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Litter Biomass and Soil Organic Matter Content in a Chronosequence of *Tectonia Grandis* [L.f.] Stands in Shasha Forest Reserve, Nigeria

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Abstract: This study was conducted to determine and compare forest floor litter biomass between *Tectonia grandis* (teak) stands of different ages and adjacent natural forest. This was to investigate the pattern of soil organic matter and nutrient build-up under a Chronosequence of the teak stands in Shasha Forest Reserve of Osun State, South-Western Nigeria. The teak plantations were planted in 1965, 1970, 1975, 1980 and 1985. The Forest litter biomass was highest for the 1975 plantation (100 t/ha) followed by 1980 plantation (8.3t/ha). The biomass for forest floor litter collected under 1965 (6.7 t/ha), 1970 (7.4 t/ha), 1985 (6.8 t/ha) plantations and natural forest (7.0 t/ha) was not significantly different. The nitrogen contents in the litter were 10.5 kg/ha, 15.4 kg/ha, 11.2 kg/ha, 6.7 kg/ha, 11.4 kg/ha and 11.8 kg/ha while phosphorus contents were 7.2 kg/ha 8.1 kg/ha, 7.9 kg/ha, 8.1 kg/ha, 7.1 kg/ha and 9.7 kg/ha for soil organic matter, 1965, 1970, 1975, 1980, 1985 teak plantations and natural forest respectively.

Key words: Litter biomass, Chronosequence, *Tectonia grandis*, Forest reserve.

INTRODUCTION

The efficient cycling of nutrients in humid tropical forest ecosystems is dependent on a variety of integrated biological components and processes in the soil-plant system. Disruption of any one of the key biological processes can alter the cycling and efficiency of nutrient use, either temporarily or permanently (Swift and Wommer, 1993). The productivity and sustainability of traditional slash-and-burn agriculture rely on the short-term disruption and subsequent restoration of biological processes and components, whereas the failure of many current slash-and-burn systems is a result of long-term uncoupling of the processes (Sanchez *et al*., 1999). Soil organic matter is crucial to the productivity of slash-and-burn and other low-input agricultural systems because it helps maintain soil fertility and soil structure. Nutrients are stored in both organic and minerals forms on the exchange site of soil organic matter. Decomposition of soil organic matter releases the organic nutrients into plant available form, but as the level of organic matter declines, the rate of nutrient release is reduced and the soil structure deteriorates (Elliote *et al.*, (2002).

The maintenance of soil organic matter is dependent on continual input of organic materials. The input of organic materials is a key process for maintaining soil organic matter in natural and derived ecosystems. A common practice in the establishment of plantation in Nigeria is the initial clearance of natural forest and the involvement of farmers in tree planting through taungya afforestation. Consequently taungya afforestation involves a slash-and-burn phase and the subsequent replacement of the primary forest with monoculture plantations. However, after two or three years of cropping, the land is then left to fallow under monospecies plantation for renewed fertility. Thus taungya afforestation is an age long practice in Nigeria and it constitutes a cheap means of tree plantation establishment. However, it is yet to be established whether the fertility status of the plantation forest is comparable to that of the primary forest after conversion despite the age long fallow period. According to Nye and Greenland, 2004 and Sanchez (2006), the clearing and cultivation of tropical forest are usually accomplished by a declined in the amount of organic matter in the underling soil and the ability of the soil to supply mineral nitrogen for crop growth.

The objectives of this study is therefore to determine the litter biomass and soil organic matter contents of *Tectona grandis* plantation of different ages and compare the nutrient levels with those of the adjacent

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natural forest; to investigate the pattern of soils organic matter and nutrient build-up under an age series of teak stands and to investigate the effect of soil depth on nutrient status under different age series of *Tectonia grandis*.

MATERIALS AND METHODS

The study was conducted in Shasha Forest Reserve of Osun State, Nigeria. Shasha Forest Reserve is situated in Ife South Local Government Area of Osun State. It lies (latitude 7º24¹N, longitude 4º35¹E) in the semi-decidous tropical lowland rainforest (Keay, 1999) zone. The mean annual temperature is about 28ºC (Min. 17ºC and Max. 32ºC). The relative humidity ranges 85% and 92% during the wet season and less than 60% during the dry season. The average annual rainfall is 1200mm (Kio, 1998). The soils are well-drained sandy 10am.

