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LEAF LITTER PRODUCTION OF *Diospyros crassiflora* (Hiern–FWTA) IN AN AGROFORESTRY ECOSYSTEM IN OKWUTA-IBEKU, UMUAHIA, ABIA STATE, NIGERIA

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ABSTRACT

The study of the leaf litter production of Diospyros crassiflora in an Agroforestry ecosystem in Okwuta-Ibeku, Umuahia, Abia State, Nigeria was conducted in the Humid Forest Research Station, Forestry Research Institute of Nigeria (FRIN). A Randomised Complete Block Design (RCBD) with three replicates was used to study the mean monthly leaf litter of Diospyros crassiflora in 4/5 years old plantation. The leaf litterfall was collected from January-December in 2016 and in 2017. Three 1m x 1m leaf litter trays were randomly positioned in each block (10m x 25m). Leaf litter was collected from block and placed in paper bags every 28th day of each month. The result of the mean leaf litterfall values of January, November and December, 2016 were not significantly different from each other. November, January and February, 2016 had leaf litterfall similar values. December2017 had significantly highest leaf litter production. Although leaf litter was produced throughout the periods of study (2016 and 2017) in Diospyros crassiflora plantation, there was much of the leaf litter falling between the dry season months of November to March. The D. crassiflora leaf litter should be conducted in matured/aged D. crassiflora plantations in different ecological zones in Nigeria and other regions.

Keywords: *Diospyros crassiflora*, leaf litterfall, plantations, agroforestry ecosystem

INTRODUCTION

Litter production and decomposition are key processes in biogeochemical process of forest ecosystem and varies with climate, season, substrate quality, and type of biota (Bisht *et al.*, 2014). Plants generally grow both in natural forest and forest plantations in the tropics. The condition of plant habitats affects leaf litter production. Forest plantation establishes the major pathway for recycling of nutrients in soil system through litterfall (Bubb *et al.*, 1988). Fast growing exotic plant species are used for soil erosion control, leaf litter production and for fuel wood production in Nigeria (Ogbonna and Nzegbule, 2010). According to Manuel *et al.*, (2005), plant litter comprises:(a)dead leaves, bits of barks or other plant matter; (b)mixtures of fallen and dead materials on the forest floor which are made up of leaves, barks, stems and branches; (c)leaves that have fallen from a plant due to seasonal changes or diseases. Clarke and Paul (1970) described plant litter as non-living materials, morphologically recognizable as of plant origin, composed mainly of dead parts and other fallen plant organs lying on the surface of the soil but not standing dead matter. Leaf litter is the main shelter for small animals which include insects, centipedes, isopods and other micro- organisms.

Leaf litter on the soil surface intercepts and stores a certain amount of rainfall and hence reduce run - off and soil erosion on the forest floor. On the forest floor, litter is the imperative link between the autotrophs and heterotrophs (Bray and Gorham, 51964). It reduces bulk density, increases water holding and cation-exchange capacity of soil and serves as reserve store of plant nutrients (Ogbonna and Nzegbule, 2010 and Longman, 2007). Forest litter is an important stage in habitat conservation providing nutrient return and organic matter replenishment (Ogbonna *et al.*, 2010). The standing state of litter provides an estimate of the net production of the vegetation. Besides having enormous utilities to the ecosystem, the litter paradox yet needs to be explored. It is a common phenomenon that litterfalls throughout the year in most trees, and that most trees shed more of their leaves during

the dry season, rather than the wet season. According to Ogbonna and Nzegbule (2010), although litter falls throughout the year, there is usually a distinct seasonal trend, with much of the litter falling between March and April particularly in the pure *Pinus caribeae* stand. The months of March and April are within the dry season which is characterized with low relative humidity, and great fluctuations in diurnal temperatures (Ogbonna and Nzegbule, 2010). The seasonal characteristics probably favour the increase in litterfall. In pure *Gmelina arborea* stand, litterfall peak is in the month of September. This trend is due to heavy rainstorms that promote dislodgement of more litter materials

