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INFLUENCE OF TEAK (*Tectona grandis)* LINN ON SOIL NUTRIENTS STATUS IN AKANGA TEAK PLANTATION, NASARAWA STATE, NIGERIA

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ABSTRACT

Teak species have been found to have effects on soil properties different from those of indigenous natural forests in terms of organic matter accumulation and soil properties on the forest floor. This research aims at evaluating the physico-chemical properties of soil under Teak plantations in Akanga Teak plantations, Nigeria. Soils were sampled and analyzed based on procedures described by Bouyoucos, Day, and Reeuwijk. Based on the results, soil particle size from the plantation had the highest percent of sand **(**74.5±1.1**)**. There was a fluctuation of soil pH between the age series, 1981 age series had the highest pH **(**6.2±0.0**)** in both seasons. The nitrogen content had a steady declined as the plant age increased, while the organic matter and phosphorus content increased with the age of the plant species in the area. There was a decline in soil nutrients during the wet season, which also coincided with the active growth period of forest trees. Thus, it is evident from this study that monoculture plantation of exotic species may lead to an initial reduction of soil organic content and nutrient elements in the soil; then a gradual buildup of soil organic matter and exchangeable cations with age.

Keywords: Chemical, Nutrients, Physical, Plantation, Properties, Soil, Nasarawa State

INTRODUCTION

Tectona grandis Linn (teak) is a tropical plants with a wide range of applications. Teak is one of the best hardwoods on the planet; it can be harvested as early as the sixth year after they are planted. It is one of the plants used to make power poles, and it can grow to the size of timber, which may be sawn and used to make furniture. Teak species as an exotic species have vital role on soil nutrients and properties. Exotic tree species have been found to have effects on soil properties differing from those of indigenous natural forests in terms of organic matter accumulation, soil conditions and type of vegetation growing on the forest floor. Exotic tree species have been found to have effects on soil properties different from those of indigenous natural forests in terms of organic matter accumulation, soil conditions, and the type of vegetation growing on the forest floor.

Forest floor housing soil, plants, air, water, and organisms; these interrelate directly or indirectly within the ecosystems. Trees affect the morphology and chemical conditions of the soil due to the characteristics of above- and below-ground litter inputs (Kai and Jiao-Jun, 2015). The soil system strongly influences the structure and function of ecosystems and acts as a buffer to global climate change (Pareek, 2017). Understanding the process in the soil is crucial in the context of the ecosystem management. The soil is an important reservoir of organic carbon in terrestrial ecosystem, since it contains two to three times more organic carbon than does vegetation (Ontl and Schulte, 2012). Soils vary enormously as a nutrient reservoir particularly when comparing fertile arable soils and associated crops to many forest situations. This research aims at evaluating the physical and chemical properties of soil under teak at different age series; and to determine litter accumulation under the tree canopy and the changes in microbial composition and population under teak at the different age series in Akanga Teak plantations, Nasarawa State, Nigeria.

MATERIALS AND METHODS

Study area

Soil samples were collected from distinct age series under an established teak plantation in Akanga Teak Plantation, Nasarawa State, Nigeria. Akanga teak plantation is located between Latitude 8^0 18'N and Longitude 8^0 34'E; about 185m above sea level within the Southern Guinea Savanna of Nigeria. Annual rainfall varies from 1143 mm to 1397 mm. Red Ferrallitic soils (Rhodic Ferrasols), Ferruginous Tropical soils (Eutric Cambisols), Juvenile soils on the Riverian, Groundwater Laterite (Gleyic Luvisols), Hydromorphic soils, and other land types such as iron stone outcrops, iron stone hills, and eroded areas along the stream make up the study area (Dachung, *et al.*, 2018; 2019). The property is frequently burned by local people for hunting adventures during the months of December to April.

Soil Samples Collection

Based on location and reduced impact from external factors, three age series were evaluated for sampling. The trees were planted in the years 1979, 1980, and 1981, totaling 78, 28, and 40 hectares, respectively. At 20 x 20 m plots, soil samples were designated for soil collection. To create a composite, soil samples were taken at random locations in each sample plot. As a control, soil samples from the area around the plantation were taken. An auger was used to collect soil from a depth of 0 to 20 cm. This zone was chosen for sampling because it contains the majority of plant nutrients (Dachung, 2019).