The study was conducted in the teak plantations at Shasha Forest Reserve, which were established in the main stations called Apoje and Agbele. All the teak plantations were established through taungya afforestation at an espacement of 2.4 x 2.4 m. The establishment started in 1964 and continued up to 1990.

Soil and Litter Sampling:

In each of 1965, 1970, 1975, 1980 and 1985 teak plantations, a plot of 50 m x 40 m was demarcated at the centre. Each marked plot was sub-divided into twenty 10 m x 10 m sub-plots. Two of the twenty sub-plots were randomly selected. In each sub-plot, two composite soil samples at 0 – 20 cm and 20 – 40 cm depth were taken.

Nitrogen and phosphorus contents of the dried and ground litter samples were analyzed as described by Anderson and Ingram (2005). Nitrogen was determined by distillation and titration while phosphorus was determined colorimetrically using the Vanado-molybdate yellow method. Sodium and Potassium were determined by flame photometry while calcium and magnesium were determined by atomic absorption to spectrophotometer (IITA, 2002).

Statistical Analysis:

Data on soil characteristics were analyzed using two-way analysis of variance for factorial experiment in completely randomized design while completely randomized design was used for the litter characteristics. Analysis of variance was carried out to test whether significant differences existed among the soil and litter characteristics of the control plots and the plantation age-series. Duncan's multiple range test (Zar, 1994) was used to identify the means that were significantly different from each other.

RESULTS AND DISCUSSION

The forest litter biomass g/m^2 under age series of teak stands at Shasha forest reserve is shown in table 4. It was observed that litter biomass was highest in the 1975 plantation followed by the 1980 stand. The litter biomass values for 1965, 1970, 1986 plantations and natural forest did not vary markedly among each other.

The summary of the result of analysis of variance on nutrient contents of litter is shown in Table 1. ANOVA results shows that, there were no significant differences in the phosphorus (P) and Nitrogen (N) content in the litter collected under different plantation age series and under natural forest. However, significant differences existed for Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg) contents in the litter for different plantation series (Table 1).

Furthermore, the result of Duncan's Multiple Range Test (DMRT, Table 2), show that the sodium content in the litter did not differ significantly between 1970, 1980 and 1985 plantation age series. The difference in sodium content between natural forest and 1975 plantation was also not significant. These were however, significantly different from that of 1965 plantation, where the mean sodium content was least.

Table 1: Summary of Results of Analysis of Variance (ANOVA) of Nutrient Content of Litter.

Nutrient Element	F_{Cal}	F_{tab} (5% level of significance)	Conclusion
P	0.006	3.89	Not significant
N	1.30	3.89	Not significant
Na	42.4	3.89	Significant
K	38.4	3.89	Significant
Ca	54.4	3.89	Significant
Mg	13.3	3.89	Significant

Table 2: Mean Nutrient Contents of Litter Collected Under Teak Plantations of Different Ages and the Natural Forest in Shasha Forest Reserve.

Forest Type	P(%)	N(%)	Na(%)	K(%)	Ca(%)	Mg(%)
1965 plantation	0.72^a	1.05^a	0.04^b	0.32^a	2.32^e	0.15^a
1970 plantation	0.81^a	1.54^a	0.07^a	0.33^a	1.54^a	0.14^a
1975 plantation	0.79^a	1.12^a	0.21^a	0.62^b	2.06^d	0.15^a
1980 plantation	0.81^a	0.67^a	0.08^a	0.31^a	1.92^{be}	0.11^a
1985 plantation	0.71^a	1.14^a	0.08^a	0.54^c	2.48^c	0.17^a
Natural forest	0.97^a	1.18^a	0.31^c	0.73^b	2.81^c	0.38^b

Data in a column followed by the same letter are not significantly different according to DMRT (P>0.05).

