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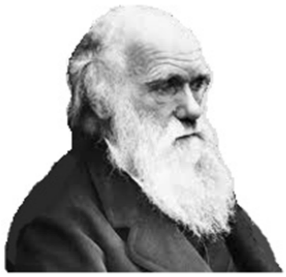

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Statistical relationship between leaf litter and tree growth characteristics of *Tectona grandis* species

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ABSTRACT

Forest productivity relies on the quantity and quality of litter as this influences nutrient cycling in the ecosystem. Many studies have been carried out on litter fall, but few attempts have been made to relate litter fall nutrient content with the tree growth variables. The aim of this work was to investigate basic relationships between the leaf litter nutrient content of *Tectona grandis* and tree growth characteristics. The study was done at the arboretum of the Department of Forestry and Wildlife Management, University of Port Harcourt, Rivers State, Nigeria. Data were collected from four (4) randomly selected 20 m × 20 m (0.04 ha) plots. Within each plot, four (4) litter traps at 8 m apart was set at random to collect litter on a weekly basis, while the tree growth variables were measured on trees around the trap. The collected litter was put into zip-lock bags and taken to the laboratory for a nutrient content analysis. Nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na), and magnesium (Mg) contents, and pH were included in this study. The result shows that the average weekly leaf litter collected from the trap was 11.8 g. In terms of average nutrient content, Nitrogen had the highest average at 1.8, while Sodium (Na) had the lowest value at 0.14. Among the tree growth variables, only height had a positive correlation with the litter collected. The results also show that Nitrogen micronutrient content was related to the amount of litter collected (0.536). In addition, all the exchangeable bases analysed in the study were also related to the amount of litter collected. Conclusively, the amount of litter produced is a major indicator of the primary productivity because as litter quantity increases, available nutrient content for the plant growth also increases, hence, having influence on the tree height.

***Keywords*:** Correlate, Forest, Litter, Nutrient, Productivity, *Tectona grandis*

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1. INTRODUCTION

The central source of biodiversity is the forest whose production efficiency is dependent on the quantity and quality of litter fall which in turn influences nutrient cycling in the ecosystem. Pande *et. al*., (2002) stated that the litter fall exerts an immense influence on physical, chemical, and biological characteristics of soil, as well as growth of trees. Tropical forest is endowed with a high litter production which has led to the stability of the plant and soil relationship in the ecosystem. However, there is always a disruption in this plant – soil relationship, as a result of deforestation or degradation.

Despite of many studies carried out on litter fall as an important pathway for the transfer of litter mass and minerals to the soil surface in the forest ecosystems (Lodhiyal *et al*., 2002; Martius *et al*., 2004; Polyakova and Billor 2007) a few attempts have been made to relate litter fall nutrient content with the tree growth variables. It is vital to understand nutrient dynamics in the forest ecosystem. Understanding of litter quality and its role in governing ecosystem processes is influenced by the knowledge about the functional traits of plants (Díaz and Cabido, 2001).

Litter contain a significant amount of essential nutrients which, when available, facilitates the tree growth (Mishra and Kumar, 2016). The efficiency of nutrient use in the forest ecosystem depends on the amount of litter fall and nutrients content in litter. Hence, the importance of knowing the quality and quantity of litter produced and their nutrients concentration in an ecosystem cannot be over-emphasised. The aim of this study was to analyse the nutrient content in litter fall of the tree species and show how it influences the growth characteristics.

2. METHODOLOGY

2. 1. Study Area

This study was carried out in the Arboretum, University of Port Harcourt, and Rivers State, Nigeria. The University of Port Harcourt is located on a land area of about 400 hectares in Obio/Akpor Local Government Area of Rivers State (Latitude 4.90794 and 4.90809 N and longitude 6.92413 and 6.92432 E). The area is characterized by two seasons, the dry season, and wet season with a rainfall distribution that is nearly all year round (Aiyeloja *et al.*, 2014). The arboretum is located at the North Eastern area of Abuja campus of the University, and covers a total land area of about 4,226,258.15 m², containing several tree species, including *Gmelina arborea*, *Tectona grandis*, *Khaya grandifoliola*, *Nauclea diderrichii*, and *Irvingia gabonensis.*

2. 2. Data Collection

Data were collected from temporary sample plots due to the fact that the permanent sample plots are not available in the study area. Four (4) Plots of 20 m × 20 m (0.04 ha) in size were randomly located in the *Tectona grandis* plantation. All the trees in the selected plots were enumerated and the number of trees in the selected plot was identified.

