LITTERFALL AND NUTRIENT RETURNS IN ISOLATED STANDS OF *TERMINALIA CATAPPA* TREES IN THE RAINFOREST AREA OF SOUTHERN NIGERIA

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Abstract

This study assesses litter production, concentrations and returns of nutrient elements with respect to seasons, so as to provide empirical information on nutrient flux by the isolated exotic stands of Terminalia. Litterfall samples were collected from the isolated stands of Terminalia catappa and adjoining native rainforest which serves as control for the experimental research for 12 months. Data collected were analyzed in the laboratory and the results were subjected to both descriptive and inferential statistical analyses using the SPSS 15.0 version. Average litter production for the Terminalia catappa and the adjoining rainforest were 83.04 g/m²/yr and 77.31 g/m²/yr respectively. Results of the Independent Samples T-Test showed significant difference in litter production, nutrient concentrations and the returns of nutrient elements via litterfall between the two sample sites (P value). Both litter production and the return of nutrient elements varied with the seasons of the year. While Terminalia catappa stands produced the highest litter in the months with heavy rainfall, the adjoining rainforests produced the highest litter in the dry season months. The order of nutrient elements return via litterfall by Terminalia catappa stands was Ca > N > K > Mg > P > Na, while that of the adjoining rainforest was N > Ca > K > Mg > P > Na. Results of Pearson's bivariate analyses showed significant positive relationships between litter production and nutrients return through litterfall at the 5% levels, with the correlations ranging between 0.984 – 0.999 in Terminalia catappa stands and 0.944 – 0.991 in the adjoining rainforest. Therefore, the cultivation of Terminalia catappa which is an exotic tree species to this study area has implications in returning nutrient elements to the soils of the rainforest ecosystem.

Keywords*: Litterfall, Nutrient returns, Seasonal variation, Southern Nigeria, Terminalia catappa, Tropical rainforest.*

Introduction

In the tropical rainforests, plants and soils are in equilibrium involving an almost closed cycling of nutrients which is achieved by a very high rate of litter production, rapid mineralization and a rapid attainment of equilibrium with respect to organic matter relationships (Bernherd-Raversat, 1987; Vitousek and Sanford, 1986; Terborgh, 1992). However, whenever the forest is cleared for cultivation, the plant – soil relationship is disrupted irrespective of whether field or tree crops are planted (Adejuwon and Ekanade, 1988). Even after the tree crops have matured, with their characteristics closed foliage, environmental degradation is not arrested, at least when compared with a mature tropical rainforest (Ojeniyi and Agbede, 1980; Adejuwon and Ekanade, 1988). Therefore the replacement of tropical rainforests with plantations of exotic tree species does not maintain the equilibrium which the native rainforest does. In this regards, it becomes imperative to study nutrient cycling under different isolated tree species in order to account for the contribution of nutrient elements by individual tree species.

Indeed, plants and soils in the rainforest ecosystems are closely related, and they influence one another (Nye and Greenland, 1960; Ekanade, 2007). Plants get their nutrients from the soil in which they grow. As the plants develop, they shed their leaves and branches as litter which decays to enhance the nutrients of the soil that are again used up by plants, a process known as nutrient

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cycling (Nye and Greenland, 1960; Wood *et al*., 2006). Nutrient returns to the soil through litterfall help to maintain soil fertility by increasing the organic matter in the soil (Bernhard-Reversat, 1993; Muoghalu *et al*, 1993; Muoghalu *et al*, 1994; Hermansah *et al*, 2002; Perez *et al,* 2003). Thus, there is a link between the soil and plant cover regarding cycling of nutrient elements.

In the rainforest zone of southern Nigeria, tree plant such as Indian almond is planted to produce fruits and shade for resting places within the settlements and surrounding areas. Many of this tree stands are found in isolation (i.e. their canopies are far separated from one another) since they are not cultivated in plantations. However, no effort has been previously directed to the consideration of their ecological implications in terms of nutrient cycling and the return of nutrient elements through litterfall in this part of the world.