Soil and Litter Analysis:

Soil:

The soil samples were air-dried, ground and passed through a 2-mm sieve. Particle size analysis was determined by hydrometer method and international classification of diameter classes was adopted (Berrow and Mitchell 2004). The following chemical determination were made: (i) pH was determined electrometrically in both water and 0.1 M $Cacl_2$ at a ratio 1:2.5, using glass electrodes (Bates, 1994), (ii) Soil organic carbon was determined by the Walkey-Black wet oxidation method, (iii) Total nitrogen was determined by micro-Kjedal method after grinding the samples to pass through 0.5mm sieve, (iv) Phosphorus was extracted with 0.2 m Sulphuric acid at a soil/solution ratio of 1:20, and in the ascorbic acid reducing agent. (v) Exchange cations, Ca, Na, K and Mg, were leached with neutral normal ammonium acetate solution. Ca, Na and K were determined by Flame Photometry and Mg by ethylene diamine tetra acetic acid (EDTA) titration and expressed in milli equivalent per 100gram (meq/100g).

Litter:

The thirty-six (36) litter sample collected were weighed and sub-samples taken for oven dry weight. The oven dry weight of the sub-samples was used to correct for the oven dry weight. The litter biomass was expressed in kilogram per hectare.

Organic matter contents of soils under the 1990 and 1985 plantations were not significantly different but there were significant differences in organic matter contents of soil under 1965, 1970 and 1980 plantations as well as the natural forest. The nitrogen content also in soils under natural forest, 1965 and 1985 did not significantly differ, likewise for the 1970 and 1975 plantations. However, the nitrogen content under 1980 plantation differed significantly. Potassium contents under 1965, 1970 and 1985 plantations were not significantly different (Table 4). Potassium content under natural forest and the 1975 and 1980 plantations differed significantly.

Calcium and Sodium contents in all the plantations and the natural forest differed significantly. The magnesium content in soils under 1965 plantation and natural forest were not significantly different, but were significant differences in the magnesium content under 1970, 1975, 1980 and 1985 plantations. The phosphorus contents for 1965, 1975 and 1985 plantations were not significantly different. However, the phosphorus contents of soil under natural forest, 1970 and 1980 plantations were significantly different (DMRT P>0.05).

Table 4: Mean Nutrient Contents of Soil Under Teak Plantations of Different Age in Shasha Forest Reserve

Forest type	pH	OM	N	K	Ca	Na	Mg	P
1980 plantation	5.79^e	4.57^b	0.24^a	0.10^d	9.93^b	0.45^a	3.16^a	2.13^d
1985 plantation	5.79^e	2.53^e	0.14^c	0.10^d	4.11^f	0.16^d	2.41^d	2.42^c
1990 plantation	6.31^c	3.32^d	0.15^c	0.19^b	6.40^e	0.09^f	2.06^e	2.12^d
1995 plantation	6.63^b	3.40^c	0.17^b	0.40^a	7.28^c	0.36^b	3.09^b	6.02^a
2000 plantation	5.88^d	2.99^d	0.22^a	0.09^d	7.05^d	0.28^c	2.64^c	2.18^d
Natural forest (NF)	6.73^a	5.63^a	0.26^a	0.16^c	0.14^e	0.14^e	3.60^a	4.28^b

Means followed by the same superscript along column are not significantly different according to DMRT (P>0.05).

Conclusion:

It could be concluded from the present study that forest floor litter accumulation was generally higher under the teak plantations than in the natural forest. It has to be stated also that this higher value may not be real for reasons of intensity of sampling in time as sampling took place once and also at the peak of litter fall. Also the nutrient elements found in the litter collected under teak plantations were generally lower than that of natural forest. Furthermore, there was a reduction in the soil organic matter contents under plantations of *Tectonia grandis*.

It was observed that the conversion of natural forest to mono species plantations of *Tectona grandis* was characterized with a reduction in the soil organic matter contents. However, the exchangeable cations in the soils under the teak plantations were generally higher than that of the adjoining natural forest. It could also be concluded from this study, that the mineral contents in the soil under vegetative cover or litter on the forest floor were generally higher within soil depth 0 – 20 cm than that of the soil depth 20 – 40 cm. Finally, it is evident from this study that the conversion of natural forests to monoculture plantation of exotic species, though may lead to an initial reduction of soil organic content and nutrient elements in the soil. This condition is followed by a gradual build up of soil organic matter exchangeable cations with increasing plantation age.

Recommendation:

It is hereby recommended that Research of this nature should be extended to include monoculture species of younger ages for the purpose of monitoring the trend of nutrient reduction after conversion of natural forest to mono species plantations and the gradual nutrient build-up with increasing plantation age.

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