous chloride reduction method (Jackson, 1973); potassium, sodium, calcium and magnesium were extracted with neutral normal ammonium acetate solution and content of each determined with the AAS.

2.8 Data Analysis

Analysis of variance using the general linear models procedure of the Statistical Analysis Systems Institute (SAS, 2008) was employed to determine the significant effects of agro-forestry species on soil physical and chemical properties, and the means were separated by the use of the Standard Error of Means (SEM).

3 Results and Discussion

3.1 Tissue analysis and litter quality of agro-forestry species

Table 1 shows information on chemical properties of the agro-forestry species used for the experiment. The Ca content was higher in the teak litter than in the gmelina and masquerade tree litters by 6.77 % and 100 % respectively but the gmelina litter had 87.33 % higher Ca content than the masquerade tree litter; whereas K content in teak litter was higher in the gmelina and masquerade tree litter by 3.69 and 37.41 % respectively but the gmelina litter had 32.53 % higher K content than the masquerade tree litter. On the other hand, organic carbon and total nitrogen contents of masquerade tree litter was higher than those of the teak and gmelina litters by 12.49 and 1.66 % but gmelina litter had 9.63 % higher organic C content than the teak litter. For the total nitrogen content of the litters, masquerade tree had 2.50 and 3.54 % higher total N than the teak and gmelina litters respectively but the teak litter had 1.01 % higher total N than the gmelina litter. The overall implication is that the teak litter is of fairly higher quality than the gmelina; the gmelina having a higher quality than the masquerade tree litter sequel to the lowest C:N ratio attributed to the teak litter (23.14).

Table 1 Tissue analysis of agro-forestry species' litters

	OC	**TN**	**C:N Ratio**	**Ca**	**K**
	%	**%**		**mg/kg**	**mg/kg**
Masquerade tree	52.05	2.05	25.39	2880.0	837.57
Teak	46.27	2.00	23.14	5760.0	1150.9
Gmelina	51.20	1.98	25.86	5395.0	1110.0
Mean	-	-	-	-	-

3.2 Decomposition rate of agro-forestry litter

The decomposition rate (DR) of the agro-forestry species used for the experiment is shown in Figure 1. While the DR varies from 0.02 to 0.05 g/day for the masquerade tree; it varies from 0.09 to 0.12 g/day for the gmelina litter; but varies from 0.03 to 0.18 g/day for the teak litter. Thus, teak litter had significantly ($P \leq 0.05$) higher DR than the gmelina litter than the masquerade tree litter. This is attributable to the higher quality of the litter of the teak litter over the gmelina litter over the masquerade tree litter.