Agroforestry system is characterized by selective thinning of the forest prior to the establishment of utilizable forest food seedlings, for example, cacao (cabruca) (Rice and Greenberg, 2000). The peak period of litterfall in cabruca systems corresponded to the leaf-drop cycle of cacoa trees in October. Forest systems also experience peak litterfall from October through December, in accordance with the observations of native forests by Mori *et al.* (1983). Litterfall and litter accumulation are usually continuous throughout the year in the tropics, but are often characterized by seasonal peaks (Okeke and Omaliko, 1994). This implies that there is a relationship between the time of highest wind speed, associated with the dry season and also period of highest rate of litterfall accumulation.

The pattern of litter production varies from plantation to plantation, and also from species to species. Polgkase and Attiwill (1992) noted that the differences are attributed to the species composition of the stand which influences the pattern and quantity of litter and characteristics of litter. Evergreen forest vegetation, for example, pine plantation, produces more litter than deciduous forest vegetation (Vogt *et al*., 1986). The monthly litterfall production pattern is mainly controlled by community characteristics and environmental factors. Seasonal changing in pattern of productivity is correlated with climatic factors prevailing in the zone (Zafar *et al*., 2012). The seasonal pattern of litterfall differs among forests but a consistent pattern of bulk litter fall during spring is found for all forests (Yu *et al.*, 2005).

This shift is important to understand leaf litter production patterns along forest development stages and environmental gradients. For example, based on several studies in litter production from world forests, Bray and Gorham (1964); Albrektson (1988) noted that annual litter production increases rapidly during stand development until canopy closure, and then remain relatively constant over a long period of time before it decreases in old stands. Based on this established facts, the study of leaf litter production of *Diospyros crassiflora* (African Ebony) in 4/5 years old plantation in Okwuta-Ibeku, Umuahia, Nigeria was conducted to monitor the trend on the study species.

MATERIALS AND METHODS

Study Area

This study of leaf litter production of *Diospyros crassiflora* (African Ebony) in an agroforestry ecosystem was conducted in Okwuta-Ibeku,Umuahia, Abia State, Nigeria. The study location was in the Humid Forest Research Station, Forestry Research Institute of Nigeria (FRIN), Umuahia North Local Government Area, Abia State, Nigeria. Okwuta-Ibeku, Umuahia is located at kilometres five (km 5) along the Umuahia / Ikot Ekpene highway. It is within the lowland rainforest (Keay, 1959) on latitude 05^{o} $29^{'}$ N and longitude 07^{o} $33^{'}$ E (Nwankwo *et al.*, 2009; Njoku and Ebeniro, 2009); 122m above sea level in 2016 and 2017. Figure 1 shows the Map of Abia State, Nigeria and the study site (Okwuta – Ibeku, Umuahaia). The soil type is Ultisol which ranges from sandy loam to sandy clay-loam (Nwankwo *et al.*, 2009). Umuahia has the following mean annual climatic data: rainfall: 2238mm, maximum and minimum temperatures: 32^{o}C and 23^{o}C respectively, and relative humidity: 65 -80% (Source: Metrological Station, NRCRI, Umudike, Nigeria (2016)).

The vegetation of the study site within the Humid Forest Research Station, according to Ariwaodo, (2017) has the following plant species: *Bambusa vulgaris* (Poaceae), *Milletia aboensis* (Papilonaceae), *Rauvolphia vomitoria*,(Apocynaceae), *Tabernae montata pachysiphon* (Apocynaceae), *Elaeis guineensis (*Arecaeae), *Alcornea cordifolia* (Euphurbiaceae), *Anthoncliesta djalonensis* (Loganiaceae), *Mallotus oppositifiolius (*Euphorbiaceae), *Antiaris africana* (Moraceae), *Combretum* spp(Combretaceae), *Lonchocarpus cyanescens(*Loganiaceae*)*, *Palisota*

hirsute (Commelianaceae), *Massularia acumminata (*Rubiaceae), *Macaranga barteri* (Euphorbiaceae), *Dalbergia melanoxylon* (Papilonaceae),*Melicia excelsa* (Meliaceae), *Entandrophragma angolense* (Meliaceae) and *Carpolubia lutea* (Polygalaceae).

