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Above and Below-Ground Decomposition of Leaf Litter in *Leucaena leucocaephala* Plantation of Federal University of Agriculture, Abeokuta (FUNAAB), Nigeria

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ABSTRACT

A decomposition study was carried out on the leaf litters of *Leucaena leucocaephala* to determine the rate of decomposition of its leaves with respect to its placement on, above, or below the ground levels in *L. leucocaephala* plantations of the Federal University of Agriculture, Abeokuta, Nigeria. In the study, leaf litter were randomly handpicked from the forest floor, of this, 40 g each were weighed into thirty (30) litter bags of 2 mm mesh size, in which 15 were randomly placed on the forest floor (above-ground) and the remaining 15 were buried in the soil between 5-10 cm depth (below-ground). Data were analysed using descriptive statistical techniques, such as percentage, while inferential statistics (simple linear regression) was used to determine relationships between various nutrient elements and days of decomposition (DOD). We noted that the percentage of mass loss of leaf litter increased with time, in days after deposit, and was higher (29.93%, 32.43 % and 33.25%, 41.65%) at 80 to 100 days of placement above- and below-ground, respectively. Moreover, the exchangeable basic cations and chemical compositions of litters were not consistent with respect to DOD. Regression analysis of nitrogen (N) and organic carbon (OC) showed that these elements significantly contributed to the high (86%) overall decomposition of litter ($p < 0.05$, $p < 0.01$) below-ground level. It is, therefore, concluded that decomposition of leaf litters occur faster below ground, than above ground, within the forest plantation.

Keywords: Forest plantation, mass loss, nutrient contents, ground level, release pattern, leaf litter, *Leucaena leucocaephala*

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1. INTRODUCTION

Litter decomposition plays a crucial role in the budget of forest ecosystem, where vegetation depends mainly on the recycling of nutrient contained in the plant detritus. During the process, litter fall and decomposition is influenced by environmental factors and also by physical and chemical properties of plant parts, such as stem wood, leaves, root, etc. (Temel, 2003; Oyebamiji *et al.*, 2017a).

Litter fall is a fundamental process in the nutrient cycling and it is the main means of transfer of organic matter and mineral element from vegetation to the soil surface (Reginal *et al.*, 1999). Litter fall has also been described as a major pathway for the return of organic matter and nutrients from aerial parts of the plant community to the soil surface. Decomposition is a key process in the nutrient cycling and formation of soil organic matter (Berg and McClaugherty, 2002). The decomposition of leaf litters is a major source of nutrient in forest ecosystem (Temel, 2003).

As leaves are broken down by insects and microbial decomposers, organically bound nutrients are released as free ions to the soil solution which are then available for uptake by plant. Litter decomposition is one of the key biogeochemical process in forest ecosystem, it is estimated that the nutrient released during litter decomposition can account for 69-87% of the total annual requirement of essential elements for forest plant (Swift *et al.*, 1997). Understanding of quantification of the nutrient flux associated with litter fall is important (Daisy *et al.*, 2006).

Litter production from plants, particularly trees is a major source of organic matter in soil under restoration for agricultural purpose. Both, the species and age of plantation largely determine the amount of litter production of trees. The efficient conversion of this litter to soil humus by soil organisms depends largely on climatic factors and the selected species (litter quality). In tropical forest, both, litter production and litter decomposition rates are often higher in forest than in other part of the world, although large variations occur between forest types and within sites (Lissanework and Micheeasen, 1994).

The net litter accumulation on the forest floor at any given time largely varies with species and many other factors, such as site fertility, species and age of stand even the elevated CO_2 (Norby *et al.*, 2001). Ola-Adams and Egunjobi (1992) summarized that, in monoculture stand, the amount of and composition of litter returned to the forest floor determines the restoration of fertility of soil after each harvest period. Moreover, the quality and composition of combustible fuel provided by litter on the forest floor determines the incidence and intensity of wildlife and measures to control them. The objective of this study therefore investigated the rate of mass loss in the above and below ground decomposition of leaf litters in *L. leucocaephala* plantation.