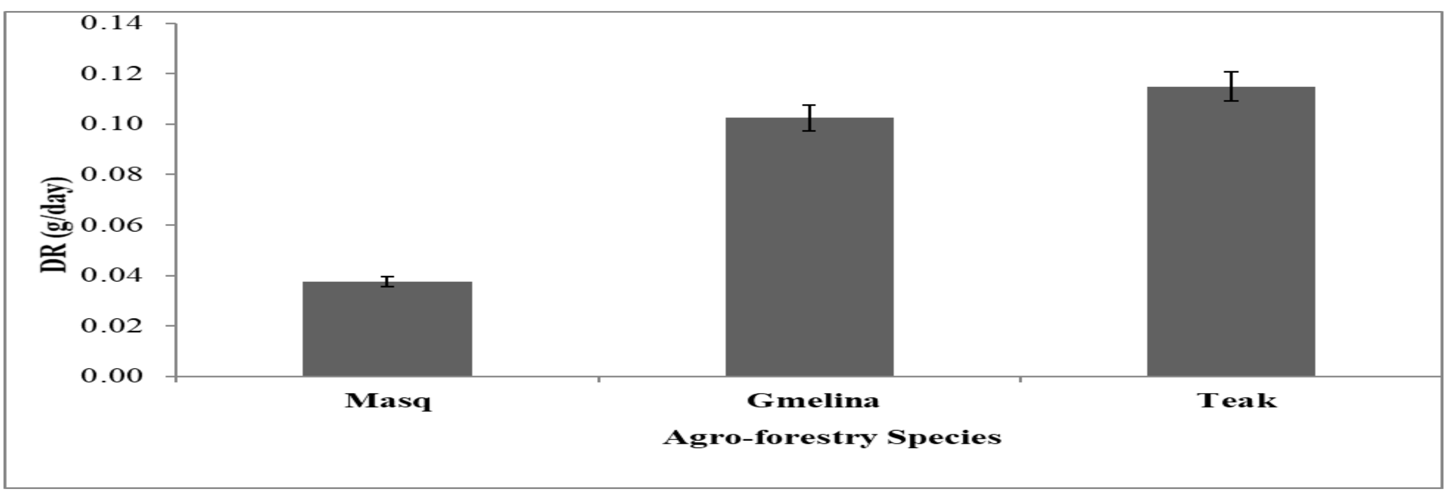

Figure 1. DR of three agro-forestry species after 50 days

3.3 Effect of Litter Decomposition on Soil Texture

The texture of the initial soil sample was made up of 84.40 % sand, 6.40 % silt and 9.2 % clay. After 50 days of applying masquerade tree's litter, between 86.00 and 88.00 % sand content, 2.00 and 6.00 % silt content and 6.00 and 10 % clay content were recorded. Similarly, after the period of the experiment with gmelina, sand proportion of the texture was between 76.00 and 90 %; silt proportion was between 4 and 18 %; whereas clay fraction recorded between 6.00 and 8.00 %. For the soil under decomposition of teak for the period, sand content was between 84.00 and 88.00 %; silt fraction was between 4.00 and 8.00 %. Hence, the soils had sand, sandy loam and loamy sand textural classes.

Sand fraction of the particle sizes did not differ significantly between the treatments and initial but the silt and clay fractions of the soil showed significant differences between the treatments and the initial. Averagely, the sand fraction of the soil increased at the end of the experiment, although not significantly ($P \leq 0.05$); silt fraction decreased in the masquerade tree and teak experimental units but increased in the gmelina experimental unit. This is attributable to the addition of organic matter to the soil and thereby, resulting in binding of more particles that could not be reasonably dispersed during the determination of soil texture. Organic matter is acknowledged as binding agent of soil particles which needs to be reasonably removed before texture determination. Mean values of the particle sizes are shown in Table 2.

Table 2: Effect of litter decomposition on texture of the soil

	Masquerade tree	Gmelina	Teak	Initial	Mean value
Sand (%)	87.50	85.50	86.50	84.40	86.00
Silt (%)	4.50	8.00	6.00	6.40	6.00
Clay (%)	8.00	6.50	7.50	9.20	8.00
Texture	Loamy sand	Loamy sand	Loamy sand	Loamy sand	Loamy sand

3.4 Organic Matter Content of Soil under Different Litter Decomposition Trials

Generally, the organic matter of the soil in the plots under masquerade tree, gmelina and teak litter decomposition experiments was significantly increased ($P \leq 0.05$) with the value ranging from 0.48 to 2.86 % in the masquerade tree; 1.74 to 4.11 in the gmelina plot; and 1.19 to 1.88 % in the teak plot. The difference in OM content could be linked to the quality of the various litters. The litter of higher quality decomposes fast, adding up more organic matter than the litter of lower quality and as well, such organic matter from higher quality litter can be degraded faster. That is why the gmelina plot could have higher OM in the soil being maintained than the other plots. Mgbonu and Ikpe (2010) reported similar trend for Alchornea cordifolia and Dactyledeia barteri where Alchornea with a higher litter quality maintained lower OM in the soil than Dactyledenia. Figure 2 shows the effect of litter decomposition on soil OM.