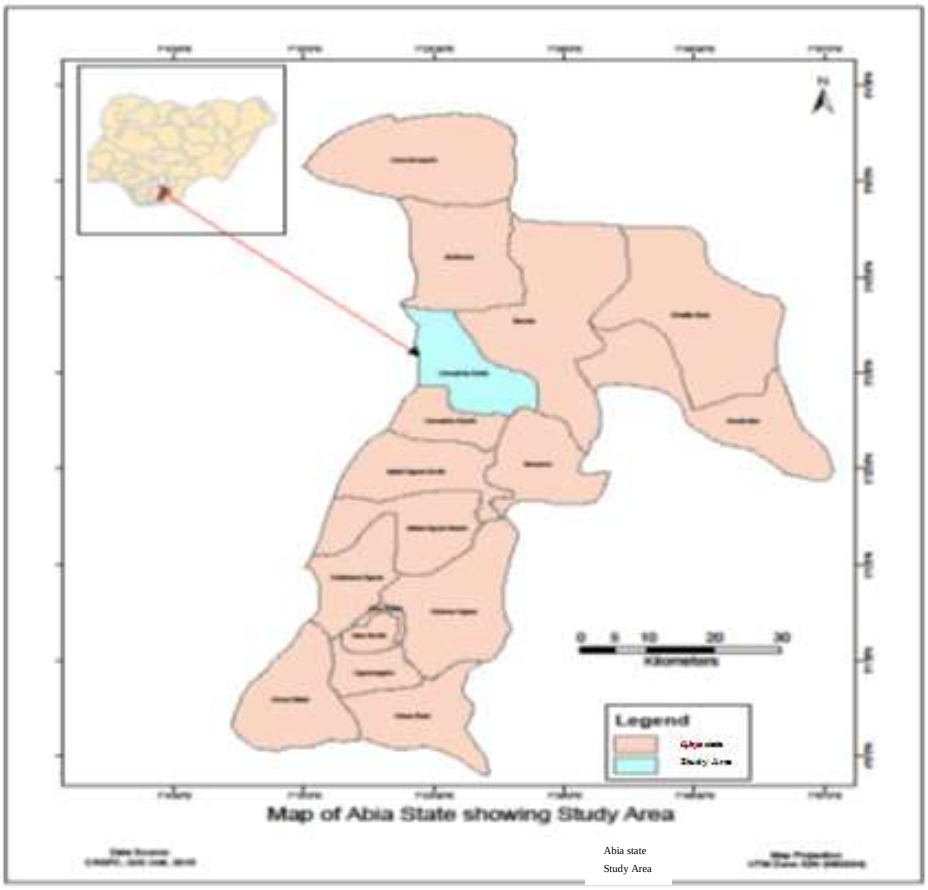

Figure 1: Map of Nigeria, Abia State, and Umuahia North Local Government Area (LGA) showing the Study Site at Okwuta-Ibeku.

Experimental Design

A Randomised Complete Block Design (RCBD) with three replicates was used to study the mean monthly leaf litterfall of *Diospyros crassiflora*. Three 1m x 1m trays were randomly positioned for collection of leaf litter production from 4/5 year old *Diospyros crassiflora* species in each block (10m x 25m).

Data Collection

Leaf litter was collected from each of the three litter trays per block and placed in paper bags every 28th day of each month from January-December in 2016 and in 2017.The monthly collected leaf litter was oven-dried at 70^{o}C for 48 hours at the Laboratory of the Department of Forestry and Environmental Management, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria. The oven-dried leaf litters per litter tray were weighed to obtain the total litter production each month.