The returns of nutrient elements have been observed to vary with the floristic composition of plant cover (Hermansah *et al*., 2002; Pypker *et al*, 2005). The amount of nutrients returned from trees to the soil in nutrient cycling will therefore vary depending on the type of tree in question. Studies by Nwoboshi, (1985), Boettcher and Kaliz (1990), Weltzin and Coughenor (1990), Dunham (1991) and Ekanade (2003), have revealed that notevery tree species has significant impact on the improvement of soil organic matter, exchangeable cations, build-up of the extractable micronutrients–iron, copper, manganese and zinc under their canopies. The low organic matter concentration and nutrients in soil underneath the tree canopies is due possibly to frequent cultivation and burning of the vegetation prior to cultivation as opined by Nye and Greenland (1960). Indeed, the extent to which plant communities are determined by resource availability is central to ecosystem studies, but patterns of small-scale variation in resource availability are poorly known.

This study therefore, presents the first assessment of litterfall and nutrient returns, with special regards to seasonal variations in nutrient flux under isolated exotic tree stands. Also, since the earlier studies were conducted on the drier ecosystem, this study therefore, presents an insight on the returns of nutrient elements through litterfall in the wetter rainforest ecosystem. Therefore this study becomes necessary, and it is the first assessment of nutrient cycling under isolated tree stands in the rainforest zone of southern Nigeria. However, the choice of *Terminalia catappa* species was determined by the differences in the tree crown architecture, stem and branch morphology, leaf size and arrangement.

The main objective of this study was to examine litter production and nutrient returns through litterfall by isolated stands of *Terminalia catappa*, and determine the contributions of nutrient elements to the rainforest soil by the isolated exotic, through a direct comparison with the adjoining rainforest. The study also centered on determining whether the returns of nutrient elements through litterfall varied with seasons of the year.

Methodology

Study Area

This study was conducted on the isolated stands of *Terminalia catappa* (tropical almond) in the moist tropical rainforest of Orogun in Southern Nigeria. This study area falls within the humid sub-equatorial climate of Af Koppen's classification, with annual rainfall above 2000mm, and average temperature of about 26ºC (Efe, 2006; Ndakara, 2006). The topography is a low plain with slope of ≤ 2º. The soils are classified according to the U.S. soil Taxonomy System (Soil Survey Staff, 1994) as alfisols, oxisols/ultisols orders. The natural vegetation is the moist evergreen tropical rainforest with tree forms ranging in strata from shrubs to exceedingly tall members. This rainforest vegetation has been affected owing to centuries of human activities, such that the originally contiguous ecosystem now feature as island habitats or sacred groves (Ndakara, 2006; 2009), and confined to sacred places where human induced degradation activities are restricted. The rainforest tree species that featured prominently in the study area include *Piptadeniastrum africanum*, *Ceiba pentandra, Albizia adianthifolia, Terminaliasuperba, Alstonia boonei, Milicia excelsa,Ricinodendron heudelotii, Musanga cecropioidea* and *Antiaris toxicaria*. In this study area, exotic tree species such as *Terminalia cattapa* (tropical almond), Mango (*Mangifera indica*), and Avocado pear (*Persea gratissima*) are planted to produce fruits and shade for resting places within the settlements, schools and farmland areas. Many of these tree plants are found in isolation, with their canopies far separated from one another, and are not cultivated in plantations.