2. 3. Measurement of Tree Variables

Within each sample plot, the following tree variables were measured for all trees:

i. Total height
ii. Clear Bole height
iii. Crown length
iv. Crown diameter
v. Diameter outside the bark at breast height (DBH, 1.3 m above the ground).

Haga altimeter and distance tape were used for the height measurements while diameter tape was used to measure the diameter outside the bark at breast height.

2. 4. Collection of Litter Sample

Within each plots, four (4) litter traps at 8 m apart were set at random to collect litter on a weekly basis. The collected litter was pooled for each plot at the sampling time. The collected litter was put in a zip-lock bag and taken to the laboratory for analysis on the weight of litter, as well as the concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sodium (Na), magnesium (Mg), and pH.

2. 5. Data analysis

The data collected from tree measurements were processed into a suitable form for statistical analysis. Data processing include the stem volume estimation, basal area estimation, crown variable estimation, and nutrient content in the litter fall.

2. 6. Stem volume estimation

The stem volume for each tree in each sample plot was estimated using the Huber's formula, as presented by Husch *et al*., (1982)

$$V = g_m x L -------- Equation 1$$

where: V = Stem volume (m^3), g_m = cross sectional areas at the middle of the tree (m^2), and L = length or height of the solid.

2. 7. Basal area estimation

The basal area for each tree in each sample plot was estimated using the formula:

$$BA = \frac{\pi D^2}{4} -------- Equation 2$$

where: BA = Basal area, D = diameter at a breast height (m)

2. 8. Crown variables estimation

Crown projection area for each tree in the plots was estimated using the formula:

$$CPA = \frac{\pi(CD^2)}{4} ------- Equation 3$$

where: *CPA* = crown projection area, and *CD* = crown diameter.

Crown ratio will also be computed for each tree using the formula:

$$CR = \frac{CL}{H} ------- Equation 4$$

where: *CR* = crown ratio, *CL* = crown height, and *H* = total height.

2. 9. Statistical analysis

Descriptive (tables and graph) and inferential statistics were used in this study. A product moment correlation analysis was used to evaluate relationship between the measurable tree characteristics and a nutrient content in the leaf litter.

3. RESULTS

3. 1. Tree growth characteristics and leaf litter production

From the descriptive statistics, in **Table 1** below, the average tree height and dry weights of the leaf litter produced were 9.5 m and 5.14 g/m^2/day, respectively. The maximum and minimum values of the basal area were 0.41 m^2 and 0.002 m^2, and that for the volumes were 3.82 m^3 and 0.006 m^3, respectively.

Table 1. Descriptive statistics for the tree growth variables

	Minimum	**Maximum**	**Mean**	**Std. Deviation**
DB (cm)	21.0000	86.0000	41.273034	11.3558692
CD (cm)	135.0000	640.0000	321.789326	94.0156060
HT (m)	4.0000	14.5000	9.523034	2.0744281
DBH (m)	.0430	.7193	.100299	.0537621
BA (m$^{2)}$	.0015	.4064	.010200	.0302154
VOL (m^3)	.0058	3.8201	.102570	.2870626
LITTER (g/m^2/day)	2.26	7.67	5.14	1.25
CPA (m$^{2)}$	1.4316	32.1741	8.824122	5.3791054

DB = diameter at the base, CD = crown diameter, HT = tree total height, DBH = diameter at breast height, BA = basal area, VOL = volume, CPA = crown projection area

3. 2. Nutrient content

The nutrient content of leaf litter in the studied site is presented in **Table 2** below. The descriptive statistics shows that nitrogen had the highest value (1.84%), while sodium had the lowest value (0.15%). Phosphorus, Potassium, and Calcium had an average value of 0.29, 0.58, and 0.96, respectively. The leaf litter collected had the mean pH of 8.88 (Table 2). The order of the nutrient concentration in leaf litter of the studied species was: N > Ca > K > Mg > P > Na.