Laboratory Analysis

For laboratory analysis, the soil samples were air-dried, pulverized, and sieved through a 2 mm sieve. Conventional standards were used to make the following determinations: The hydrometer method, as reported by Bouyoucos, was used to assess particle size distribution (1951). Samples were taken with core samplers, and bulk density was calculated as the weight of dry soil per unit volume of moist soil (Campbell and

Henshall, 1991). Total porosity (percentage) was calculated using data from a bulk density of 2.65gcm-3 (Vomocil, 1965). The pH of the soil was determined using the technique of Hendershot *et al*. (1993). The technique outlined by Bray and Kurtz was used to obtain the available phosphorous (1945). A flame photometer was used to determine Na and K, while an Atomic Absorption Spectrophotometer was used to extract exchangeable bases (Dachung *et al.,* 2019). The method of Walkley and Black was used to determine organic carbon (1934). Total nitrogen was determined based on the procedure reported by Page *et al.* (1982).

RESULTS

Physicochemical Properties of Soils in Akanga Teak Plantations

Result on influence of Teak (*Tectona grandis)* Linn on soil physical properties at the Akanga Forest Reserve is shown on Table 1. The result from the study revealed that, soil physical properties (particle size) under *T. grandis* for the three age series recorded highest percentage of sand (74.5±1.1), while Control had the highest percentage of silt (20.0±0.8), clay (19.7±0.5) and porosity (37.9±0.4) in the area. This could be attributed to diversity of plant residues found in the control (forest reserve). According to the result from this finding, the soil samples from the study area showed a significant variations between the seasons (dry and wet) at which the soil samples were collected at different age series. Clay soil was significantly different (p=0.000) across the age series, so also Control. Porosity, sand, silt and BD of the soil all showed significant (p=0.000) different between the two seasons at varied age series; while under the age series of 1979, only soil silt had no significant different (p=0.059). Also, soil porosity and sand under age series of 1980 had no significant different at p=0.059 and p=0.116, respectively.Mostly, the values of the soil properties in the area appeared higher during rainy season and lower values during the dry season as revealed from this study; except % sand which had a reverse case i.e. vise-versa while BD g/cm^3 remained constant in both season.

Table 1: Physical Properties of Soil at varied Age-Series and Seasons in Teak Plantation, Akanga Forest Reserve Nasarawa State, Nigeria

Location	Season	Samples	% Clay	% Porosity	% sand	%Silt	BD g/cm^3
Control	Dry	6	14.95±0.8^a	37.9±0.4^a	65.3±1.4^a	20.0±0.8^a	1.7±0.0^a
	Wet	6	19.7±0.5^b	37.3±0.1^c	63.8±0.3^b	16.8±0.5^b	1.7±0.0^b
-	-	***p*-value**	**0.000**	**0.004**	**0.025**	**0.000**	**0.013**
1979	Dry	6	11.5±0.1^a	36.0±0.6^a	74.5±1.1^a	14.1±0.9^a	1.7±0.0^a
	Wet	6	13.6±0.9^b	36.7±0.0^b	71.4±0.3^b	15.0±0.5^a	1.7±0.0^b
-	-	***p*-value**	**0.000**	**0.014**	**0.000**	**0.059**	**0.049**
1980	Dry	6	10.9±0.1^a	35.9±0.5^a	73.8±0.1^a	15.7±0.4^a	1.7±0.0^a
	Wet	6	12.9±0.5^b	36.3±0.5^a	73.5±0.9^a	13.6±0.3^b	1.7±0.0^b
-	-	***p*-value**	**0.000**	**0.116**	**0.425**	**0.000**	**0.010**
1981	Dry	6	14±0.0^a	36.8±0.3^a	66.9±0.7^a	19.1±0.7^a	1.7±0.0^a
	Wet	6	21.5±1.6^b	35.5±0.1^b	62.4±0.3^b	17.1±0.2^b	1.7±0.0^b
-	-	***p*-value**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**

Survey Data, 2010 – 2011.

Values on the same column with different superscript are statistically different at 0.05 levels

Table 2 showed the chemical properties of soils sampled from 1979, 1980 and 1981 age series in teak plantations situated in Akanga forest reserve, Nasarawa State-Nigeria. The soil chemical properties ranged from pH, Total Nitrogen (g/kg), Organic Carbon (g/kg), Organic Matter, Available Phosphorus (mg/kg), Calcium (Cmol/kg), Magnesium (Cmol/kg), Potassium (Cmol/kg) and Cation Exchange Capacity (cmol/kg). There was no significant difference (p =0.142) between the soil pH under the varied age series of teak plantation in dry and wet seasons. There was fluctuation of soil pH between age series of Teak plantations; with1981 age series had the highest pH scale of 6.0 ±0.0 (dry season) and 6.2±0.0 (in wet season).

Total nitrogen from the study area was had no significant difference between the age series and across the seasons; the highest (1.1±0.1 (g/kg) total nitrogen was recorded under 1981 age series (dry season) than under 1979 and 1980 age series. The organic content of 8.8±01 (g/kg) was recorded as the highest value under 1979 age series (in dry season), while 1981 age series was had the highest (8.0±0.2 g/kg) organic content during the wet season. For organic matter, available phosphorus, calcium, magnesium, potassium and sodium recorded from the study area, the results indicated no significant (p >0.150) difference between the age series.

