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RESEARCH ARTICLE

Bacteria and Fungi Population of Surface Soils under Various Land Use Types in Minna, Southern Guinea Savanna

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ABSTRACT

The study was carried out at the Teaching and Research Farm of the School of Agriculture and Agricultural Technology, Minna, in the month of July 2014. The aim of the study was to estimate the bacteria and fungi population of three selected vegetation types at three soil depths and correlate microbial counts with the physicochemical properties of soils. The experiment was a 3 by 3 factorial experiment, arranged in a completely randomized design. The treatments were vegetation types (fallow, gmelina, and teak) and three soil depths (0–5 cm, 5–10 cm, and 10–15 cm). Data obtained were subjected to ANOVA while means were separated using the Student–Newman–Keuls test Linear relationship. The standard pour plate method was used to estimate bacteria and fungi colony-forming units (CFU) in 1 g soil. Physical and chemical analyses were carried out by standard laboratory methods. The bacterial and fungal counts were highest in the gmelina vegetation and least under teak. The 0–5 cm soil depth had the highest microbial counts. Bacterial population correlated positively and significantly with the fungal population and organic content while microbial population correlated negatively with soil pH. Gmelina vegetation produced the highest microbial population followed by fallow and teak in that sequence. Fallow recorded the narrowest C/N and C/P ratios, respectively, implying N mineralization and P solubilization while the tree vegetations recorded wider ratios signifying N and P immobilization. It can, therefore, be inferred from the results obtained that tree vegetations can be under cultivation with much sacrifice in inorganic N and P fertilizers. Fallow land, on the other hand, will require lower inorganic N and P inputs and, therefore, has prospects in reduction of environmental pollution and subsequent increase in crop production.

Key words: Bacteria, depth, fungi, population, soil, vegetation

INTRODUCTION

Forest ecosystem is a natural woodland unit consisting of all plants, animals, and microorganisms in an area functioning together with all non-living physical factors of the environment. The forest ecosystem represents 31% of the total land area and supports more than 1.6 million people around the world. At the same time, they are important because they are home to 80% of the terrestrial biodiversity which includes plants, animals, and microbes with their interactions manifesting in the various habitat functions which include the transfer of energy, community interactions, and nutrient recycling. Once defined the forest soil as a soil developed under forest cover or vegetation with a characteristic organic layer on the soil surface known as the forest floor. This layer contains fresh organic material from dead plants and animals, degraded by microorganisms most especially bacteria and fungi, with the thickness of the layer varying, depending on the topography, vegetation, and parent materials in which the forest has been established. Soil microorganisms are said to play significant roles in ecosystem processes because 80–90% of soil processes are mediated by microorganisms.

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Table 1: Effect of soil depth and vegetation on microbial population and soil texture

Treatment	Bacteria (CFU×10^{10} g^{-1})	Fungi (CFU×10^{10} g^{-1})	Sand (g kg^{-1})	Silt (g kg^{-1})	Clay (g kg^{-1})	Textural class
Soil depth (S)						
0−5 cm	62.0	46.0	732	108	160	Sandy loam
5−10 cm	14.0	7.0	692	110	198	Sandy loam
10−15 cm	7.0	33.0	707	95	198	Sandy loam
LSD (0.05)	NS	NS	NS	NS	NS	
Vegetation (V)						
Fallow	18.0	31.0	738	74	188	Sandy loam
Teak	9.0	12.0	681	125	194	Sandy loam
Gmelina	56.0	43.0	712	114	174	Sandy loam
LSD (0.05)	NS	NS	NS	NS	NS	
Interaction						
S×V	NS	NS	NS	NS	NS	