2. MATERIALS AND METHODS

2. 1. Study Site

The study site is *Leucaena leucocaephala* plantation established as an agroforestry plot in year 2000 in the Federal University of Agriculture, Abeokuta, Nigeria. Photographic descriptions of *L. leucocaephala* tree showing its leaves, fruits, flowers and seeds were presented in **Figures 1a** and **1b**, respectively.

Figure 1a. *Leucaena leucocephala* plant showing its leaves, fruits and flowers.

Figure 1b. *Leucaena leucocephala* plant showing its seeds.

The site is on Latitude 7º58" N and Longitude 3º2" E. It is at a height of 600 m above sea level. The general topography of the site is undulating while local topography is upper mid-slope. Originally, the vegetation was derived savanna now regenerated with *L. leucocaephala.* The plot sample for litter collection was at square spacing of 2.4 m^2 and total land area of 1,456.68 m^2. The soil is a fertile sandy loam, very dark in colour at the top surface and grayish brown in the subsoil with occasional areas with loamy soil. It lies within the humid lowland region with two distinct seasons. The wet season extended from April to October while the dry season extends from November to March.

The mean annual rainfall is 1113 mm, while, the bimodal distribution of rainfall has its peaks in July and September and break in August. Generally, the rainfall could be heavy and erosive and sometimes accompanied by lightning and thunderstorms at the beginning and the end of the rainy season. The mean monthly temperature varies from 22.74 ºC in August to 36.32 ºC in March. The relative humidity is high ranging from 75.52% in February to 88.15% in July (Funaab Meteorological data, 2017).

2. 2. Collection of Litter

Twenty wooden litter trays with nylon net (1 m × 1 m) with 0.2 m mesh were distributed randomly within the plantation. The trays were slightly raised with 20 cm pegs above the ground to prevent leaching of the nutrients as a result of contact with soil. The litter was collected from each tray twice in a month for a period of two (2) months (October-November, 2009). The collected leaf litters were oven dried and weighed.

2. 3. Litter Bag Techniques and Leaf Decomposition Studies

Leaf litter decomposition was evaluated using a litter bag technique as describe by Anderson and Ingram, 1993; Swift *et al.* (1997); Oladoye *et al.* (2008). Forty (40) g leaf litters were weighed into 2 mm mesh litter bags of 35 cm × 35 cm in size, and closed at both ends. The mesh size chosen was to prevent inflow of excess materials into weighed samples. Thirty (30) litter bags were used, in which 15 litter bags were randomly placed on the forest floor (above-ground level) while the remaining 15 litter bags were buried in the soil between 5-10 cm depth. Three (3) litter bags each were randomly retrieved five (5) times from the forest floor (above-ground) and below-ground samples, respectively, at every 20 days interval for 100 days. The litter bags were carefully removed and packed to the laboratory, where the contents were spread to remove attached clump of soil and fine roots. The samples were dried at 75 ºC to a constant weight to determine the final weight. Fresh leaf litter samples collected from the forest floor were analysed as control.

2. 4. Leaf Litter Nutrient Content Analysis

The air dried samples used were ground for chemical analysis to get the results of organic carbon content which was determined by wet oxidation method of Walkley-Black, as described by Allison (1965). Total N was analysed by Macro-Kjeldahl digestion, followed by distillation and titration (Brandstreet, 1965; Anderson and Ingram, 1993). The C:N ratio was computed as the ratio of N to C. Available P was extracted by Bray 1 method. The P concentration in the extract was determined colorimetrically by using the Spectronic 20 and absorption was read-off, as described by Bray and Kurtz (1945), and modified by Murphy and Riley (1962).

Exchangeable Na, K, Ca, and Mg were extracted using ammonium acetate. K was determined on flame photometer, and Ca and Mg, by Atomic Absorption Spectrophotometer.

2. 5. Data Analysis

Descriptive statistical technique, such as percentage, inferential analysis, like simple linear regression was used to compare days and percentage of initial mass, carbon and nitrogen remaining. The R^2 values were obtained to estimate significance of the parameters as predictors of decomposition rate, used to analyse the data.