Table 2: Chemical Properties of Soil under three Age-Series in Teak Plantations, Akanga Forest Reserve Nasarawa State, Nigeria

Season	Location	pH	Total N(g/kg)	Org C (g/kg)	OM	Av. P (mg/kg)	Ca	Mg	K	Na	CEC (cmol/kg)
Dry	Control	6.16±0.1	0.9±0.0	7.1±0.5[a]	1.3±0.4	6.0±1.2	3.5±0.5	1.7±0.0	0.3±0.0	0.6±0.0	7.9±1.9
	1979	5.9±0.1	0.9±0.1	8.8±0.1[b]	1.3±0.5	7.7±0.4	4.0±0.0	1.8±0.1	0.3±0.0	0.6±0.0	8.8±0.1
	1980	5.7±0.2	0.9±0.0	8.1±0.6[b]	1.3±0.4	8.3±1.0	4.0±0.0	1.8±0.1	0.3±0.0	0.6±0.0	8.1±0.6
	1981	6.0±0.0	1.1±0.1	8.6±0.2[b]	1.2±0.3	7.1V1.2	3.7±0.6	1.7±0.2	0.3±0.0	0.5±0.1	8.6±0.2
		0.142	**0.193**	**0.004**	**0.996**	**0.287**	**0.572**	**0.725**	**0.329**	**0.215**	**0.725**
Wet	Control	5.9±0.4	0.8±0.0	8.0±0.4	1.0±0.1	7.9±1.5	3.1±0.2	1.3±0.2	0.2±0.0	0.4±0.1	8.0.±0.4
	1979	5.9±0.1	0.7±0.1	7.7±0.1	1.3±0.2	6.8±0.9	3.5±0.2	1.6±0.1	0.3±0.0	0.4±0.0	7.7±0.1
	1980	5.9±0.2	0.9±0.0	7.8±0.2	1.1±0.3	7.2±2.5	3.2±0.1	1.3±0.1	0.2±0.0	0.4±0.0	7.8±0.2
	1981	6.2±0.0	0.8±0.2	8.0±0.2	1.1±0.3	6.7±1.0	3.4±0.3	1.5±0.1	0.3±0.0	0.4±0.0	8.0±0.2
		0.551	**0.088**	**0.626**	**0.830**	**0.860**	**0.419**	**0.177**	**0.112**	**0.429**	**0.626**

Values on the same column with different superscript are statistically different at 0.05 levels

Litter Accumulation in Akanga Teak Plantations

Table 3 shows the rate of litter accumulation under different age-series and seasons in the study area. Based on the result of this finding, leaf accumulation was higher (463.81±54.59 kg) in the dry season under the 1981 age series. This was followed by 474.14±35.7(in 1979), while the 1980 age series accumulated the least rate (378.87±22.60 kg) of leaves in the area. The rate of twigs in the study area was evaluated and the results are shown in the table. There was a higher accumulation of twigs in the dry season than recorded in the wet season across the three age series under study under the age series of the teak plantations.

Fruiting and flowering of teak species take place in the dry and wet seasons, respectively. This finding indicates that the rate of flowering and fruiting increases as the age of the tree species increases. In the dry season, for instance, a mean of 28.76±4.6 kg was accumulated in the 1979 age series, 32.22±0.33 kg was recorded under the 1980 age series, and 37.61±1.76 kg was the highest accumulated under the age series of 1981 teak plantation. Flowering was at its peak (8.90±0.99 kg) under the 1981 age series. This was followed by the 1980 age series, which recorded a mean of 5.86±1.39 kg, while a mean of 4.64±1.44 kg was recorded under the 1979 age series of Teak plantations in the study area. As shown in table 3, each of the flowering and fruiting results differed significantly across the age series studied.