Experimental Design and Samples Collection

The study area was divided into 5 units based on the existing 5 quarters of the clan (Umusu, Unukpo, Imodje, Emonu and Ogwa). The quarters were so used in this study to ensure that every part of the study area was covered. In each quarter, 3 isolated stands of *T. catappa* trees were selected, making a total of 15 tree stands sampled. The selection of the isolated stands of *T. catappa* was based on the condition that they were not subjected to sweeping and burning which expectedly could have impact on the soil properties underneath the trees in the process of nutrient cycling. Also, each tree was so selected such that their canopies were separated from other tree canopies, thereby eliminating relationships with it. In each quarter, a sample plot of 30m × 30m divided into 3 quadrats of 10m × 30m was chosen from the adjoining rainforest cover to serve as control for this study (that is, 15 sample sites were established in the adjoining rainforest). The adjoining rainforest covers were matured native forest confined to sacred places, and have been referred to as island habitat or sacred groves (Ndakara, 2006; 2009).

Data collections were on litter production and litter nutrient concentrations. The litter samples were collected from the isolated tree stands and the adjoining rainforest; using litter bags with collection areas measuring 0.5m². Four (4) litter bags were set under each of the isolated tree stands, and each established sample points in the adjoining rainforest. The bags were made from sack materials and perforated at the bottom to allow rain water to drip out easily. In each month, 30 litter samples were collected from February 2010 to January 2011 respectively. This makes a total of 360 litter samples collected. The litter samples were put into labeled sacks 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.

Laboratory Analyses of Samples

The litter collected was sorted into leaf, fruits, flowers and small wood litters. Apart from leaf and flower litter, only litter of ≤ 2.5 cm in diameters was included in this study. The litter samples were dried to constant mass in an electric oven at temperature of 105ºC for 24 hours. Analyses were based on litter production and nutrient concentrations. The oven-dried litter samples were weighed by the use of "top loading electronic balance". The weights represented the litter production for the isolated tree stands and the adjoining rainforest, and reported in g/m². The oven-dried litter samples were then ground into powdery form and analyzed for the concentrations of elements such as nitrogen, phosphorus, potassium, calcium, sodium, magnesium and pH. To determine the concentrations of nitrogen and phosphorus, this study adopted the approach of a modified Kjeldahl digestion on a Tecator 2000 Digestion System (Wood *et al.,* 2006). The nutrient cations (K, Ca, Na and Mg) were analyzed by digesting the ground litter samples in HNO_3 / H_2O_2 on a block at 105ºC. The samples were then re-dissolved in 50ml of 10% nitric acid for analysis using Spectro CIROS CCDE Inductively Coupled Argon Emission Plasma Spectrometry (ICP). The pH values were determined by the use of pH meter.

Statistical Analyses of Data

Results of laboratory analyses were subjectedtothe descriptive and inferential statistics using the **SPSS 15.0** versions. The technique of mean was used to determine the mean values for the litter production, as well as the concentrations and returns of nutrient elements. The Independent Samples T-Test Analysis was employed to determine the differences in litter production, concentrations and the returns of nutrient elements in litterfall between the isolated stands of *Terminalia catappa* and the adjoining rainforest respectively. While Pearson's bivariate correlation analysis was employed to ascertain the relationship between litter production and nutrient returns to the soil through litterfall for both the stands of *Terminalia catappa* and the adjoining rainforest respectively.

Results

Litter Production

The quantity of litter produced varied between the isolated stands of *Terminalia catappa* and the adjoining rainforest. The mean annual litter production for the *Terminalia cattapa* and adjoining rainforest are 83.04 g/m² and

77.31g/m²respectively (table 1). The annual litter production was higher in the stands of *Terminalia catappa* than in the adjoining rainforest.

Litter production by the stands of *Terminalia catappa* is higher in the rainy season, while it is higher in the adjoining rainforest during the dry season. The seasonal variation is as shown in fig. 1.

The amount of litter produced also varied seasonally and obviously with the phonological changes which occurred in the different tree species.While *Terminalia catappa* produced higher litter between June and October, the native adjoining rainforest produced more litter between November and March.