Table 2. Descriptive statistic of nutrient content in leaf litter

Nutrients	Minimum	Maximum	Mean	Std. Deviation
PH	8.7000	9.1000	8.876404	.1484553
N	1.6000	2.2100	1.836236	.2358873
P	.2600	.3300	.287247	.0268445
K	.5000	.6500	.575562	.0560566
Ca	.8000	1.2200	.963034	.1708199
Mg	.2500	.5300	.374831	.1038481
Na	.1000	.1800	.149888	.0302343

N = Nitrogen, P = Phosphorus, K = Potassium, Ca = Calcium, Mg = Magnesium, Na = Sodium, pH = basic and acidic contents in the leaf

3. 3. Relationship between tree growth variables

Table 3. Correlation matrix of the tree growth variables

	DB	CD	HT	DBH	BA	VOL	LITTER
DB	1						
CD	.755**	1					
HT	.756**	.496**	1				
DBH	.439**	.376**	.378**	1			
BA	.102	.098	.104	.932**	1		
VOL	.154*	.136	.159*	.948**	.997**	1	
LITTER	.077	-.047	.155*	-.060	-.090	-.087	1

DB = diameter at the base, CD = crown diameter, HT = tree total height, DBH = diameter at breast height, BA = basal area, VOL = volume, LITTER = dry weight of leaf litter
**. Correlation is significant at the 0.01 level

Correlation analysis was carried out to determine the relationship that exists between thetree growth variables and the leaf litter content. The results show that the various tree growth variables are related to each other. There was a positive relationship between the girth size (DBH) and height, DBH and crown diameter (r = 0.376, and 0.378, respectively). Tree volume also had a positive relationship with DBH, BA. Among the tree growth variable measured, the dry weight of leaf litter had a weak correlation (r = 0.155) with height alone (**Table 3**).

3. 4. Relationship between tree growth variables and macronutrients in leaf litter

Nitrogen, phosphorus, and calcium were the macro nutrients analysed in the leaf litter collected. Correlation analysis was carried out to reveal the relationship between the tree growth variables and the macro-nutrients. From the correlation matrix presented in **Table 4** below, among the macro nutrients analysed in the study, only nitrogen had a positive linear relationship with the dry weight of the leaf litter.

Table 4. Correlation matrix of the tree growth variables and macro-nutrient in the leaf litter

	DBH	VOL	CD	LITTER	N	P	K
DBH	1						
VOL	.948**	1					
CD	.376**	.136	1				
LITTER	– .060	–.087	–.047	1			
N	–.075	–.082	–.092	.536**	1		
P	–.080	–.031	–.084	.070	-.090	1	
K	.049	.001	.118	–.036	.046	–.959**	1

DBH = diameter at breast height, VOL = volume, CD = crown diameter, LITTER = dry weight of the leaf, N = nitrogen, P = phosphorus, K = potassium
**. Correlation is significant at the 0.01 level

3. 5. Relationship between tree growth variables and exchangeable base with pH

The result reveals that among the exchangeable base analysed in the leaf litter, magnesium and sodium had a weak negative correlation with the diameter at the base (r = –0.15) and crown diameter (r = –0.18), respectively. The dry weight of leaf litter consistently showed a positive relationship, with pH and exchangeable base (**Table 5**).

Table 5. Correlation matrix of the tree growth variables and exchangeable base with pH

	DBH	VOL	CD	LITTER	PH	Ca	Mg	Na
DBH	1							

VOL	.948**	1						
CD	.376**	.136	1					
LITTER	–.060	–.087	–.047	1				
pH	–.050	–.079	–.013	.454**	1			
Ca	–.078	–.076	–.118	.527**	.750**	1		
Mg	–.153*	–.125	–.054	.449**	.235**	.573**	1	
Na	–.014	.007	–.175*	.253**	.173*	.735**	.307**	1

DBH = diameter at breast height, VOL = volume, CD = crown diameter, LITTER = weight of litter, pH= basic and acidic content, Ca = calcium, Mg = magnesium, Na= sodium.
**Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed)

4. DISCUSSION

4. 1. Tree growth characteristics and leaf litter production

The range of the tree growth variables measured in the study shows the productivity of the studied site. Transfer of nutrients from vegetation to the soil occurs through litter fall, and litter plays the key role in nutrient cycling in the forest ecosystem (Vitousek *et al*. 2010). Litter production, as well as the concentrations and returns of nutrient elements in litter fall varies under different conditions, such as tree species (Hermansah *et al.*, 2002, Pragasan and Parthasarathy, 2005; Wood *et al.*, 2006). The mean dry weight of the leaf litter produced per day was 5.14 g/m^2. This value was within the range, as observed from other studies (Mohit and Appadoo, 2009; Abib and Appadoo, 2012). Litter production in this study was rather very high compared with the studies like Navarette and Rivera (2002); or Rajkaran and Adams (2010). However, the much higher litter production observed in this study could be attributed to the tree crown architecture of the studied species.

