Litter fall and macronutrients return of *Millettia thonningii* [Schumach and V Thonn.]Bak and *Pterocarpus santalinoides*[L' Herite, ex Dc.] stands in south-western Nigeria

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ABSTRACT

The patterns of litter fall and macronutrients return were assessed for two indigenous tree legumes; *Millettia thonningii* and *Pterocarppus santalinoides* in 24 months. Annual litter fall of *Millettia thonningii* was 8.7 t/ha/yr and was not significantly different (P=0.05) from that of *Pterocarpus santalinoides* (7.1 t/ha/yr). Seasonal variation of litter fall showed that *Millettia thonningii* had its peak period of fall from November to January (886 –746 kg/ha) while peak period for *Pterocarpus santalinoides* was from October to December (962–807 kg/ha). Nutrient concentration of leaf litter of these species showed that the concentration of N, P, and K decreased, while there was an increase in Ca and Mg concentrations. *Millettia thonningii* and *Pterocarpus santalinoides* leaf litters retranslocated 40-49% and 48-60% respectively of N P K nutrient elements before leaf fall. Mean annual nitrogen return from the litter fall to the surrounding soils was about 180 kg N /ha/yr for *Millettia thonningii* and 125 kg N/ha/yr for *Pterocarpus santalinoides* stands. Nutrient turn over from litter fall of both species was of the following order: Ca >K> N > Mg > P. The nutrients (N, P, K, Ca and Mg) turn over from litter fall was higher in *Millettia thonningii* than *Pterocarpus santalinoides.*

Key words: Litter fall, macronutrients, retranslocation and nutrient cycling

RESUME

Les modes de chutte de feuilles et de régénération des macro éléments nutritifs de deux types de légumineuses locales: *Millettia thonningii et Pterocarpus santalinoides* ont été étudiés au cours d'une période de 24 mois. Le taux de chutte annuelle des feuilles de *Millettia thonningii* était de 8.7 t/ha/an; ce taux n'était pas statistiquement différent de celui de *Pterocarpus santalinoides* (7.1 t/ha/an). La variation saisonnière indique que, la haute péroide de chutte des feuilles de *Millettia thonningii* est comprise entre novembre et janvier (886-746kg/ha), alors que celle de *Pterocarpus santalinoides* se situe entre octobre et decembre (962-807kg/ha). La concentration des élément nutritifs dans les feuilles de la litière a montré que les pourcentages de N, P et de K décroissaient alors que ceux de Ca et Mg augmentaient plutôt. La retranslocation des éléments nutritifs N, P et K des litières de *Millettia thonningii* et de *Pterocarpus santalinoides* était de 40-49% et de 48-68% respectivement. La moyenne annuelle d'azote retenu dans la litière au sol était de 180 kg N/ha/an pour *Millettia thonningii* et de 125 kg N/ha/an pour *Pterocarpus santalinoides.* Le rendement des éléments nutritifs de la litière des deux éspèces végétales était par ordre décroissant de Ca>K >N>Mg>P. D' autres parts, le rendement des éléments nutritifs (N,P,K,Ca et Mg) de la litière de *Millettia thonningii* était plus élévé que celui de *Pterocarpus santalinoides.*

Mots clés: Chute des feuilles, Macro-éléments nutritifs, Retranslocation et cycle des nutriments

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INTRODUCTION

Litter fall is the main tenet of nutrient cycling processes in the forest or woodland ecosystems. Large quantities of plant nutrients are taken from the soil by trees and could be returned to the soil through litter fall. However species vary extensively in their capacity to take-up and recycle plant nutrients. Trees have the potentials to enhance soil fertility either through biological nitrogen fixation (BNF) or litter fall due to their greater root volume and ability to capture nutrients at lower sub-soils (Garrity and Mercado 1994, Ingram 1990, Ghuman and Lal 1990, Adam and Attiwill 1986 and Ewel 1976). Nevertheless, variations of litter-fall do occur from year to year even at the same spot (Owen 1954, Tarrant et al 1951). In the case of tree plantations, there is a general belief that trees have great demand on soil nutrients and therefore rotation of species on different sites is necessary to reduce deterioration due to imbalance of nutrient input and output in the area or site (Nwoboshi 1970). In the case of the forest ecosystem, maintaining a stable productivity, requires stable nutrient cycles that form an equilibrium between the tree and soil (DeAngelis 1992). There are two vital mechanisms by which trees minimize the loss of nutrients from the ecosystems. Firstly, there is retranslocation of mobile nutrients from the renewal parts into the permanent structures for internal reuse (Vitousek 1982). Secondly the plants should have an efficient system of absorbing nutrients mineralised from the decomposition of litter (Knops et al 1997; Jordan and Herrera 1981).