NS: Means not significant, * significant at Pr<0.05, CFU: Colony-forming units

Table 2: Effect of soil depth and vegetation on soil chemical properties

Treatment	pH (H_2O)	pH ($CaCl_2$)	OC (g kg^{-1})	TN (g kg^{-1})	Av. P (mg kg^{-1})	Exchangeable bases			
						Ca	Mg	Na	K
						(Cmol kg−1)			
Soil depth (S)									
0−5 cm	6.81	6.12	24.84	0.10	2.30	0.13	0.07	1.30	1.00
5−10 cm	6.78	6.07	17.22	0.11	1.86	0.12	0.10	0.59	0.48
10−15 cm	6.76	6.05	14.27	0.11	2.19	0.12	0.08	0.59	0.52
LSD (0.05)	2.25	0.06	NS	NS	NS	NS	NS	NS	NS
Vegetation (V)									
Fallow	6.76	6.05	14.32	0.10	2.68	0.12	0.08	0.70	0.72
Teak	6.86	6.14	18.40	0.10	1.72	0.13	0.08	0.85	0.73
Gmelina	6.74	6.04	23.63	0.11	1.95	0.12	0.09	1.03	0.55
LSD (0.05)	2.26	0.06	NS	0.72	NS	NS	NS	NS	NS
Interaction									
S×V	*	*	*	NS	NS	NS	NS	NS	NS

NS: Not significant, * significant at Pr<0.05. OC: Organic carbon, TN: Total nitrogen, Av. P: Available phosphorus, LSD: Least significant difference

Table 3: Interaction between soil depth and vegetation on organic carbon content

Treatment	Vegetation		
	Fallow	Teak	Gmelina
Depth (cm)			
0−5	21.76[a]	26.17[a]	26.69[a]
5−10	12.65[c]	14.21[c]	24.79[a]
10−15	8.67[d]	14.73[c]	19.41[b]
SE±		1.32	

Means with the same column followed by the same letter (s) are not significantly different at *P*>0.05.

Researches have shown that microbial population in the soil is governed by interactions between plant type, climate, soil characteristics, and management practices on these lands [Table 1].

In Africa, monoculture plantation agriculture has been embraced by farmers, and it contributes a significant proportion of export earnings. In Nigeria, several studies in literature have either looked at the effect of various forest tree species on soil properties with particular reference to a particular ecological zone, but studies that investigate the effect of these dominant tree crops on soil microbial population in the Southern Guinea Savannah ecological zones of Nigeria are not well documented [Table 2]. Zeller *et al.* (2001) stated that because soil microbial communities are the driving force behind soil processes regulation such as organic matter decomposition and nutrient cycling, it is imperative to have a better understanding of the factors that regulate its population and in turn its activities. In view of this, a research was undertaken to:

1. Determine the bacteria and fungi population at different depths under two forest vegetations and a fallow land.
2. Determine the relationship that exists between soil physicochemical properties and soil microbial population.

METHODOLOGY

The study area

This study was carried out at the Federal University of Technology, Minna Forest Reserve, which lies approximately on longitude 09°31' 214" N, latitude 06° 27' 604" E, and elevation of 233 m and located within the Southern Guinea Savannah ecological zone. This forest reserve was established 10 years ago under the university afforestation scheme [Tables 3 and 4]. The climate is subhumid tropical with mean annual rainfall of about 1200 m (90% of the rainfall is between June and August). The mean daily temperature rarely falls below 22°C with peaks of 40°C and 36°C between February–March and November–December, respectively.

Table 4: Interaction between soil depth and vegetation on soil pH in H_2O

Treatment	Vegetation		
	Fallow	Teak	Gmelina
Depth (cm)			
0–5	6.89[a]	6.90[a]	6.64[d]
5–10	6.70[cd]	6.84[ab]	6.81[ab]
10–15	6.69[cd]	6.83[ab]	6.75[bc]
SE±		0.04	

Means with the same column followed by the same letter (s) are not significantly different at $P>0.05$

Table 5: Interaction between soil depth and vegetation on soil pH in $CaCl_2$

Treatment	Vegetation		
	Fallow	Teak	Gmelina
Depth (cm)			
0–5	6.18[a]	6.20[a]	5.97[d]
5–10	5.96[cd]	6.14[ab]	6.10[ab]
10–15	6.01[cd]	6.08[ab]	6.06[bc]
SE±		0.03	

Means with the same column followed by the same letter (s) are not significantly different at $P>0.05$.