Table 3: Litter Accumulation at varied Age-Series and Seasons in Teak Plantation, Akanga Forest Reserve Nasarawa State, Nigeria

Location	Season	Flowers (kg/ha)	Fruits (kg/ha)	Leaves (kg/ha)	Twigs (kg/ha)
1979	Dry	-	28.76±4.6	474.14±35.7^{a}	7.20±0.74
	Wet	4.64±1.44	-	62.96±3.7 ^{b}	1.45±0.71
	***p*=value**	-	-	**0.004**	**0.008**
1980	Dry	-	32.22±0.33	378.87±22.60	4.81±0.91
	Wet	5.86±1.39		53.11±0.80	1.62±0.26
	***p*=value**			**0.002**	**0.042**
1981	Dry	-	37.61±1.76	463.81±54.59	6.76±0.49
	Wet	8.90±0.99	-	64.14±4.52	2.53±2.23
	***p*=value**			**0.009**	**0.121**

Survey Data, 2010 - 2011

Values on the same column with different superscript are statistically different at 0.05 levels

DISCUSSION

Physicochemical Properties of Soils in Akanga Teak Plantations

The result from the study revealed that, soil physical properties (particle size) under teak for the three age series recorded the highest percentage of sand, while Control had the highest percentage of silt, clay, and porosity.Most of the values of the soil properties (exception of percentage sand) appeared higher during the rainy season and low values during the dry season could be attributed to the high presence of micro-organisms, grasses, and low vegetation, which are generally in abundance during the rainy season due to adequate rainfall in the study area. Soil under Control (forest reserve) showed higher values of physical properties than soil taken from different age series of teak plantation. This result indicates that forest reserves have a higher influence on soil physical properties than teak plantations.

The result of this finding on soil pH is not in accord with the report of Alvarado and Fallas (2004), reported that, soils with pH lower than 5.5 are more likely to have low Ca Sat and show high Mg Sat, while soils with pH higher than 5.5 generally have Ca Sat values higher than 68% (critical level for the species.

The result on chemical properties of soil from teak plantations indicates significant variation on organic content (g/kg) between the soil from age series and Control (reserve). This finding implies that, teak species has significant influence on organic content of the soil in the study area. The result of chemical properties of soil from the area indicates insignificant increase and unsteady increase between soils from the age series of teak plantation and natural forest (Control). This result is in line with the report of Dagba *et al.* (2011), reported that, for a forest soil to maintain a flourishing tree and agricultural crop, all the necessary qualities of a good soil (physical, chemical and biotic factors) must be at an acceptable level of equilibrium.

Total Nitrogen had a steady increase as the plant age increase in dry season, while the Organic matter (g/kg) and Phosphorus content fluctuate with the age of the plant species in the area. The soil properties under teak and the control plots had no significant difference ($p>0.05$). Exchangeable catio was recorded higher values under the older age series of the plantations. Also, seasons (rainy and dry) had effect on soil chemical properties (pH, P, N, Ca, Mg, K, Na and CEC). During the wet season, which also corresponded with the active growth period of forest trees, soil nutrients decreased. This study shows that monoculture plantations of exotic species might result in an initial drop in soil organic content and nutritional components. With increasing plantation age, this state is followed by a progressive increase of soil organic matter and exchangeable catios. Plantations had higher nitrogen, phosphorus, potassium, and calcium levels than forest reserves, indicating a higher nutrient return in the plantations. Dachng *et al*., (2018),reported that,Choubey *et al.* (1988) discovered that litter production in teak plantations (20-23 years) was 1.5-2.0 times higher than in adjacent forest.

Litter Accumulation in Akanga Teak Plantations

Leaf accumulation was higher during the dry season than in the wet season, with an increase over age. This implies that more leaves are shaded mostly during the dry season; this could be due to the high rate of wind in the dry season coupled

with the seasonal phenology process associated with plants in the study area. Each of the flowering and fruiting results vary significantly between the age series. Teak trees change their leaves in the dry season while flowering takes place in the wet season. The accumulation of leaves takes place in all the seasons, while flowering and fruiting take place in the wet and dry seasons, respectively, in the study area. Maintenance of forest productivity is dependent in part on the efficient break-down of litter (Nwoboshi, 2000). One of the most obvious effects of vegetation on the soil is the deposition of dead parts like leaves and other plant materials. The rate of litter breakdown and humus incorporation in tropical soils characterized by broad-leaved trees is dependent on the number, species and the activities of micro-organisms (Dagba *et al.*, 2011). Leaf litter fall was higher in teak than in eucalyptus, according to Singh *et al.*, (1990). In the wild and in the research, the litter degradation rate differed greatly.

CONCLUSION

Based on the results of this finding, the soil particle size from the plantation had the highest percent of sand **(**74.5±1.1**)**. There was a fluctuation of soil pH between the age series. The 1981 age series had the highest pH **(**6.2±0.0**)** in both seasons. The nitrogen content had a steady decline as the plant age increased, while the organic matter and phosphorus content increased with the age of the plant species in the area. There was a decline in soil nutrients during the wet season, which also coincided with the active growth period of forest trees. Leaf accumulation was higher during the dry season, and increased over time. Thus, it is evident from this study that monoculture plantation of teak species could lead to an initial decline of soil organic content and nutrient elements in the soil, followed by a gradual buildup of soil organic matter and exchangeable cations with age.

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