Millettia thonningii and *Pterocarpus santalinoides* are indigenous leguminous tree species found in the forest and fallow lands of west and central Africa. These species have medicinal uses, for example, the roots and the bark of *M. thonningii* when boiled is used as a blood purifier while the leaves, bark and seeds of *P. santalinoides* are very good antiseptics used in washing cuts or wounds (Abbiw 1990). Being leguminous species, their nodulation activities enhances soil fertility through biological nitrogen fixation (BNF). These tree species are being actively evaluated for possible incorporation into agroforestry systems (Egbe 1997). Their role in maintaining soil fertility in agroforestry systems depends on BNF on one hand and the accumulation of organic matter in the soil through litter fall on the other hand. However, information on the litter fall pattern, quantity and quality is grossly lacking for these species. This study was therefore designed to elucidate on the litter fall pattern of these species as well as quantify the macronutrients return to the soil under two monoculture tree plantations.

MATERIALS AND METHODS

This experiment was carried out at IITA main station in Ibadan (7° 30' N; 3° 45' E and altitude of 224 m) southwestern Nigeria. This site has a mean annual rainfall of 1360 mm and the rainfall pattern starts from late March and ends in early November, with a short break in mid-August. The peak periods of rain are from late May to early August and from September to mid-October. The mean annual temperature is 28.5°C and the relative humidity had a range of 67-85 % and the soil type is an Alfisol (Oxic paleustalf).

The litter traps used were made of wooden frames and wire-mesh with mesh size of 2 mm to allow free drainage of rainwater. The traps were 50 x 50 x 15 cm in size and suspended from wooden stands 30 cm from the ground. The traps were randomly placed under the stands of *P. santalinoides* and *M. thonningii* which were more than 11 years old and had a spacing of 2 m x 4 m. The stands of *P. santalinoides* and *M. thonningii* were demonstration plots and each had an area of 1200 m^2. This area was subdivided into three and each part had an area of 400 m^2 and 12 litter traps were used for each species. Litter fall was collected every two weeks, air-dried, and sorted into leaves, twigs and reproductive structures (flowers, flower buds, fruits and seeds). Some green leaves were sampled from top and middle of the trees twice in a year; at three months after flushing when most of the leaves were matured and just before peak fall of their leaf litter.

These materials were oven dried at 60°C for 72 hours for the leaves and the reproductive structures while the twigs were oven dried at 80°C for 48 hours. The oven-dried samples were weighed and 20 – 50 g of the bulk sample for each plant part in a month was milled to powder with a Wiley mill, sieved with a 0.2 mm sieve, and analyzed for macronutrients. Nitrogen was analysed by micro-Kjeldahl method (Bremner, 1965). The samples were digested with concentrated nitric acid and hydrochloric acid for Ca, Mg, K, and P determination (Blanchar et al; 1965). Phosphorus concentration in the digest was determined with Technicon autoanalyzer while Mg and Ca were determined by atomic absorption spectrometer. Potassium was determined by flame emission in the Perkin-Elmer 5000 spectrophotometer (IITA, 1982). The data collected was subjected to analysis of variance using SAS (1985) and the mean separation was carried out with Duncan Multiple Range Test (DMRT) at a probability of 5% level. Percentages were also used for the interpretation of results.