Data Analysis

The data obtained from the leaf litter production (kg ha^{-1}) study was statistically analyzed using Analysis of variance (ANOVA), and the Fisher's Least Significant Different (F-LSD) at $p \leq 0.05$ was used to separate mean according to the procedures of Steel and Torrie (1980) and Alika (2006).

RESULT

Table 1 and graph below shows that December, 2016 had significantly higher mean monthly leaf litter (15.32 kg ha $^{-1}$) of *Diospyros crassiflora* than months of February, March, April, May, June, July, August, September and October, 2016. November, January and February, 2016 had similar leaf litterfall values. However, the November, 2016 leaf litterfall value was significantly higher than the leaf litter results of March, April, May, June, July, August, September and October, 2016 in Table 2. The leaf litterfall

result of January, 2016 was similar ($p \leq 0.05$) to the leaf litterfall rates of February and October, 2016. However, the leaf litterfall rate of January, 2016 was significantly higher than those of March, April, May, June, July, and August, 2016. The leaf litterfall values of February, 2016 was higher ($p \leq 0.0\ 5$) than those of June, 2016. However, the litterfall rates of February, March, May, August, September and October, 2016 were similar. October, 2016 had higher ($p \leq 0.05$) leaf litterfall value than June, 2016. The leaf litter values of October, March, April, May, July, August and September, 2016 were not significantly different from each other. The leaf litterfall rates of July, September, August, May, March, April and June, 2016 were statistically similar. Table1 shows that the dry season months (November, December and January, February, 2016) had significantly higher leaf litterfall rates than the rainy season months of March, April, May, June, July, August, September, and October in 2016.

Table 1 and graph below also shows that December, 2017 had significantly the highest leaf litter production. January, 2017 had higher ($p \leq 0.0\ 5$) leaf litter production than March, April, May, June, July and August in 2017. However, January had similar ($p \leq 0.05$) leaf litter values as February, September, October and November in 2017. November in 2017 had higher leaf litter production than April and July. However, November, 2017 had statistically similar leaf litter production value with February, March, May, June, August, September and October. The leaf litter production values of February, March, April, May, June, July, August, September and October in 2017 were not significantly different from each other.

Table 1: Monthly leaf litter production of *Diospyros crassiflora* plantation between 2016 and 2017 at Okwuta - Ibeku, Umuahia, Nigeria

Time (month)	Mean monthly leaf litter production over time (kg ha^{-1})	
	2016	**2017**
January (ds)	10.52	28.70
February (ds)	7.48	16.10
November (ds	11.58	22.70
December (ds)	15.32	59.70
March (rs)	2.71	11.30
April (rs)	1.98	4.80
May (rs)	3.17	6.60
June (rs)	0.87	6.90
July (rs)	4.21	5.40
August (rs)	3.45	8.70
September (rs)	3.45	12.70
October (rs)	6.03	13.00
Total	**70.56**	**196.60**
F-LSD	**4.91**	**16.85**

(ds = dry season; rs = rainy season)

Table 2: Analysis of variable (ANOVA) of Monthly leaf litter production of *Diospyros crassiflora* plantation between 2016 and 2017 at Okwuta- Ibeku, Umuahia, Nigeria

Year	SOV	df	ss	ms	f-tab	f-cal
2016	Month	11	658.245	59.840	7.13	<.001*
	Rep.	2	59.241	29.620	3.53	
	Residual	22	184.716	8.396		
	Total	**35**	**902.202**			
2017	Month	11	7841.60	712 .87	7.20	<.001*
	Rep.	2	63.10	31.55	0.32	
	Residual	22	2177.53	98.98		
	Total	**35**	**10082.24**			

