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Influence of Tree Characters and Climate on Litter Characteristics in *Daniellia oliveri* (Rolfe) Hutch. & Dalziel

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***KEYWORDS*: Climate, *Daniellia oliverii*, litterfall, nutrient cycling, savanna, tree characters.**

ABSTRACT: Litter production and decomposition rates have great importance in maintaining the fertility of the soil. The study was carried out to determine the relationship tree characters (girth size, canopy radius, tree height, leaf area and number of primary branches), litter production and quality, and climatic variables among stands of *Daniellia oliveri* (Rolfe) Hutch. & Dalziel growing in University of Ilorin campus. Twelve trees of different girth sizes were selected and their physiognomic characters measured. Litter samples (leaves and twigs) were collected from the stands on monthly basis (January to May) using 1 m^2 traps. The collected litters were air-dried, ground and analysed for carbon, nitrogen, phosphorus, potassium, calcium and magnesium using standard methods. Rainfall and temperature data were collected during the sampling months. Girth size range was 0.32 – 0.67 m. Tree height range was 13.90 – 31.81 m. Primary branches range was 3 - 16, crown radii was 2.5 - 5.2 m and leaflet area between 24.62 cm^2 and 90.90 cm^2. Higher leaf litter was recorded in January and February, but twigs were more in the other months. Leaf and twig litters positively correlated with girth size (r = 0.572 and 0.614 respectively), but the former also correlated with crown radii (r = 0.834). Carbon, calcium and magnesium contents in leaves and twigs were lower in May compared to January, but reverse trend were observed for nitrogen and phosphorus. The number of rain (rainy days) negatively correlated with total monthly litter (r = -0.291). The study concluded that climatic conditions influence tree characters, which in turn affect litterfall and nutrient returns to the soil. ©JASEM

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Introduction: Daniellia oliveri (Rolfe) Hutch. & Dalziel is a fast-growing light demanding deciduous tree in the family Fabaceae (Eggeling and Dale, 1951), predominant in southern guinea savanna belt of Nigeria. The tree originates from Senegal eastwards to Sudan and Uganda, and luxuriant in sandy well-drained soils typical of savanna ecosystems. *D. oliveri* flowers during the first half of the dry season from October to march usually when trees are leafless or when trees are developing new leaves and fruits from January to June. Its leaves, which are paripinnately compound, with the gum and bark have been extensively used for medicine (Schmelzer and Louppe, 2012). Disturbances from herbivores and seasonal fire expose the savanna ecosystem to nutrient loss (Cech, 2008). Fire as a non-selective herbivore consume available herbaceous materials and woody biomass produced during the growing seasons, depleting nutrient returns to the soil and affecting the composition of labile elements including nitrogen and phosphorus (Bond and Keeley, 2005). The fire-tolerant species, such as *D. oliveri*, cope with this condition and sustain the nutrient cycling of the ecosystem via litter deposition.

Litterfall is a major pathway for the return of organic matter and nutrients from aerial parts of the plant community to the soil surface (Odiwe and Moughalu, 2003), which fertlizes and protects ground surfaces from the scouring actions of rainfall, by reducing soil erosion (France, 1997). Litterfall measurement has been a standard non-destructive technique for assessing the productivity, phenology, and turnover of biomass in a plant community, where the biomass of the litter and its chemical content (including heavy metals) quantify the annual return of organic matter and nutrient elements to the soil (Perez *et al.*, 2003). Trees also improve the nutrient balance of soil by reducing unproductive nutrient losses from erosion and leaching and by increasing nutrient inputs through nitrogen fixation and increase biological activities by providing biomass and suitable microclimate (Schroth and Sinclair, 2003). The amount of nutrients returned from trees to the soil depends upon tree species, phenology, age and influence of climate, all of which determines litter fall from species to species (Liu *et al.*, 2004). Nutrient accumulation which is influenced by litterfall, changes the physical and chemical environments, affecting plant community structure, a processes linked through a positive feedback (Kitayama and Aiba, 2002). During prolong dry condition, plant-water relation is affected causing increased leaf drop and abscission of leaves and floral parts, as a means

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to retaining water (Cianciaruso *et al*., 2006). Strong winds, especially during the rainy season, also cause branch-falls, and abscission of immature fruit and leaves which constitute litter. The closed canopy in some vegetation could enhance moisture retention and delay leaf shedding thereby affecting litter.