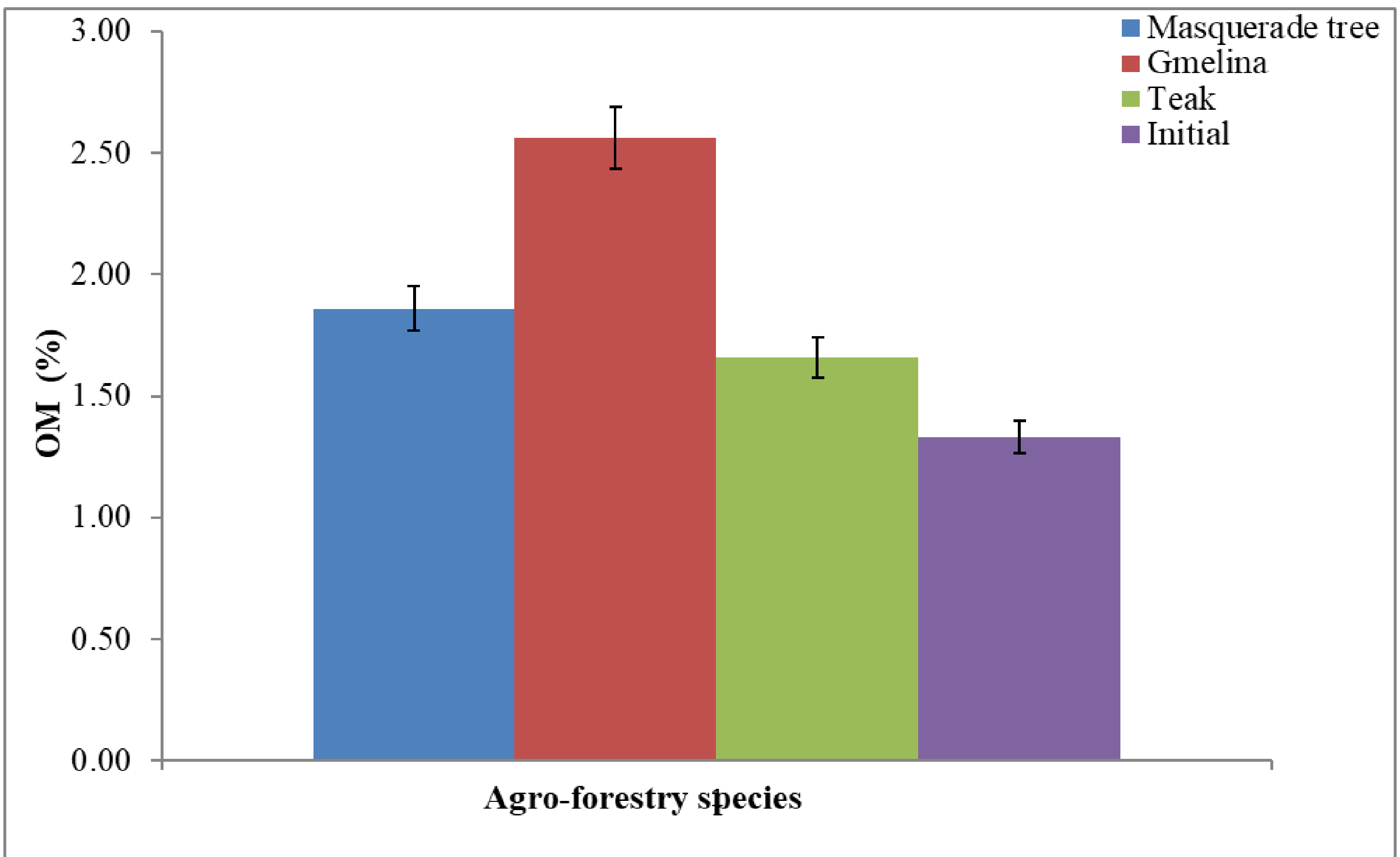

Figure 2. Effect of litter decomposition on OM content of soil

3.5 Total Nitrogen Content of the Soils

Total nitrogen (TN) content of the soils differed significantly (P ≤ 0.05) between the plots with different agro-forestry species' litters. In the plot with the masquerade tree litter, TN was between 0.02 and 0.07 %; between 0.05 and 0.10 % in the plot that had gmelina litter; but between 0.03 and 0.05 % in the teak litter plot; against the initial value of 0.05 %. The trend is similar to the trend of SOM, which is popularly known among researchers and scientists alike. Figure 3 shows TN content of the soils under the decomposition trials.