**= significant different*

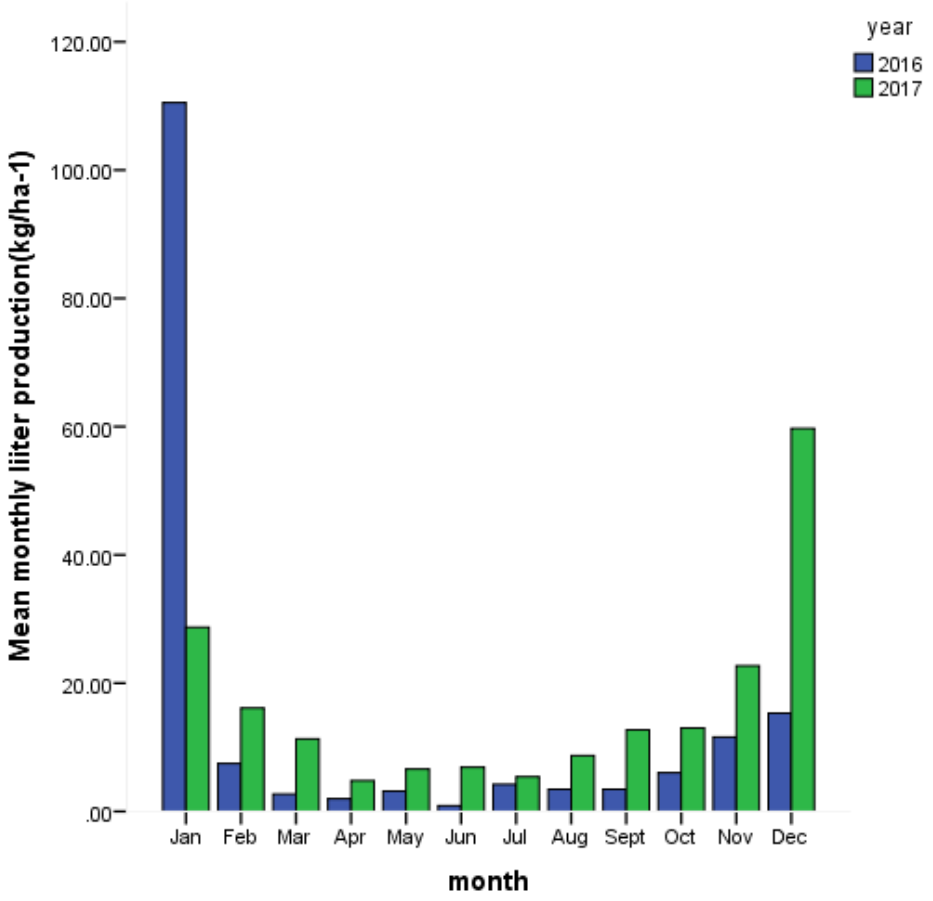

Figure 2: Graph showing monthly leaf litter production of *Diospyros crassiflora* plantation between 2016 and 2017 at Okwuta- Ibeku, Umuahia, Nigeria

DISCUSSION

Although leaf litter was produced throughout the periods of study (2016 and 2017) in *Diospyros crassiflora* plantation, there was a distinct seasonal trend with much of the leaf litter falling between the dry season months of November to March. This is in line with the reports of Otorokpo (2012); Ogbonna and Nzegbule (2010); IIoyanomon and Ogunlade (2009); Ekpendu, (2003) and Okeke and Omaliko (1992).The dry season months of November to March impact heavily on leaf litter fall of evergreen woody species. These months of peak leaf litter production are periods of intensive water stress, low moisture content, high temperatures and low relative humidity in south – eastern Nigeria. These features of low moisture contents, low relative humidity and high temperature regime usually lead to increased leaf senescence and increased leaf litter fall.

Bisht *etal.* (2014) reported marked seasonal variations in the amount of litterfall (leaf litter and non leaf litter), with the higher rates during the summer rainy season compared to autumn-winter in the study of Sub-alpine Forest Communities of the Northwest Himalaya. The bimodal annual leaf litterfall of *Diospyroscrassiflora* in the Humid Forest Research Station, Umuahia, Nigeria is in line with the findings of Otorokpo (2012) and Okeke and Omaliko (1992) in the *Entandrophragmacylindricum* at Swamp Forest Research Station, Onne, Rivers State, Nigeria and *Dactyladeniabarteri* bush fallow in Nsukka, Enugu State, Nigeria respectively. The patterns of leaf litterfall in *D. crassiflora* plantation in 2016 and 2017 were unique, due to similar trends of leaf litter production. The bimodal pattern of the leaf litterfall of *D. crassiflora* also contradicts the findings of Yang *et al.*(2003) in *Casanopsiskawakami* in sub-tropical China where leaf litter fall followed a unimodal distribution pattern with a distinct peak in April. Although, Umuahia is in the tropical humid/rain forest zone of Nigeria, the difference between the leaf litterfall patterns (manners) of *D. crassiflora* and *C. kawakami* could be due to seasonal modal distributional patterns.