RESULTS

Seasonal variation of litter fall

Figures 1a and 1b show the monthly pattern and the peak periods of litter fall of *M. thonningii* and *P. santalinoides*. Seasonal variation is the monthly means of the two years of observation (Table 1a and 1b). The peak periods of leaf fall for *P. santalinoides* was from October to December (962 –807 kg/ha) while that of *M. thonningii* was from November to January (886 –746 kg/ha). The least leaf fall of *P. santalinoides* was in March and in June for *M. thonningii*. The highest twig fall in *M. thonningii* was in January (269 kg/ha) while for *P. santalinoides* it was in February and April (202 kg/ha). The least twig fall for both *P. santalinoides* and *M. thonningii* was in August (53 kg/ha) and (50 kg/ha) respectively. The fall of reproductive structures had a range of 735 –12 kg/ha for *M. thonningii* and 264 – 12 kg/ha for *P. santalinoides*. The highest fall in reproductive structures was in December for *M. thonningii* and February for *P. santalinoides*. Least fall in reproductive structures of these species was in August and October for *M. thonningii* and *P. santalinoides* respectively.

Annual litter fall

Table 1a and 1b, show the mean annual litter fall of *M. thonningii* (8.7 t/ha/yr). This was not significantly different (P=0.05) from that of *P. santalinoides* (7.1 t/ha/yr). Leaves contributed about 48% of the total litter fall in *M. thonningii* and 60% for *P. santalinoides* stands. Twigs and reproductive structures of *M. thonningii* contributed about 20% and 31% respectively of the total litter fall. The contribution of twigs and reproductive structures of *P. santalinoides* to the total litter fall was about 21% and 19% respectively.

Fig. 1a

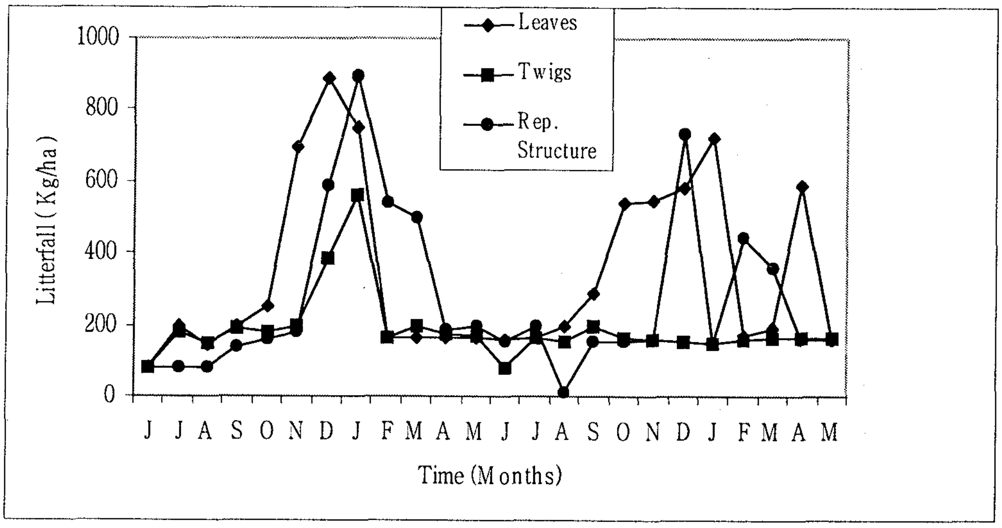
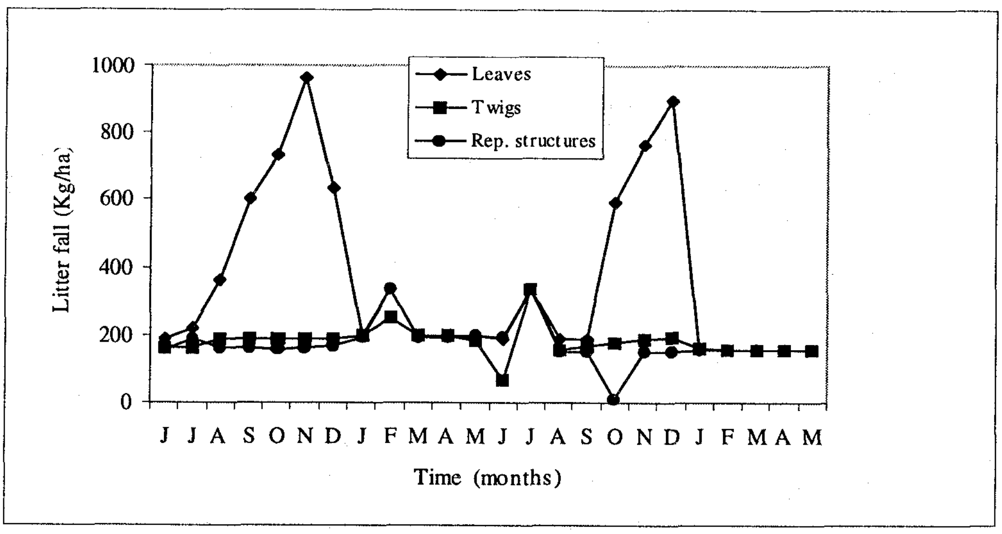