Table 1: Monthly litter production in g/m²

Months	Indian Almond (*Terminalia catappa*)	Adjoining Rainforest
Feb	30.02	128.40
Mar	49.01	148.62
Apr	62.13	62.95
May	89.33	50.16
Jun	82.10	48.71
Jul	99.18	40.47
Aug	142.00	49.20
Sep	147.16	50.28
Oct	186.34	54.61
Nov	42.16	82.11
Dec	38.41	104.92
Jan	28.62	107.24
Mean	**83.04**	**77.31**

Source: Field work

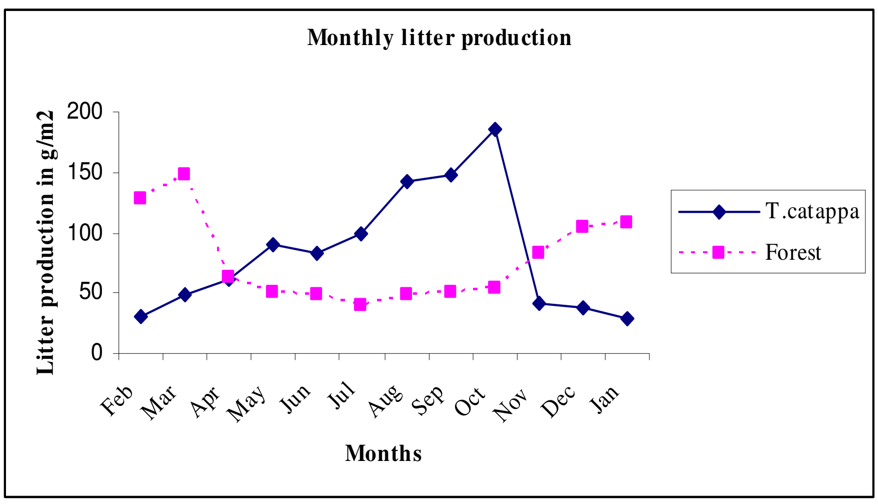

Fig. 1: Seasonal Variations in Litter Production

Table 2: Independent Samples T-Test Results for Litter Production between*Terminalia catappa*and Adjoining Rainforest

		Levene's Test fo Equality of Varian		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-taile	Mean Differenc	Std. Erro Differenc	Lower	Upper
litter	Equal variances assumed	1.243	.277	.314	22	.757	5.7325	18.2826	-32.1832	43.6482
	Equal variances not assumed			.314	19.704	.757	5.7325	18.2826	-32.4410	43.9060

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The mean difference in litter production between the isolated stands of *Terminalia catappa* and the adjoining rainforest was 5.73, which is significant at 0.76 2-tailed levels. The standard error difference was 18.28, while the t-value and F-value were 0.314 and 1.243 respectively

Nutrient Concentrations

The concentrations of nutrient elements in litterfall vary between the isolatedstands of *Terminalia catappa* and the adjoining rainforest.

Table 3 shows the mean annual concentrations of nutrient elements in litterfall. Except for the concentrations of potassium, nutrient elements are all higher in the adjoining rainforest than in the stands of *Terminalia catappa*. Generally, the concentrations of Ca and N are higher than other nutrient elements.

The mean monthly differences in the concentrations of nutrient elements in litterfall between the stands of *Terminalia catappa* and the adjoining rainforest were tested with theindependent samples t-test statistics. The results show that except for phosphorus, potassium and sodium, the concentrations of the nutrient elements are significantly different at the 5% 2-tailed levels. Significant differences in the concentrations of phosphorus, potassium and sodium are 0.516, 0.150 and 0.076 respectively at the 2-tailed levels. This shows that there is a significant difference in the concentrations of nutrient elements between the isolated stands of *Terminalia catappa* and the adjoining rainforest.

Returns of Nutrient Elements to the Soil via Litterfall

The return of nutrient elements through litterfall to the soil in nutrient cycling varies between the isolated stands of Terminalia catappa and the adjoining rainforest, as well as the seasons of the year. In the process of nutrient cycling, the returns of nutrient elements through litterfall accounts for the amount of nutrients circled from the tree plants to the soils underneath (Wood *et al,* 2006).