3. RESULTS AND DISCUSSION

3. 1. Leaf Litter Decomposition

Leaf litter decomposition tends to reduce as the days increased. Loss in weight of decomposing leaf litter above- and below-ground in a secondary forest with days was rapid. Mass loss was higher at 100 days, 32.43% and 41.65%, in above- and below-ground from initial weight of the leaf litter.

This means that approximately half of the initial litter mass below the ground had decomposed within three months, as more than one-second decomposed above the ground. It could be inferred that the leaf litter decomposition in secondary forest can be more rapid as a result of microbial activities within the forest floor and forest nature (Berg and McClaugherty, 2005).

Leaf litter decomposition is an important aspect in mineral cycling as it determines the rate at which nutrients in the litter become available for recycling. Decomposition rate of leaf litter in this study was gradual, as it progressively increased with passing days (Oyebamiji *et al.*, 2017). It therefore means, that different species have different rate of decomposition, as reported by Moughalu *et al.* (1994) and Temel (2003) (**Tables 1** and **2**).

Table 1. Above-ground decomposition of leaf litters in a *Leucaena leucocaephala* plantation at FUNAAB

Days	Decomposition	Weight (g)	Mean R (g)	Mean weight (g)	Mass Loss	% mass remaining	% mass Loss
20	D1	40	37.97	37.97	2.03	94.92	5.08
40	D2	40	33.94	33.93	6.07	84.82	15.18
60	D3	40	31.83	31.83	8.17	79.57	20.43
80	D4	40	28.04	28.03	11.97	70.07	29.93
100	D5	40	27.04	27.03	12.97	67.57	32.43

R: Replicate

Table 2. Below-ground decomposition of leaf litters in a *Leucaena leucocaephala* plantation at FUNAAB.

Days	Decomposition	Weight (g)	Mean R (g)	Mean weight (g)	Mass Loss	% mass remaining	% mass Loss
20	D1	40	35.73	35.73	4.27	89.32	10.68
40	D2	40	31.50	31.50	8.50	78.75	21.25
60	D3	40	29.20	29.20	10.80	73.00	27.00
80	D4	40	26.73	26.70	13.30	66.75	33.25
100	D5	40	23.34	23.34	16.66	58.35	41.65

R: Replicate

3. 2. Nutrient Release Pattern

Different species have different decomposition and nutrient release pattern. It was clearly noticed in this study that decomposition rate of litter was gradual, as it increased with days (Temel, 2003). In this decomposition study, mass loss in leaf litters differed in the above- and below-ground decomposition study. At 20 days of the above-ground decomposition, only 5.08% of the initial 40 g of leaf litters had been lost, while 10.68% of the below-ground was lost, which could be attributed to the soil depth 5-10 cm being the zone of active microbial activities as there is always a population of decomposer organisms residing in the root zone.

Mass loss between below and above ground levels showed a similar trend with 41.65% below ground and 32.43% above ground. The progressive decomposition also revealed that only 4.27 g and 2.03 g of the leaf litters were lost within the first ten days, 10.80 g and 8.17 g within sixty days, and, 16.66 g and 12.97 g within hundred days, in both, below and above ground samples, respectively. A total of 58.35% and 67.57% of initial sample was left undecomposed below and above the ground after the termination of decomposition study. This suggests that there is always litter remaining before new litter falls, a situation that favours erosion control in plantations. The various mineral elements showed different pattern of decomposition for above- and below-ground. Sodium, potassium, calcium, magnesium, nitrogen, and organic carbon, remaining after 100 days of decomposition were significantly lower compared to the initial nutrient concentration above and below ground. Sodium, potassium, and nitrogen in both, above and below ground witnessed a sharp increase in nutrient release within 40 and 60 days of decomposition, respectively. However, values were higher in above the ground. This indicated that they had high exchangeable bases (Kava'ova and Acek, 2003). Phosphorus and organic carbon during 100 days of decomposition experienced a noticeable increase both, in above and below ground much more than the initial nutrient concentration. At 100 days, for all relative increase in nutrient content of the below ground samples, there was a corresponding decrease in the available nutrient. This indicates that the nutrients were further leached downward; an indication that nutrient availability in the *L.*

leucocaephala plantation increases with depth. This must have been caused by a high rainfall, causing leaching of the nutrient.