Fig. 1b



Figs Ia and 1b : Monthly variations of litter fall of a) *Millettia thonningii* and b) *Pterocarpus santalinoides* at Ibadan, south-western Nigeria.

Table 1a: Seasonal variation of litter fall of *Pterocarpus santalinoides* in South-western Nigeria. (Kg/ha).

Time(Months)	Leaves	Twigs	Reproductive structures	
January	177.1 efg	150.4 a	126.9 bcd	
February.	214.6 efg	201.8 a	288.6 a	
March	103.8 g	112.6 a	74.69 edf	
April	149.2 efg	202.0 a	118.8 bcde	
May	134.3 fg	101.5 a	203.7 abc	
June	127.5 fg	66.4 a	102.8 cdef	
July	274.8 e	180.6 a	220.2 ab	
August	239.3 ef	52.8 a	123.0 bcd	
September	396.7 d	94.7 a	11.6 ef	
October	656.0 c	108.3 a	3.8 f	
November	962.3 a	119.7 a	14. 6 edf	
December	807.1 b	151.0 a	38.8 edf	
Total	4242.7	1541.8	1327.49	= 7.11 t/ha/yr

DRMT 5%
Means in th same column with the same letter(s) are not significantly different.

Table 1b: Seasonal variation of litter fall of *Millettia thonningii* in south-western Nigeria(Kg/ha)

Time(Months)	Leaves	Twigs	Reproductive structures	
January	746.2 ab	269.3 a	496.0 ab	
February.	129.5 bc	120.1 ab	451.3 ab	
March	119.7 c	204.0 ab	370.8 ab	
April	327.4 abc	140.3 ab	126.3 b	
May	104.7 c	147.2 ab	131.8 b	
June	87.1 c	74.9 ab	72.0b	
July	171.9 bc	123.8 ab	150.4 b	
August	148.4 bc	50.4 b	12.2 b	
September	284.5bc	100.0 ab	48.0 b	
October	443.7 abc	140.0 ab	48.1 b	
November	723.6ab	145.0 ab	79.0 b	
December	885.9a	213.1 ab	760.3 a	
Total	4172.6	1728.1	2746.2	= 8.65 t/ha/yr

DRMT 5%
Means in th same column with the same letter(s) are not significantly different

Variation in nutrient concentrations of leaf fall and macronutrients return:

Table 2a shows mean nutrient concentration of litter fall of the species. Nitrogen concentration in *M. thonningii* leaf litter was higher throughout the experimental period than that of *P. santalinoides.* Figure 2 shows monthly variation of nitrogen concentration of leaf litter, twigs and reproductive parts of *M. thonningii* and *P. santalinoides.* Macronutrients concentrations in the litter of the two species were variable and had no trend and their cumulative means are shown in Table 2a. However there was a sharp decline in N, P, and K concentrations in leaf litter of both species. In *M. thonningii* leaf litter, this decline was as follows: 45% (N), 8% (P), and 54% (K) compared to the initial concentrations before leaf fall while Ca and Mg concentrations showed an increase. The decrease in N, P, and K concentrations in *P. santalinoides* leaf litter was as follows: 55% (N), 46% (P), and 63% (K) while Ca and Mg concentrations increased by 18% and 39% respectively.