Table 4 shows the mean annual returns of nutrient elements to the soil through litterfall. Except for the returns of phosphorus and potassium which are a little higher in the stands of *Terminalia catappa*, nutrient elements returned are all higher in the adjoining rainforest. Generally, the returns of Ca and N are higher than other nutrient elements.

The mean monthly differences in the returns of nutrient elements in litterfall between the standsof *Terminalia catappa* and the adjoining rainforest were tested with theindependent samples t-test statistics. The results show that there are differences in the returns of nutrient elements between the stands of *Terminalia catappa* and the adjoining rainforest. The observed levels of differences as shown from the mean differences are relatively close, ranging between 0.05 and 3.35, while the standard error difference (S.E.D) ranged between 0.139 and 2.355.

Seasonal Variations in Nutrients Returned to the Soil via Litterfall

The returns of nutrient elements vary with the seasons of the year. The returns of nutrients by the isolated stands of *Terminalia catappa* are higher in the rainy season, while that by the adjoining rainforest are higher in the dry season (see figs 2 -7).

Interrelationships between Litter Production and Nutrients Returned to the Soil

This section presents the findings on the relationship between litter production and the returns of nutrient elements through litterfall by employing the Pearson's bivariate correlation analysis. The results of the analyses as summarized in table 7, show that there exist significant positive relationships between litter production and the returns of nutrient elements, for both the isolated stands of *Terminalia catappa* and the adjoining rainforest.

Table 3: Mean concentrations of nutrient elements in Litterfall in mg/g

Nutrient elements	Sites	
	Indian almond *(Terminalia cattapa)*	Adjoining rainforest
Nitrogen	5.87	10.69
Phosphorus	0.66	0.72
Potassium	4.87	3.69
Calcium	7.72	9.53
Sodium	0.41	0.53
Magnesium	2.27	3.18

Source: Field work

Table 4: Mean returns of nutrient elements through litterfallin kg/ha/yr

Nutrient elements	Sites	
	Indian almond *(Terminalia cattapa)*	Adjoining rainforest
Nitrogen	5.73	9.08
Phosphorus	0.65	0.60
Potassium	4.92	3.39
Calcium	7.50	7.81
Sodium	0.41	0.49
Magnesium	2.22	2.57