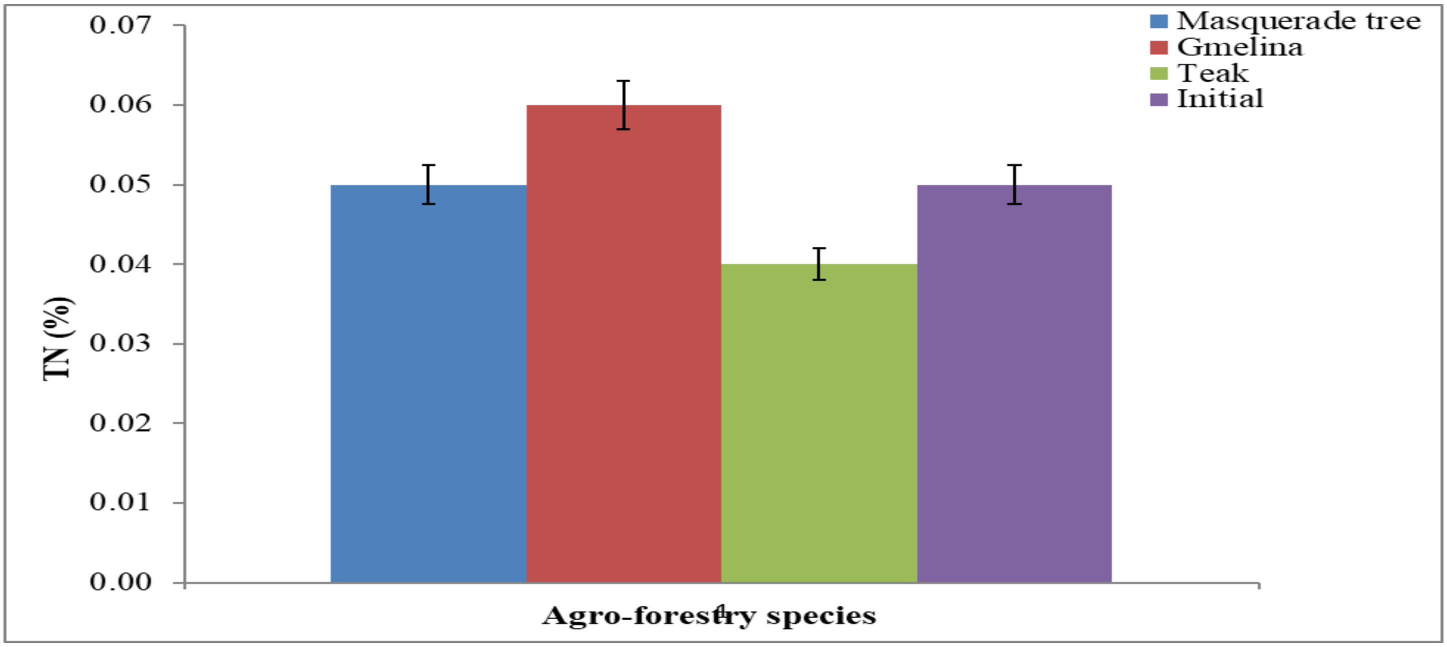

Figure 3. Effect of litter decomposition on TN Content of soil

3.6 Trend of Electrical Conductivity of Soil

Soil electrical conductivity (EC) differed significantly (P ≤ 0.05) between the soils used for the decomposition experiment such that soil electrical conductivity was at the range of 0.22 to 0.38 dS/m in the masquerade tree litter experimental plots; 0.1 to 0.16 dS/m in the gmelina plots; and 0.21 to 0.26 dS/m in the teak plots. The values of EC of the soil in the masquerade tree and teak litters' plots were relatively higher than the initial value of EC whereas in the gmelina litter plot, EC was lower than the initial value of 0.22 dS/m. Organic matter application to soil is known to have effect on electrical conductivity of soil. For instance, Bell and Bessho (1993) reported increase in EC sequel to organic matter application to an ultisol.Figure 4 shows the electrical conductivity of the soils under the species' litter decomposition.