Litterfall quantification and net nutrient returns has been the subject of many researches (e.g. Swamy and Proctor, 1994; Edmonds and Murray, 2002; Clark *et al*., 2001; Odiwe and Moughalu, 2003; Perez *et al*., 2003; Wood *et al*., 2006; Ostertag *et al*., 2008) but these studies focuses on contribution of heterogenous litter collection, in forest ecosystems or mixed plantations, rather than the nutrient return from a particular species. The present study relates the litter biomass in *Daniellia oliveri* to tree characters and climatic variables within the study location (Ilorin), and monthly variation of nutrients in the litter was also considered.

MATERIALS AND METHODS

Site Description: The study was conducted January - May, 2013 in Ilorin, Kwara State (18˚20'N, 65˚49'W) which falls within the Guinea savanna belt of Nigeria. The study site span an elevation range of 1000–1300 m with steep slopes, and characterized by wet and dry seasons. The annual rainfall in the area is about 1200mm (Olaniran, 2002). The average temperature varies between 33˚C and 34˚C during the year, with a distinct dry season from December to March (Ajadi *et al*., 2011). The study area is dominated by savanna tree species including *Daniellia oliveri*, *Vitellaria paradoxa*, *Prosopis africana*, *Parkia biglobosa* that are sparsely distributed.

Experimental Design: The experimental design was selective and based on proximity of the trees from each other, availability of varying girth sizes and spreading canopy. Twelve stands of *Daniellia oliveri* of varying girth sizes were selected for the study and tagged T1 to T12.

Data Collection: Tree characters such as girth size, height, number of primary branches, crown radii, and leaf area were determined. Girth size was measured using Quartre girth tape. Tree height was measured using clinometer. The number of primary branches was counted and the crown radius was determined from average measurement of canopy spread from two opposite sides of the trunk. The length (L) and breadth (B) of all leaflets from twenty (20) full-sized leaves per tree was measured using electronic Vernier calliper (Model Titan 23175). Area of each leaflet was calculated using the formula by Hoyt and Bradfield (1962) as: Leaf Area (Leaflet area), LA = L × B × 0.75. The average leaflet area was thus determined.

Litterfall was collected weekly using 1 m by 1 m traps suspended on 60 cm wooded pegs and placed directly under the tree canopy, in the north, east, west and south positions. The litter from each trap was sorted into leaves and twigs, air-dried and stored from January to May, 2013. The air-dried litters (leaves and twigs) were weighed per monthly collection, ground into coarse powder and analysed for organic carbon, nitrogen, potassium, calcium and magnesium.

Organic carbon content was determined using Walkley-Black wet oxidation method. Percentage nitrogen was determined using macro Kjeldahl method while phosphorus was by colorimetric method. Potassium, calcium and magnesium were determined with Bulk Scientific Atomic Absorption Spectrophotometer (Model - 210/211VGB) at 766.5 nm, 422.7 nm and 285.2 nm respectively after $HClO_4$-HNO_3 wet digestion. Meteorological data were collected from University of Ilorin Meteorological Station (Department of Geography), University of Ilorin, Ilorin.

Statistical Analysis: Pearson's correlation was used to determine the strength of the relationship between litter biomass (leaf and twig) and tree characters, as well as with rainfall and temperature data. Student's t-test was used to compare the biomass and nutrient for leaf and twig litter, and analysis of variance to compare the monthly variation in nutrient composition of the litter materials at 0.05 α-level.