Source: Field work

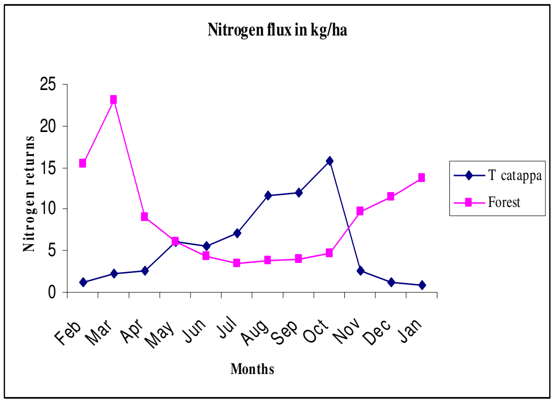

Fig. 2: Seasonal Variations in Nitrogen flux

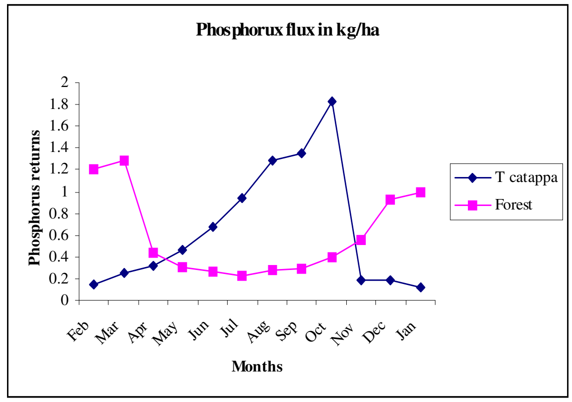

Fig. 3 Seasonal Variations in Phosphorus flux

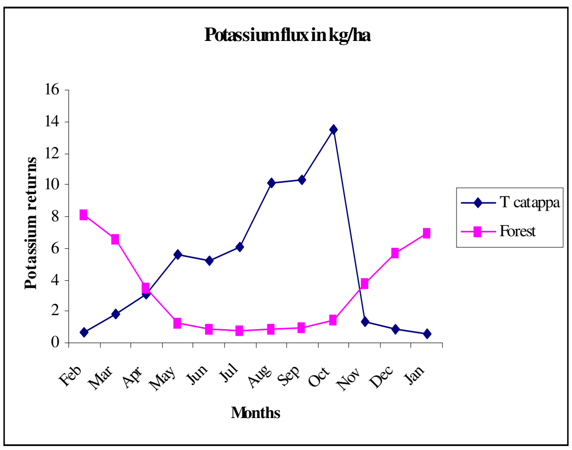

Fig. 4: Seasonal Variations in Potassium flux

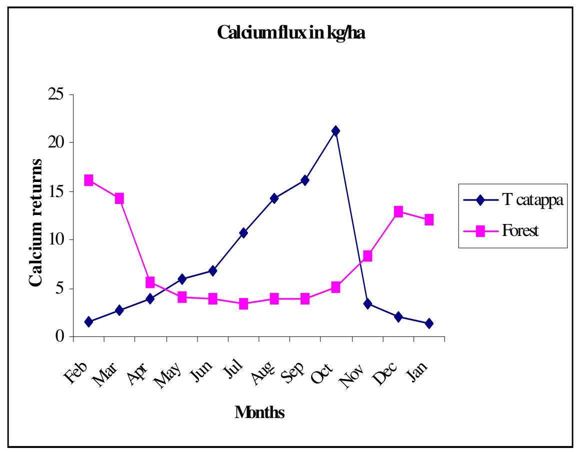

Fig. 5: Seasonal Variations in Calcium flux

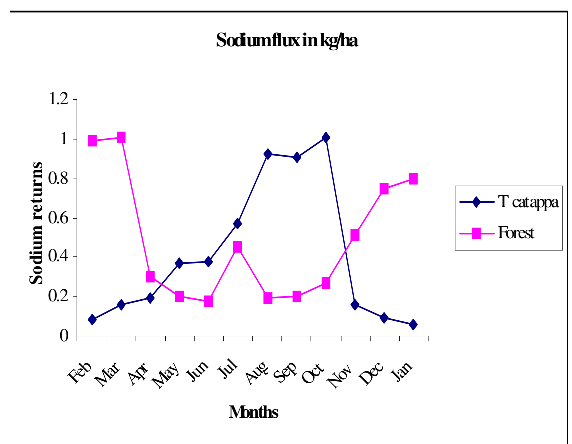

Fig. 6: Seasonal Variations in Sodium flux

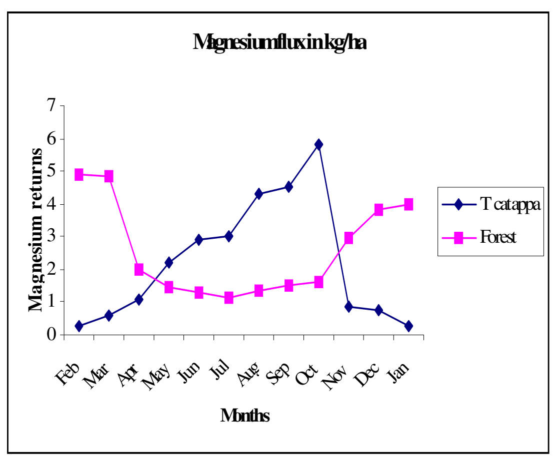

Fig. 7: Seasonal Variations in Magnesium flux

Table 7: Summary of Pearson's Bivariate Correlations between Litter Production andNutrient Returns in Litterfall.