4. 2. Nutrient content in leaf litter

According to Clark *et al*. (2001), leaves are the main component of litterfall (around 75%) and contain the primary nutrients in a high amount after reproductive parts (Cuevas and Lugo, 1998). Research carried out by Bellingham *et. al.* (2013) further emphasize the percentage of leaf in the litter fall by stating that the leaf litter comprises 79% of the total litter fall. This study focused on the leaf litter portion of the litter fall. Therefore, amount of nutrient return to the soil or nutrient cycling depends on the leaf fall (Moraes *et al.*, 1999). Several studies have used elemental concentration to determine the nutrient status of plant. The elemental concentration of macro-nutrients were examined in this study. The result shows that the leaf litter contributes at 1.6-2.21% N, 0.26-0.33% P, 0.5-0.65% K, 0.8-1.22% Ca, 0.25-0.53% Mg, 0.1-0.18 % Na, with pH values equaling 8.7-9.1. According to Moya *et al*. (2012), N ranges between 1.7-2.3%, which is consistent with the findings of this study. The high concentration of nitrogen in the leaf litter may be due to the fact that the trees are young, and as such, require a high concentration for their fast growing stage. The concentration of N was higher than other nutrients analysed in the study, contrary to the findings of Muoghalu *et al*. (1993) and Ndakara (2012) whose results revealed that Ca had the highest concentration in isolated stand compared to other nutrients. Results of the adjoining rainforest in the study of Ndakara (2012) and Perez *et. al.* (2003) corroborate findings of this study. This variation may be due to the effect of age and species. Studies have shown that the nutrient concentration varies with age of the tree and it is considered to be a general trend in the plant nutrition (Barker and Pilbeam, 2006; Yuan *et al.*, 2007). Generally, studies have shown that the litter fall production and its nitrogen concentration is higher in tropical regions.

4. 3. Relationship between tree growth variables

Diameter at breast height had a positive correlation with the tree growth variables. The result is in agreement with other studies that show a positive correlation of girth size with the tree height (0.378). It therefore implies that taller trees possess wider diameter and vice versa, which in turn protects the tree against a wind throw. From the results, it was observed that the trees with larger DBH had larger crown. Research has shown that the development of wider canopy helps to maximize the light interception and increase the photosynthetic efficiency which translates to increase the food store, possibly accounting for the wider girth in these trees. This relationship has been established in other studies, involving other species, such as *Acacia nilotica*, *Azadirachta indica*, *Delonix regia*, *Khaya senegalensis*, (Arzai and Aliyu, 2010). The positive weak correlation of the leaf litter with tree height is an indication that the leaf litter production varies with the tree height which is directly related to the girth size and crown cover.

4. 4. Relationship between tree growth variables and nutrients in leaf litter

The result from this study reveals that litter production is related with the nutrient content in leaf litter. Ndakara, (2012) also observed a similar trend in his work where all the nutrients (N, P, K, Ca, Mg, Na) had a high positive relationship with the litter production in the study site. According to Barker and Pilbeam (2006), N is related to the plant litter production. The high nutrient content observed in the leaf litter and its positive relationship with quantity of litter produced was an indication of its importance in the process of nutrient cycling. It can therefore be said that the leaf litter production by the stands helps to improve the soil nutrient status characteristics underneath the tree stands in the process of nutrient cycling. However, the amount and contributions of nutrients to the soil is an indication of the tree species effectiveness in the management of the ecosystem.

5. CONCLUSIONS

Litter fall measurement has been a standard non-destructive technique for assessing the productivity, phenology, and turnover of biomass in a forest ecosystem. Nutrient concentration in litter is considered a useful parameter to evaluate the nutritional status of a stand and as a reference to evaluate plantation fertilizer recommendations.

The leaf litter production of *Tectona grandis* in the studied site was high compared to other studies. The tree growth character, such as height, was related to the quantity of litter produced by the tree. It can be inferred from the study that the quantity of leaf litter produced influences the nutrient status of the litter. Generally, relatively high values of leaf litter nutrients are required to maintain an appropriate nutritional status in teak and to ensure forest productivity and sustainability.

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