High rate of nitrogen release from the leaf litters could be attributed to influence of soil micro- arthropods. The sudden increase in nitrogen content at the end of the study also indicates that, soil nitrogen which is being immobilized by decomposing organisms are later mineralized (Alfred and Sullivan, 2001). The carbon-nitrogen ratio in this study showed that, the ratio was higher in above ground and lower in below ground. Thus, there was a significant difference in nutrients availability, with respect to placement (**Tables 3** and **4**).

Table 3. Percentage nutrient content remaining in leaf litters after decomposition in above-ground

Days	**Decomposition**	**Na (mg/kg)**	**Ca (mg/kg)**	**Mg (mg/kg)**	**K (mg/kg)**	**P (%)**	**N (%)**	**OC (%)**	**C/N**
20	D1	550.00	115.00	280.50	650.00	5.22	0.30	26.09	85.81
40	D2	850.00	150.00	100.00	600.00	5.75	0.33	26.37	81.12
60	D3	800.00	75.00	85.00	700.00	5.18	0.29	23.44	81.38
80	D4	800.00	2.18	85.00	900.00	6.33	0.30	18.69	71.90
100	D5	600.00	2.50	550.00	600.00	5.30	0.35	20.51	50.58
	Control	2500.00	1000.00	750.00	6000.00	4.11	14.90	22.60	1.52

Na: Sodium, Ca: Calcium, Mg: Magnesium, K: Potassium, P: Phosphorus, N: Nitrogen, OC: Organic carbon, C/N: Carbon and nitrogen ratio

Table 4. Percentage nutrient content remaining in leaf litters after decomposition in below-ground

Days	**Decomposition**	**Na (mg/kg)**	**Ca (mg/kg)**	**Mg (mg/kg)**	**K (mg/kg)**	**P (%)**	**N (%)**	**OC (%)**	**C/N**
20	D1	750.00	155.00	135.00	750.00	5.10	0.17	25.49	147.35
40	D2	750.00	142.50	110.00	700.00	6.49	0.22	19.60	9.49
60	D3	900.00	165.00	122.50	950.00	7.65	0.23	22.32	7.47
80	D4	750.00	325.00	150.00	900.00	6.58	0.38	21.34	6.91
100	D5	600.00	167.00	145.00	550.00	4.69	0.36	19.67	4.04
	Control	2500.00	1000.00	750.00	6000.00	4.11	14.90	22.60	1.52

Na: Sodium, Ca: Calcium, Mg: Magnesium, K: Potassium, P: Phosphorus, N: Nitrogen, OC: Organic carbon, C/N: Carbon and nitrogen ratio

Nitrogen and organic carbon, significantly contributed (63%) to the overall of decomposition observed during the study at 5% and 1% probability levels. Also, 79% and 86% were the joint contributions of nitrogen and organic carbon that were decomposed in above-below-ground, respectively. The rate of decomposition, positively depended on nitrogen and negatively on organic carbon, as observed by Agren *et al.* (2001); they said that, species with a high initial nitrogen content decomposes more rapidly than species with low nitrogen content. Sarah (2000) added that, nitrogen fertilization stimulates decomposition of the low-lignin litters. Seneviratne (2000) and Oyebamiji *et al.* (2017b) also emphasized that the major key factors that control decomposition processes and rates of any leaf litters are nitrogen concentration of the litter and/ or the C:N ratio (**Table 5**).

Table 5. Regression analysis of decomposition rate in both above and below-ground decomposition

	R^2	A	N	OC
Overall	0.63	217.54	105.49*	-8.26**
Above	0.79	279.12	139.40*	-11.90**
Below	0.86	53.04	236.97**	-2.57

Significant at *p < 0.05; **p < 0.01

4. CONCLUSIONS

Both, the above- and below-ground decomposition experienced increased, with days of placement in the percentage mass loss of leaf litters. The exchangeable basic cations and chemical compositions of litters were not consistent with respect to the days of decomposition. Decomposition of leaf litters and nutrient release (nutrient mass loss) occurred faster in the below-ground level than above-ground in a *Leucaena leucocaephala* plantation at FUNAAB.

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