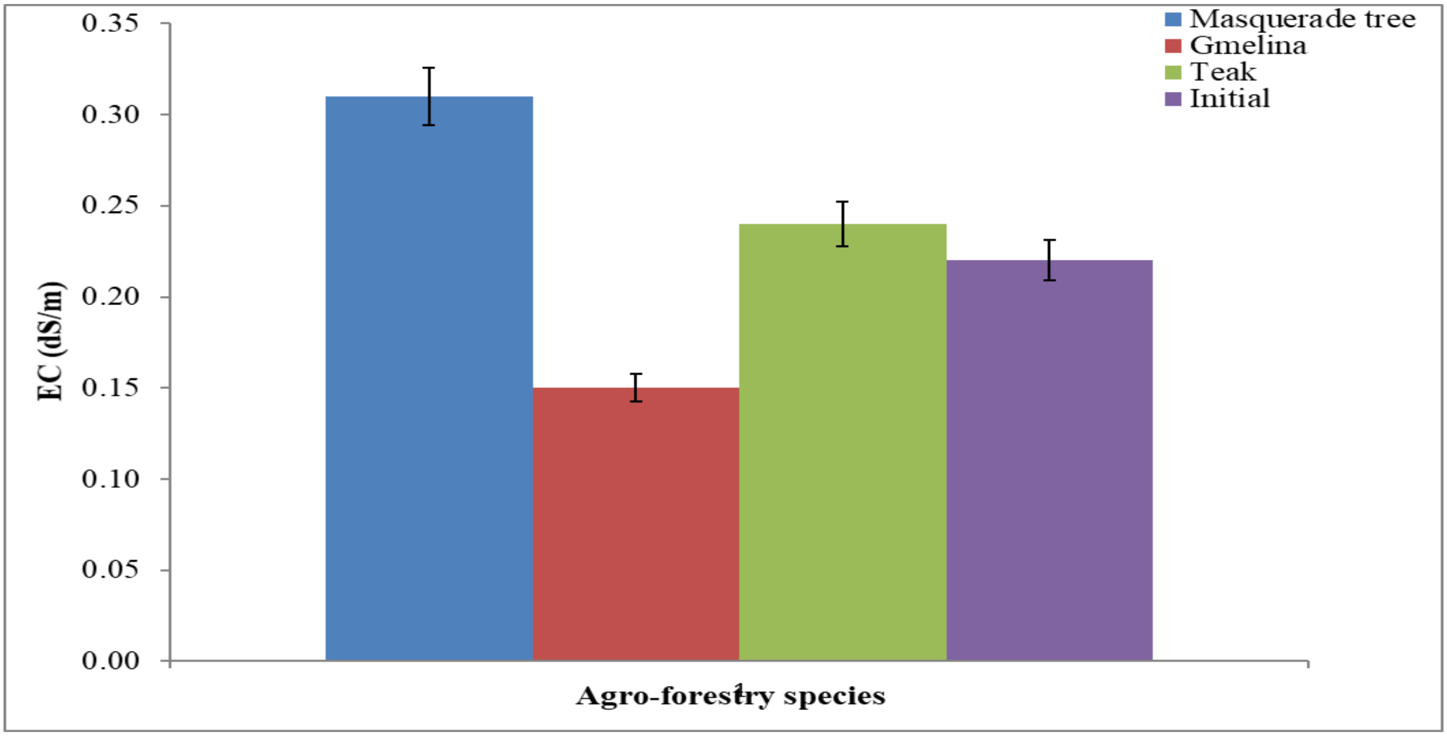

Figure 4. EC of soil under different litter decomposition trials

3.7 Trends in the Exchangeable Bases (Ca, Mg, K and Na)

Exchangeable Ca was between 8.00 and 12.80 cmol/kg in soil of the plots that masquerade tree litter was decomposed; between 11.20 and 14.40 cmol/kg in the soil for the gmelina litter decomposition; but between 10.40 and 12.60 cmol/kg in the soil for the teak litter decomposition. These on average, were decreases in the Ca content when compared to the initial value of 12.90 cmol/kg exchangeable Ca. Meanwhile, the content of exchangeable Ca was significantly different ($P \leq 0.05$) between the treatments. Exchangeable Mg was between 3.40 and 4.11 cmol/kg in soils for the masquerade tree litter decomposition plots; between 3.00 and 5.20 cmol/kg in soils for the gmelina litter decomposition plots; but between 3.00 and 5.60 cmol/kg in soils for the teak litter decomposition plots. There was significant difference ($P \leq 0.05$) in the content of exchangeable Mg between the plots. Figure 5 shows exchangeable Ca and Mg contents in the soils for the decomposition trials.