Table 2a: Commulative mean nutrient concentrations of green leaves and litter fall of M. *thonningii* and P. *Santalinoides.*

	M. thonningii					*P. santalinodes*				
Plant parts	% N	% P	% K	% Ca	% Mg	% N	% P	% K	% Ca	% Mg
Green leaf	4.45	0.12	1.69	3.44	0.48	3.76	0.13	0.98	2.66	0.44
Leaf litter	2..43 (1.98-2.65)*	0.11	0.78	3.66	0.59	1.69 (2.7-1.49)*	0.07	0.36	3.14	0.61
Twig litter	1.01	0.08	0.36	4.94	0.52	1.30	0.06	0.68	4.07	0.53
Rep. structure	1.93	0,16	3.44	1.93	0.51	2.45	0.15	2.66	1.07	0.56
LSD (0.05)	1.79	0.23	1.42	1.01	0.86	1.54	0.18	1.21	2.11	0.74

*Range of nitrogen concentration in leaf litter in 24 months.
Rep.: Reproductive

Table2b: Mean and percentage annual nutrient contribution (Kg/ha) of *M .thonningii* and *P. santalinodes* litters at Ibadan (south-western Nigeria).

Species	Plant parts	N	%N	P	%P	K	%K	Ca	%Ca	Mg	%Mg
Millettia thonningii	Leaves	115.57	64.34	4.55	53.52	82.84	46.16	139.76	56.49	22.61	56.47
	Twigs	30.58	17.03	1.26	14.81	46.30	22.46	75.51	30.53	8.58	21.43
	Rep. structure	33.46	18.63	2.69	31.67	56.31	31.38	32.11	12.98	8.84	22.09
	Total biomass	179.61	100.00	8.50	100.00	179.45	100.00	247.38	100.00	40.03	100.00
Pterocarpus santalinoides	Leaves	80.96	64.74	2.86	57.56	82.03	59.42	143.32	66.26	25.42	69.10
	Twigs	20.49	16.61	1.18	23.62	34.41	24.93	58.72	27.15	7.56	20.56
	Rep. structure	23.32	18.65	0.93	18.82	21.59	15.64	14.25	6.59	3.80	10.33
	Total biomass	125.05	100.00	4.93	100.00	138.03	100.00	216.29	100.00	36.78	100.00