Soil description and biodiversity

The soils of Minna are Alfisols (USDA) developed from basement complex rocks ranging from shallow to very deep soils overlying deeply weathered gneisses and migmatites, underlain by iron pan to varying depth. The forest reserve consists of well-managed plantations of gmelina, teak, and cashew with strips of arable lands that have been left to fallow [Table 5]. The teak and gmelina plantations have plot size of 6 hectares each. Intertree spacing within the teak plantation was 3 m and was closer than the other vegetation forming a close tree covering preventing penetration of sunlight and huge depositions of partly decomposed leaf litters on the soil surface [Table 6]. The teak vegetation had sparse undergrowth of some common shrubs like wild strawberry (*Nauclea latifolia*) and young trees like shea butter (*Butyrospermum parki*). The dominant animals present include mostly lizards, flies, centipedes, millipedes, ant, termites, mushrooms, earthworms, grasshoppers, butterflies, and dragonflies. Intertree spacing in the gmelina vegetation was wider than that of teak and was dominated with more dense undergrowth of shrubs and grasses and higher density of macrofauna population. The fallow vegetation which lied opposite the teak vegetation, comprised

Table 6: Correlation matrix between pairs of soil physicochemical and microbiological properties

	Bact	Fung	Sand	Silt	Clay	OC	TN	Av.P	pH (H_2O)	pH ($CaCl_2$)	Ca	Mg	Na	K
Bact														
Fung	0.65[×]													
Sand	0.04	−0.04												
Silt	0.11	0.08	−0.92*											
Clay	−0.36	−0.08	−0.38	−0.02										
OC	0.39[×]	0.13	0.26	0.26	−0.67*									
TN	0.06	-0.01	0.02	−0.02	−0.00	−0.02								
AVP	−0.15	0.00	0.28	−0.24	−0.16	−0.11	−0.07							
pH (H_2O)	−0.12	−0.32	−0.03	0.16	−0.18	0.17	−0.19	−0.17						
pH ($CaCl_2$)	−0.11	−0.31	−0.03	0.37	−0.26	0.09	−0.23	−0.30	0.97*					
Ca	0.29	0 0.09	−0.39*	0.51*	−0.19	0.24	−0.12	−0.52*	0.36	0.11				
Mg	−0.30	−0.33	0.06	−0.15	0.21	−0.06	0.24	0.16	−0.32	−0.23	−0.49*			
Na	0.08	−0.02	0.15	−0.06	−0.24	0.25	0.14	−0.05	−0.42	−0.44	0.13	0.41*		
K	0.35	0.18	0.28	−0.11	−0.45*	0.21	−0.20	0.10	0.15	0.09	0.21	−0.29	0.28	

TN: Total nitrogen, OC: Organic carbon, Bact: Bacteria, Fung: Fung*: Significant at Pr<0.05

of a previously irrigated field nearby which had over the years been cultivated to arable crops. Tree and grass species in the fallow include young mango trees (*Mangifera indica*) and speargrass (*Imperata cylindrica*). The land was slightly undulating with the presence of a gully.

Treatment and Experimental Design

The experiment was factorial, having two factors which are depth and vegetation. The three soil depths are 0–5 cm, 5–10 cm, and 10–15 cm under three vegetation types (teak, gmelina, and fallow) fitted into completely randomized design with each treatment replicated 3 times.

Soil sampling

Soil samples were collected from each forest and fallow vegetation according to treatments using a soil auger from 10 points under each vegetation. Before sampling, the soil auger was sterilized with flame and methylated spirit to prevent cross-contamination of the various depths. The soil was then homogenized and bulked according to depth and vegetation resulting into three composite soil samples per vegetation. Part of the soil sample was immediately stored in plastic bags and placed in a refrigerator until the use for microbial analysis while the other part was air-dried for 24 h and then hand crushed lightly. It was then screened using a 0.5 mm and 2.00 mm sieve for physicochemical analysis using standard methods outlined by the International Soil Reference and Information Center/Food and Agricultural Organization.

Microbial analysis

The standard procedure for the determination of soil microbes was adopted for bacteria culturing. A series of clean 10 test tubes containing 9 ml of sterile distilled water for the isolation of bacteria and fungi was sterilized with the autoclave at temperature of 121°C and pressure of −31 bars for 15 min. Contents were allowed to cool and to the first tube, 1 g of the soil sample was added to give a dilution of 10^1 at the presence of flame. The content was shaken properly and 1 ml of the solution taken and transferred to the next test tube containing 9 ml sterile water to make a serial dilution of 10^2. The serial dilutions were made up to 10^{10} dilution for each soil sample. Thereafter, 1 ml of the 10^{10} dilution was cultured on the nutrient agar plate using the pour plate technique. A syringe was then used to spread the dilution on the plate before the agar was poured into it. The plates were allowed to solidify and placed upside down in an incubator at 37°C for 24 h. For the isolation of the fungi, Sabouraud dextrose agar (Sabouraud, 1892) with chloramphenicol powder to limit bacteria growth was used in culturing of 1 ml of the 10^{10} serial dilution. The same procedure undertaken for bacterial culturing was repeated except that the plates were then incubated at room temperature upside down for 3–5 days. The plates were prepared in triplicate and the average CFU/g of soil was recorded after growth.[1-8]