RESULTS AND DISCUSSION

Girth size range was 0.32 - 0.67 m. Tree height was between 13.90 m and 31.81 m. Number of primary branches was between 3 and 16 while crown radii range was 2.5 – 5.2 m. Leaflet area was between 24.62 cm^2 and 90.90 cm^2 (Table 1). Generally, leaf litter were higher than twigs in January and February, but lower in March, April and May. There was no significant difference between the leaf and twig litters except in April (Table 2). There was significant positive relationship between girth size and tree height ($r = 0.597$, $P = 0.020$), between girth size and crown radii ($r = 0.834$, $P < 0.001$), as well as with leaf litter ($r = 0.572$, $P = 0.026$) and twig litter ($r = 0.614$, $P = 0.017$). Leaf litter also relates positively to crown radii ($r = 0.594$, $P = 0.021$). Leaflet area and number of primary branches were not related to girth size, crown radii and height (Table 3).

Table 1: Tree Characteristics in Stands of *Daniellia oliveri* in University of Ilorin Campus

Tree No.	Girth size (m)	Height (m)	No. of primary branches	Crown radii (m)	Leaflet area (cm^2)
T1	0.44	13.90	8	3.9	37.63 ± 10.43
T2	0.41	22.21	5	3.3	37.54± 15.40
T3	0.34	21.82	11	2.6	90.90± 14.43
T4	0.44	26.02	3	3.5	45.16± 4.06
T5	0.49	27.70	12	3.2	54.25± 10.83
T6	0.37	15.71	10	2.9	42.45± 5.67
T7	0.67	31.50	12	3.9	46.21± 5.93
T8	0.61	29.02	15	4.2	42.64± 5.08
T9	0.38	31.81	16	2.5	30.97± 6.85
T10	0.65	29.01	4	5.2	62.69± 9.53
T11	0.32	19.53	8	2.8	44.86±10.03
T12	0.42	24.40	3	3.6	24.62±3.81

Table 2: Leaf and Twig Litterfall from *Daniellia oliveri* from January – May, 2013

Tree No.	Sample	Monthly Litter (g)				
		Jan	Feb.	Mar.	Apr.	May
T1	Leaf	23.57	21.11	17.16	32.43	20.57
	Twig	28.72	15.79	45.14	16.16	18.36
T2	Leaf	33.28	25.37	10.91	11.68	13.65
	Twig	9.52	4.94	7.17	13.19	8.43
T3	Leaf	11.27	10.82	7.83	8.25	8.97
	Twig	1.68	8.35	22.25	22.36	20.31
T4	Leaf	23.22	21.43	11.85	11.57	10.95
	Twig	13.77	8.80	13.52	14.20	12.17
T5	Leaf	18.91	20.58	13.42	13.69	15.9
	Twig	6.42	7.81	8.45	11.01	9.09
T6	Leaf	42.37	33.37	13.73	14.67	14.92
	Twig	16.98	8.19	37.68	20.82	22.23
T7	Leaf	30.11	35.16	16.91	12.69	14.58
	Twig	98.77	117.09	11.94	16.93	18.65
T8	Leaf	43.15	86.74	11.73	14.70	13.73
	Twig	32.46	59.58	36.59	21.59	20.25
T9	Leaf	28.12	22.36	9.88	9.91	10.05
	Twig	18.91	15.14	15.21	35.36	21.90
T10	Leaf	29.08	60.20	7.56	15.02	13.60
	Twig	9.98	9.26	13.64	26.23	18.38
T11	Leaf	33.16	32.28	16.66	10.51	12.82
	Twig	7.75	7.724	14.38	14.91	13.34
T12	Leaf	16.33	24.88	11.85	9.44	11.39
	Twig	8.17	12.92	11.02	20.3	16.75
Mean	Leaf	27.71	32.86	12.46	13.71	13.43
	Twig	21.09	22.46	19.75	19.42	16.65
	p-value	0.419	0.390	0.069	0.042	0.061