Rep: Reproductive

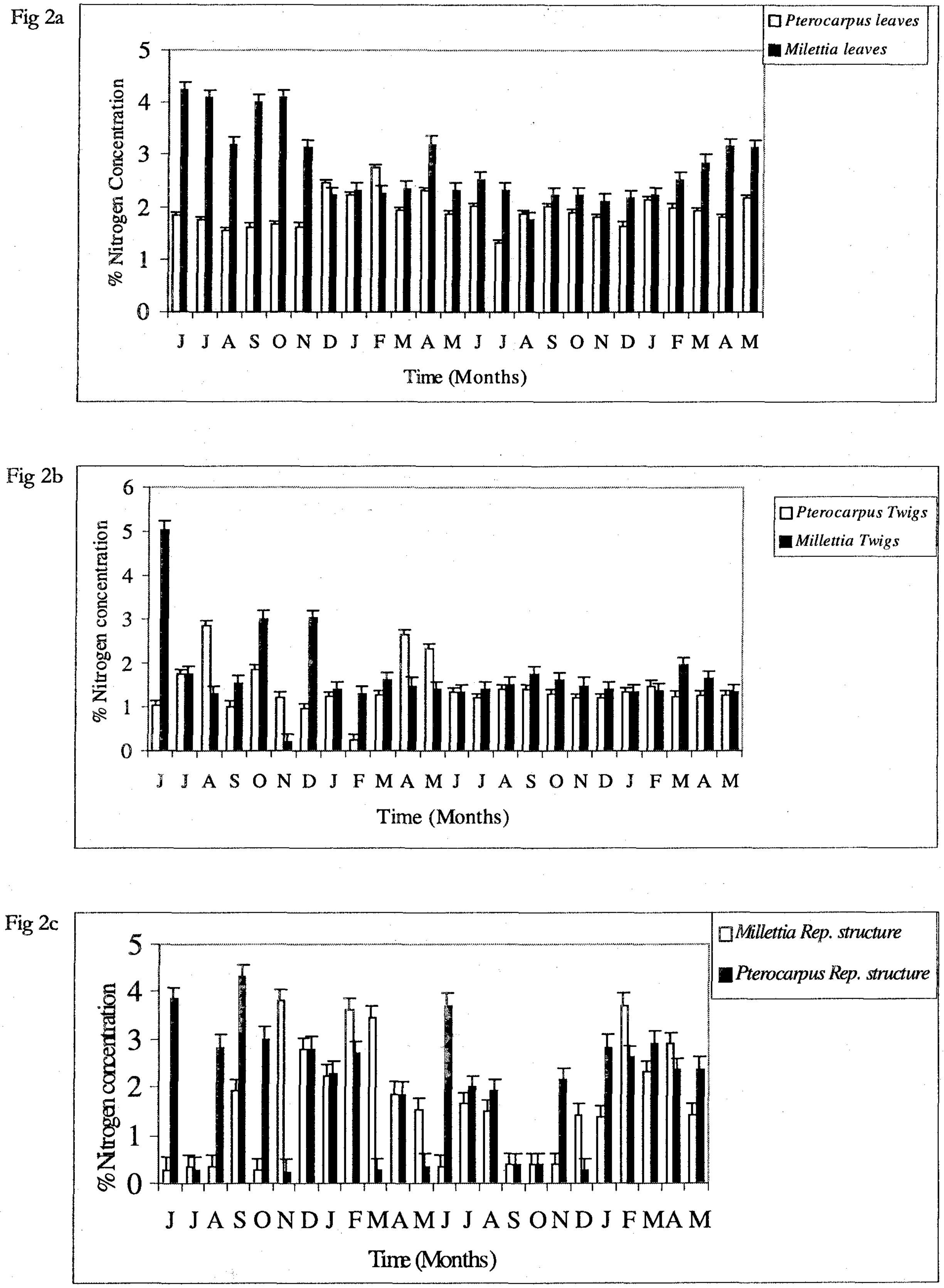
The Table 2b shows the mean annual macronutrients return from litter fall of *M. thonningii* and *P. santalinoides. Milletia thonningi*i litter fall had higher annual macronutrients return to the surrounding soils than *P. santalinoides*. Nutrients return by *M. thonningii* leaf litter into the surrounding soils as a percentage of the total nutrient biomass was as follows: P, Ca, and Mg was about 55%, N 64%, and K 46%. *Pterocarpus santalinoides* leaf litter return about 57 – 60% of the total macronutrients into the surrounding soils.

In *M. thonningii*, macronutrients return into the soils was highest in the leaf litter followed by reproductive structures in all the macronutrient except Ca, which was greater in the twigs (31.0 kg/ha) than in reproductive structures (13.0 kg/ha). However in *P. santalinoides*, after the leaf litter then followed twigs in all the macronutrients except N, which was greater in reproductive structures (23.0 kg/ha) than in the twigs (20.0 kg/ha).

Discussion

Litter fall is a major process in the transfer of organic material and nutrients from aboveground plant parts to the soil. (Szott et al.1991). The species under study are deciduous and the peak fall of leaf fall occurs in the dry season. Similarly Egunjubi and Fasehun (1972) observed higher litter production of *Pinus caribaea* in southwestern Nigeria during the dry months. Evenari et al; (1973) and Kozlowski (1971) concluded that litter fall depended on the environment and the physiology of the species. The high peak fall in reproductive structures of *M. thonningii* was caused by its fruit fall, which has a woody shell, whereas in *P. santalinoides* it was as result of flowers and early fruit abortion. The mature fruits of *P. santalinoides* are light and easily dispersed by run off water.