Data analysis

Analysis of variance (ANOVA) was used to access treatment difference. Least significant difference was used to separate means where significant differences were observed at 5% probability level while correlation matrix was used to correlate the microbial population with the soil physicochemical properties to access the relationship between these variables.

DISCUSSION AND CONCLUSION

Within a given ecosystem, depth in soil is a primary consideration for microbial habitat, and many key habitat characteristics such as oxygen levels, availability of food, and nutrients change through the soil profile. Results obtained have demonstrated that the microbial populations were highest at 0–5 cm than at 5–10 and 10–15 cm soil depths, respectively, suggesting that these microbes were averagely aerobes. Bhattacharya and Jha (2011) stated that fungal population was always higher in surface soil and decreased with increasing depths. They attributed the increase to high amounts of organic carbon, nitrogen, and higher aeration at the surface soil. The microbial population was highest under gmelina vegetation probably due to higher biodiversity. The contributions of diverse plant and animal species cohabiting in this vegetation most likely increased the energy source for microbial proliferation. Averagely, the fallow land produced a higher microbial population than teak, suggesting that nutrient recycling was enhanced by fallow system, i.e., nutrients were probably been used at

a higher rate under teak than they were returned back to the soil. The leaf litter from the teak vegetation probably did not easily decompose to release nutrients that were tied up in the leaves for microbial growth. This also shows the relationship between plant roots and microbial population of the soil as their increased presence under fallow brought about an increase in the microbial population compared with teak vegetation. It was observed that there was no vigorous undergrowth and there were few plant species beneath the teak vegetation probably as a result of shading. This most likely affected decomposition of litter and translated to lower organic carbon content observed under teak plantation compared with gmelina and a higher C/N ratio of soil under teak compared with fallow. Fungi population was higher under gmelina plantation than under fallow probably due to their strict mode of nutrition (heterotrophs) and also the presence of more resistant plant material. This is consistent with the report of Tugel and Lewandowski (2001)[14] who maintained that fungi are especially extensive in forested lands and have been observed to increase the productivity of these lands as they increase in biomass.[9,10]

The negative correlation of bacteria and fungi with clay signifies that they are aerobes and also suggests that they cannot tolerate water-logged soil condition. The positive correlation of microbes with organic carbon suggests that they are predominantly heterotrophs that need carbon for energy source, as reported by Fosbery *et al.* (2001). The positive correlation of fungi with phosphorus, potassium, and calcium suggests that the fungi population may need inorganic nutrients for their metabolism and they may be predominantly arbuscular mycorrhizal fungi that solubilize P as reported by Hossain *et al.* (2012). The positive correlation of bacteria with total nitrogen, calcium, sodium, and potassium content of soils shows that some strains of bacteria are chemoautotrophic as reported by Frey *et al.* (2004) and Bradley *et al.* (2006). The positive correlation between bacteria and fungi suggests that their association could be synergistic and may be beneficial to soil processes, as reported by Uzoma *et al.* (2014). The negative correlation of the soil microbial population with soil pH indicated that microbes thrive best in slightly acidic to neutral soils as reported by Adekunle and Dafiwahre (2011).[1,11-16]

In summary, the gmelina vegetation produced the highest microbial population followed by fallow and teak in that sequence. Microbial counts were higher at 0–5 cm than any other depth investigated. Fallow recorded the narrowest C/N and C/P ratios, respectively, implying N mineralization and P solubilization while the tree vegetations recorded wider ratios signifying N and P immobilization. It can, therefore, be inferred from the results obtained that tree vegetations can be under cultivation with much sacrifice in inorganic N and P fertilizers. Fallow land, on the other hand, will require lower inorganic N and P inputs and, therefore, has prospects in reduction of environmental pollution and subsequent increase in crop production.

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