Sites	Litter production	Nutrient elements					
		Nitrogen	Phosphorus	Potassium	Calcium	Sodium	Magnesium
Indian almond	Litter Sig.(2-tailed) N	.995** .000 12	.986** .000 12	.999** .000 12	.988** .000 12	.984** .000 12	.987** .000 12
Rainforest	Litter Sig.(2-tailed) N	.972** .000 12	.991** .000 12	.944** .000 12	.972** .000 12	.949** .000 12	.987** .000 12

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Discussion

Litter production, as well as the concentrations and returns of nutrient elements in litterfall vary between the isolated stands of *Terminalia catappa* and the adjoining rainforest. This variation is probably due to the variation in tree species contained in the adjoining rainforest as observed in studies by Bernhard-Reversat (1977), Proctor (1984), Muoghalu *et al* (1993), Hermansah *et al* (2002), Pragasan and Parthasarathy (2005), Wood *et al* (2006), and Adedeji (2008). However, the much higher litter production observed in the *Terminalia catappa*stands could be attributed to the tree crown architecture, while the close canopy influence in the adjoining rainforest may have enhanced the amount of litter produced under the rainforest cover. The concentrations and returns of all the nutrient elements were highest in the adjoining rainforest except for the concentrations and returns of potassium and phosphorus that were higher in *Terminalia catappa*. While calcium concentrations and returns were highest in the isolated tree stands, nitrogen was highest in the adjoining rainforest. The higher flux in these nutrients can presumably be due to their high availability in the soil (Vitousek, 1984). The order of nutrient concentrations and returns to the soil through litterfall as observed in the isolated tree stands is Ca > N > K > Mg > P > Na while that of the adjoining rainforest is N > Ca > K > Mg > P > Na (an indication of the ranges of nutrient elements in concentrations and returns via litterfall). The observed order for the isolated tree stands is in line with that observed by Leigh *et al* (1982), Mueller-Dombois *et al* (1984), and Muoghalu *et al* (1993); while that of the adjoining rainforest corroborates findings by Bernhard-Reversat (1977 and 1993), and Perez *et al* (2003). Seasonal variations in the concentrations and returns of nutrient elements to the soil were observed for the isolated tree stands and the adjoining rainforest. While the highest return of nutrients by *Terminalia catappa* was observed in the rainy months, the adjoining rainforest returned the highest nutrient elements in the dry season months, which is similar to that observed pattern in a study by Muoghalu *et al* (1993). However, the pattern of seasonal variation in the production of litter in the adjoining rainforest is similar to the observed patterns in studies by Muoghalu et al (1993) in a Nigerian rainforest; and Hermansah et al (2002) in the tropical rainforest of Western Sumatra, Indonesia; but varied from that by Pragasan and Parthasarathy (2005) in the tropical dry evergreen forests of south Indian in relation to season. It could therefore be deduced that the trends of litter production by *Terminalia catappa* is different from that of the adjoining rainforest.

Conclusions

From findings in this study, it could be deduced that litter production varied between the stands of *T. catappa*and the adjoining rainforest. Also, the trends in seasonal variations in the returns of nutrient elements varied. Acid content of litter from the stands of *T. catappa* and the adjoining rainforest are both moderately concentrated. This study also revealed that the isolated stands of *T. catappa* return nutrient elements to the soil in the process of nutrient cycling. While litterfall was observed as an important source of nutrients return to the soil in the process of nutrient cycling, a positive relationship was observed between litter production and the returns of nutrient elements. Therefore, litterfall by the isolated stands of *T. catappa* 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 rainforest ecosystem. In the quest for the tree species necessary for the management of such environment like the rainforest ecosystem, it is expected that such exotic tree species which exhibit more similarity with those of the existing native rainforest areas should be considered. It is therefore suggested that the growing of *T. catappa* should be encouraged in the deforested rainforest in order to ensure a sustainable maintenance of the soils in the environment within which the tree stands are grown.

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