Table 3: Pearson's correlation for the relationship in tree characters and litter materials

		Girth Size	Tree Height	No. of Primary Branches	Crown radii	Leaflet area	Leaf litter	Twig litter
Girth Size	Pearson's r	1	.597*	.085	.834*	.031	.572*	.614*
	p-value		.020	.397	.000	.462	.026	.017
Tree Height	Pearson's r		1	.302	.255	.004	.034	.309
	p-value			.170	.212	.495	.458	.164
No. of Primary Branches	Pearson's r			1	-.340	.095	.210	.482
	p-value				.140	.385	.256	.056
Crown radii	Pearson's r				1	-.016	.594*	.287
	p-value					.480	.021	.183
Leaflet area	Pearson's r					1	-.272	-.107
	p-value						.196	.370
Leaf litter	Pearson's r						1	.467
	p-value							.063
Twig litter	Pearson's r							1
	p-value							

*. Correlation is significant at the 0.05 level

The positive correlation of girth size with tree height is indicative of the taller trees possessing wider girths and vice versa. This proves a supportive mechanism against breaking, since tree trunk should be strong enough to withstand wind pressure and the tree's own weight (Fraser, 1962). The development of wider canopy helps to maximize light interception and increase photosynthetic efficiency (Jahnke and Lawrence, 1965) which translates to increase food store and possibly accounting for the wider girth in these trees. This is possible since photosynthates are regularly translocated to sinks (branches, trunk and roots) for storage from the source (leaves), where they are produced. This relationship has been established for some tree species including *Acacia nilotica*, *Adansonia digitata*, *Azadirachta indica*, *Delonix regia*, *Khaya senegalensis*, *Parkia biglobosa*, and *Cassia siamea* within the savanna ecosystem of Nigeria (Arzai and Aliyu, 2010). The positive correlation of litter (leaf and twig) biomass with crown radii is an indication that shedding of litter material varies directly with the size of the canopy. This is logical since leaves, twigs and branches form the main components of the canopy and determine its size. Leaf size, as well as those of leaflets for compound leaves, is influenced by factors including genetic, physiological and environmental. Deformities in leaves such as reduction in size, folding, twisting, decolouration, and change in nutrient composition have been attributed to genetic mutation, soil nutrient status, infection, environmental stress (Taylor and Parkinson, 1988), and establishing relationship of leaf size (or leaflet size) with some tree characters may be almost impossible at some point.

The higher leaf biomass in January and February is favoured by the dry spell. Under seasonal dry conditions, plants reduce transpiration through leaf shedding or stomatal closure (Singh and Kushwaha, 2005; Schwendenmann and Horna, 2012). Twigs, the small thin terminal branches of woody plants, are abscised just like leaves (Codder, 1999). During the onset of flowering and fruiting, the emergence and abscission of spurs (specialized short, stubby, side stem that may bear fruits) increases the twig litter. This may have accounted for the higher biomass of twigs to leaves from March to May, during the fruiting period of the tree.

There was significant difference in the percentage (g/100g) composition of C, N and Ca between leaf litter and twig litter across the months. In most cases, from January to March, nutrients in the leaves were higher than twigs. There was also significant variation in the composition of C, P, Ca and Mg on monthly basis. The percentage composition of C, Ca and Mg in leaves and twigs was low in May compared to January. The reverse was the case for N and P (Table 4). The variability in the composition some nutrients (C, N and Ca) in the leaves to that in twigs may be due to translocation of mobile nutrients (e.g. nitrogen) and the differential accumulation of immobile elements (C and Ca) in leaves (source) and twigs (sink). This is in line with the report of Taylor and Parkinson (1988) on the differential mobilization and accumulation of nutrients in aspen. There was also the variation of nutrients in the leaves with month of collection. Strikingly, C, Ca and Mg had significantly lower concentration in May compared to January, except for P. This is however contrary to the belief that collection in rainy month will have higher nutrient content, due to storms increasing the rate of fall of premature leaves, before senescence is complete or even begun, resulting in litter with much higher nutrient content (Taylor and Parkinson, 1988).