The mean annual litter fall of *M. thonningii* and *P. santalinoides* was within range of other studies. In Nigeria, Okeke and Omaliko (1991) reported 9.8 t/ha/yr from *Dactyladenia barteri* and 9.0 t/ha/yr from teak. Egunjobi (1974) reported 9.0 t/ha/yr in Gambari Forest reserve



Figures 2a, 2b, and 2c: Monthly variations in percentage nitrogen concentrations of the different litter parts (a= leaves, b= twigs and c=reproductive structures) of *Millettia thonningii* and *Pterocarpus santalinoides.*

in Nigeria. Nye (1961) noted 10.5 t/ha/yr in a secondary forest in Ghana and Jenny et al. (1949) reported 8.5 t/ha/yr, 10.1 t/ha/yr and 12.1 t/ha/yr litter fall three Colombian forest.

Chemical analysis of sampled green leaf and that of leaf litter showed that there was retranslocation of macronutrients (N, P, and K) before leaf fall. The increase in Ca and Mg in the leaf litter compared to the green leaves might be due to their immobile nature in organic materials and the formation of complexes with tannins or polyphenols to be excreted by the plants (Denffer et al. 1976). Reproductive structures of both species had higher concentration of nitrogen than twigs except Ca and Mg, which might be as result of nutrient rich flowers and the cotyledons of the seeds. Nitrogen concentration was 4.46% in *M. thonningii* green leaves and 2.65 – 1.98% in the leaf litter. This shows that about 55% of the nitrogen in the green leaf was retranslocated before leaf fall. It therefore indicates the species might depend more on mineralization of its leaf litter during decomposition and by fixation by its nodules for large amount (45%) of its required nitrogen. Nitrogen concentration in *P. santalinoides* green leaves was 3.76% and the leaf litter had a range of 2.7 – 1.49%. This indicates that about 60% of its leaf nitrogen was retranslocated before leaf fall, which suggest it may not depend much mineralization of the leaf litter for its nitrogen. The order of nitrogen concentration of the various litter parts were as follows: leaves > in reproductive structures > twigs. This trend might be related to the biochemical activities of the different plant parts. In both species, there was decrease in N, P, and K and an increase in Ca and Mg, during litter fall. This might be related to the retranslocation of the mobile elements while the immobile elements accumulated. Nwoboshi (1970) observed a similar pattern under teak plantation in southwestern Nigeria.

The annual nutrient turnover from the litter of these species showed that Ca > K > N > Mg > P. The P content in the litter fall of both species was low which might indicate that the species have low P requirement or the site was low in phosphorus. The higher nitrogen return of *M. thonningii* was as a result of higher biomass and nitrogen concentration in its leaf litter than that of *P. santalinoides.* The annual return of N, P and Mg of both species was within range reported by Nye (1961) in Ghana, Bernhard-Reversat (1975) in Cote d'Ivoire and Klinge and Rodrigues (1968) in the low land rain forest of Brazil while that of K and Ca was also observed by these authors. The higher K and Ca content in the litter fall of *M. thonningii* and *P. santalinoides* should be as result of site quality with respect to these elements. The high nutrient content of *M. thonningii* reproductive structures compared to twigs was as a result of a greater biomass of the fruits. In *P. santalinoides* the total nutrient content of twigs (except N) was higher than that of reproductive structures, which was as a result of their greater biomass.

This study shows that *M. thonningii* is more efficient in nutrient cycling than *P. santalinoides*, since most of the nutrients absorbed from the soil are returned via litter fall. This is important in plantation management and short rotation fallow management as relatively less of the nutrient in stemwood will be removed compared to that of *P. santalinoides.*

Furthermore in plantation management, less fertilizer would be required in the case of many rotations. However, since most of the macro-nutrient except Ca and Mg in *P. santalinoides* were retranslocated to other parts of the tree before leaf litter fall, the species would be useful for stabilization of waste land (not good for agricultural crops) and land threatened by erosion as most of its absorbed nutrients will be stored in its biomass.

CONCLUSION

Litter production and nutrient cycling are important in agriculture and forestry ecosystems. The study therefore emphasizes the selection of indigenous tree species that are good in recycling nutrient for planted fallow management or other agroforestry technologies. This would improve on the soil fertility, and also reduce the use of chemical fertilizer for sustainable arable crop production in the tropics.

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