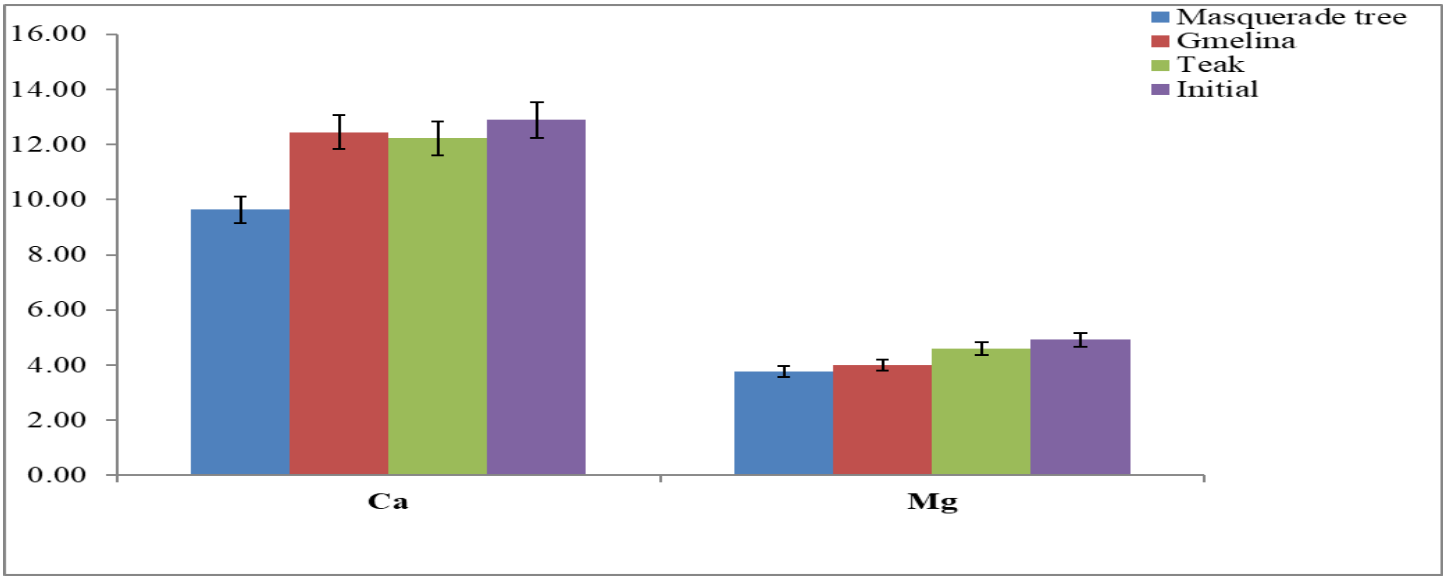

Figure 5. Effect of Litter Decomposition on Ca and Mg Contents of the Soils

Exchangeable Na was between 0.07 and 0.20 cmol/kg in soils for the masquerade tree litter decomposition; between 0.06 and 0.10 cmol/kg in soils for the gmelina litter decomposition; but 0.06 and 0.10 cmol/kg in soils for the teak litter decomposition. These contents of Na show relatively higher Na to the Na content (0.05 cmol/kg) in the initial soil sample but these were not significantly different ($P \leq 0.05$). Exchangeable K was between 0.26 and 1.24 cmol/kg in soils for the masquerade tree litter decomposition; between 0.08 and 0.13 cmol/kg in soils for the gmelina litter decomposition; but between 0.12 and 0.14 cmol/kg in soils for the teak litter decomposition. The K-content in the masquerade tree litter plot was on average higher than the initial K-content of the soil before the litter decomposition. The K-contents in the gmelina and teak litter plots were lower than the K-content in the soil before the litter decomposition trials. These trends in K-content were significantly different ($P \leq 0.05$). Table 3 summarizes the contents of K in the initial soil sample and after decomposition trials of the different agro-forestry species' litters.