Table 4: Nutrient composition in g/100g of leaf and twig litter of *Daniellia oliveri*

		Nutrient (g/100g litter)					
Month	Sample	C	N	P *	K	Ca	Mg
January	Leaf	8.34	1.12	0.78	0.65	3.42	0.24
	Twig	6.17	0.87	0.81	0.47	1.15	0.23
February	Leaf	4.40	1.27	0.59	0.54	2.52	0.17
	Twig	6.40	0.74	0.46	0.44	1.29	0.19
March	Leaf	6.67	1.44	0.60	0.40	0.75	0.19
	Twig	5.27	0.95	0.45	0.35	0.27	0.19
April	Leaf	6.65	1.40	0.30	0.24	1.08	0.20
	Twig	5.27	0.87	0.41	0.32	1.04	0.26
May	Leaf	4.56	1.15	2.60	0.19	1.06	0.16
	Twig	5.08	0.93	3.20	0.76	0.77	0.23
[a] leaf × twig		0.036	0.000	0.843	0.435	0.030	0.069
[b] month × nutrient		0.026	0.752	0.000	0.182	0.013	0.044

* %P is times 10^{-2}

a and *b* are significant values (p-values) for t-test and f-test respectively.

It rained once in both January (19.0 mm) and February (20.8 mm), while April and May had 12 rains with 173.2 mm and 44.6 mm respectively. Maximum temperature ranges was 32.0 – 35.3 ˚C (Table 5a). There was no correlation between total litter with either rainfall or temperature, except with the number of rain (rain days) where negative correlation exist (r = -0.291, *P* = 0.001) (Table 5b).

The amount of precipitation and temperature range during the study did not deter litter biomass, but for the number of rain days. This is attributable to the impact of the rain drops on increasing leaf fall (Sykes and Bunce, 1970) and changes in environmental conditions that precedes or follows. Rainfall in tropics is often preceded by extreme air temperatures, which is implicated by Black and Mack (1984) to promote leaves drop. Weak tree tissues possess cells which can be broken and ripped away by the slightest influence of external factors such as gravity, wind, heat, precipitation, and contact from herbivores. Transition from dry season to rainy season usually stimulate or create some shear force in the abscission zone of the leaves (Coder, 1999).

Conclusively, tree characters such as crown radius and girth size greatly determine the quantity and quality of litter. Since the luxuriance and phenology dictates the amount and period of leaf (or twig) drop. The role of climate which varies among the months of the year cannot be over-emphasized as it affect the physiological processes in trees such as growth (and appearance of trees), nutrient partitioning between source and sink, senescence and subsequent abscission of old leaves, as well as the premature shedding of leaves due to impact from stormy rains or turbulent winds. The study concluded that climatic conditions influence tree characters, which in turn affect litterfall and the net nutrient returns to the soil.

Table 5a: Rainfall and Temperature Data from January –May 2013 in University of Ilorin Campus

Month	No of rain days	Maximum temp (^{0}C)	Minimum temp (^{0}C)	Mean monthly rainfall (mm)
January	1	33.8	23.4	19.0
February	1	34.4	23.6	20.8
March	8	33.9	25.6	44.8
April	12	35.3	23.9	173.2
May	12	32.0	18.0	44.6

Table 5b: Pearson's correlation for total litter against rainfall, rain days and temperature.

		Total litter	Rainfall	Rain Days	Temp.
Total litter	Pearson's r	1	-.156	-.291*	.090
	p-value		.089	.001	.326
Rainfall	Pearson's r		1	.671*	.271*
	p-value			.000	.003
Rain Days	Pearson's r			1	-.334*
	p-value				.000
Temp.	Pearson's r				1
	p-value				

*. Correlation is significant at the 0.05 level

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