The variations in climatic factors (rainfall, temperature, sunshine, wind and relative humidity) during the dryand rainy seasons also have significant influence on the leaf litter production of the *Diospyroscrassiflora* species within the study periods in 2016 and in 2017. This finding is in line withthe reports of Okeke and Omaliko (1994), Nzegbule and Mbakwe (2001), Ogbonna and Nzegbule (2010) and Otorokpo (2012). This variability of climatic factors further illustrates the reason for maximum leaf litter production of *D. crassiflora* during the dry season at the Humid Forest Research Station, Umuahia, Nigeria. Seasonal variations in litter production and litter nutrient return affect stand status (Xu and Hirata, 2002).

The total annual leaf litter production in 2016 (70.56 kg ha^{-1}) and 2017 (196.60 kg ha^{-1}) of *Diospyroscrassiflora* species obtained at Humid Forest Research Station, Umuahia- Nigeria within the study period is lower than those of Sub-alpine Forest Communities of the Northwest Himalaya (2950 kg ha^{-1}) (Bisht *etal..*, 2014), *Entandrophragmacylindricum* plantation obtained at Onne-Nigeria (6228.33 kg ha^{-1}) (Otorokpo, 2012), *Pinuscarribeae* and *Gmelinaarborea* (391.24 kg ha^{-1} and 625.12 kg ha^{-1}) at Umuahia (Ogbonna and Nzegbule, 2010), Chinese fir (*Cunninghamialanceolata*) (5470 kg ha^{-1}), *Kolanitida* (lloyanomon and Ogundale, (2009) and Yang *etal*., 2003) (5100 – 8200 kg ha^{-1}), *Irvingiawombulu* (9191 kg ha^{-1})(Ekpendu, 2003) and *Casuarinaglauca* (8480 kg ha^{-1}) (Clake and Alloway, 1996). The low values of annual leaf litter fall rates in 2016 (70.56 kg ha^{-1}) and in 2017 (196.60 kg ha^{-1}) may be attributed to the age of *Diospyroscrassiflora* species within the periods of study: 4 years in 2016 and 5 years in 2017. Litterfall and nutrient re-cycling in *Treculiaafricana* stand in southern Nigeria reported the production of total annual litter of 5759.6 kg/ha/yr, which is 458% greater than that by *Dactyledeniabarteri* in a work done by Okeke and Omaliko (1994) as reported by Nzegbule, (2018). The quantity was similar to that of *Pinuscarribaea* and *Gmelina arborea* stands (625.12g/m^2 and 391.24g/m^2) as reported by Ogbonna and Nzegbule (2010). In this study, increased litterfall production in 2017 (196.60 kg ha^{-1}) as compared to 2016 (70.56 kg ha^{-1}) could be due to increase of basal area and canopy cover in 2017. Basal area influences tree size, stand volume and biomass.Continuous litterfall rate in a young forest plantation results in large tree diameter, height and above ground biomass (Montagnini *et al.*, 1994).*Diospyros crassiflora* thus had a higher leaf litterfall production in 2017. This feature is in line with the reports of Starr *et al*. (2005) who noted that litterfall production in natural forest is influenced by stand basal area, age structure, stem volume, latitude, season and climatic factors.

CONCLUSION

The study showed that the leaf litter production of *D. crassiflora* plantation had confirmed the seasonality occurrence of leaf litter production in various tree species globally.

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