Table 3: Effect of litter decomposition on other soil properties

	Masquerade tree	**Gmelina**	**Teak**	**Initial**	**SEM**	**LS**
Na ($cmolkg^{-1}$)	0.15	0.08	0.08	0.05	ND	NS
K ($cmolkg^{-1}$)	0.85^a	0.11^b	0.13^b	0.19^b	0.12	*
EA ($cmolkg^{-1}$)	3.36	2.04	1.77	1.58	0.27	*
ECEC ($cmolkg^{-1}$)	17.73	18.69	18.84	19.64	0.57	NS
pH	6.81	6.99	6.62	6.01	ND	NS
Av. (P $mgkg^{-1}$)	36.76	41.18	33.73	37.04	ND	NS
BS (%)	80.96	89.33	90.41	91.96	ND	NS

ND- Not Determined; LS-Significance Level; NS-Not Significant; * - Significant

The contents of the exchangeable bases can be attributed to microbial immobilization as well as non-mineralization of organic matter. Instances as associated with K-content can be explained by the quality of the litter which did not support microbial growth and hence reducing microbial immobilization.

3.8 Exchangeable Acidity and ECEC

Exchangeable acidity (EA) was between 2.08 and 4.64 cmol/kg in soils under the masquerade litter decomposition; between 1.76 and 2.40 cmol/kg in soils under the gmelina litter decomposition; but between 1.48 and 2.08 cmol/kg in soils under the teak litter decomposition. There was significant difference ($P \leq 0.05$) between effect of the agro-forestry species' litters on EA of the soil. ECEC was between 15.56 and 20.20 cmol/kg in soils under the masquerade tree litter decomposition; between 16.10 and 21.87 cmol/kg in soils under the gmelina litter decomposition; but between 15.69 and 21.06 cmol/kg in soils under the teak litter decomposition. ECEC was did not differ significantly ($P \leq 0.05$) between the agro-forestry species' litters decomposition. Table 3 shows the contents of EA and ECEC of the soils under the litter decomposition.

3.9 Effect of Litter Decomposition on pH, Available P and BS

These properties of soil were not significantly different under the different agro-forestry litters decomposition ($P \leq 0.05$). Soil pH was between 6.66 and 7.06 in soils under the masquerade tree litter decomposition; between 6.91 and 7.07 in soils under the gmelina litter decomposition; but between 6.03 and 6.84 in soils under the teak litter decomposition. These implied that the effect of litter decomposition on soil pH was the maintenance of a moderate acidity to neutral pH values based on the classification of the Soil Survey Staff (1993). This is tandem with the general assertion that organic matter addition to soil increases soil pH from acidic towards neutral pH (Opara-Nadi, 1992). Available P content was between 29.29 and 43.12 mg/kg in soils under the masquerade tree litter decomposition; between 33.17 and 51.96 mg/kg in soils under the gmelina litter decomposition; but between 29.85 and 37.59 mg/kg in soils under the teak litter decomposition. The initial content of the available P in the soil was 37.04 mg/kg. However, there was no significant difference ($P \leq 0.05$) between the available P content of the soils under the different agro-forestry species' litter decomposition. Base saturation was between 72.98 and 87.33 % in soils under the masquerade tree litter decomposition; between 86.04 and 91.70 % in soils under the gmelina litter decomposition; but between 86.74 and 92.38 % in soils under the teak litter decomposition. Table 3 shows the mean values of these properties for the soils.

4.0 Conclusion and Recommendations

Litter quality can simply be expressed as the C:N ratio and used to infer the ease with which such litter can decompose as well suggest the extent of nutrient the litter can contribute to the soil after full decomposition and mineralization. Based on the findings of the research, it is necessary to state that litter decomposition if not complete, can lead to reduction of nutrients such as Ca, Mg, K and even N in soils due to microbial immobilization as microbes' populations build up. Also, the research found out that the quality of litter of the agro-forestry species is in the order teak litter > gmelina litter > masquerade tree litter.

Based on the findings of this research, it is pertinent to recommend as follows:

i. Implementing agro-forestry techniques within the farming system being practiced can help in adding litter to the soil which on eventual decomposition will improve soil properties and assure sustainable agriculture.

ii. Knowledge of litter quality and their decomposition rate is important to enable for the choice of agro-forestry species to adopt for use.

iii. Synchronization of litter quality, decomposition rate and growth rate of agro-forestry species is eminent in order to predict fallow length for different agro-forestry species and for each agro-ecological zones.

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