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Soil Organic Carbon Stocking Ability of Some Soils under Oil Palm (*Elaeis guineensis* Jacq.) and Rubber (*Hevea brasiliensis* Muell Arg.) Plantations in Edo State, Nigeria

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ABSTRACT

This study evaluated soil organic carbon stock and its relationship with some soil microbial, physical and chemical properties. The soils were Alagba, Orlu, Ahiara and Kulfo series located in two (2) locations within Edo State namely; Nigeria Institute for Oil Palm Research (NIFOR), Benin City, (latitude 06.33' to 06.47'N; longitude 05.37'E to 05.46'E) and Rubber Research Institute of Nigeria (RRIN), Benin City, (latitude 06.08'N to 06.11'N; longitude 05.34'E to 05.38'E). With the aid of soil maps, in each of the soil types, random auger samples were collected at a soil depth of 0-30 cm. Similarly, core samples were taken from the same point where auger boring were made. The results obtained from the study indicated that, there were significant differences among the various soil types and soil properties. The study revealed that, most of the soils were dominated by sand in Texture. The results further revealed that there were considerable variations among the soils in soil organic carbon stock contents. For example, NIFOR location had mean values ranging from 14.76 g/kg to 86.16 g/kg. While, that of RRIN ranged from 26.28 g/kg to 104.6 g/kg. Total bacteria count ranged from 16.07 cfu/g x 10^3 (Kulfo soils) - 24.20 cfu/g x 10^3 (Alagba soils) and Total fungi count ranged from 10.00 cfu/g x 10^3 (Kulfo soils) - 15.00 cfu/g x 10^3 (Alagba soils) respectively as recorded for NIFOR soils (location 1). While, pH value ranged from 5.4 (Ahiara soils) - 6.2 (Orlu soils), Soil organic matter ranged from 38.38 g/kg (Kulfo soils) - 55.08 g/kg (Alagba soils). Total bacteria count ranged from 16.00 cfu/g x 10^3 (Ahiara soil) - 26.00 cfu/g x 10^3 (Alagba soil) and Total fungi count ranged from 10.00 cfu/g x 10^3 (Ahiara soil) - 22.00 cfu/g x 10^3 (Orlu soil) respectively as recorded for RRIN location.

1. Introduction

Agricultural soils contain twice the amount of carbon in the atmosphere as $C0_2$ and thrice the amounts in global vegetation. Plants trap carbon dioxide during photosynthesis, and their death, decay and decomposition result in the release organic carbon earlier trapped in form of carbon dioxide. Soil organic carbon (SOM) comprises residues of plants and animals at all stages of decomposition mediated by soil microorganism (Lar, 2004).

When microorganism grow and multiply on organic debris, carbon is utilized for building the cellular materials of microbial cells with the release of carbon dioxide, methane and other volatile substances. The relationship between organic carbon and microbial population may be direct or indirect. Organic carbon is a natural substrate for saprophytic microorganism and provides nutrition to plants indirectly through the activities of soil microorganism. The microbial contribution to carbon stock is governed by the interactions between the amount of microbial population, microbial community structure, microbial by-products and soil properties such as texture, clay mineralogy, pore-size distribution, and aggregate dynamics.

In view of the increase in plantation farming activities, environmental pollution, decreasing soil fertility and adverse effects on soil microorganisms, it is of utmost concern to study the drastically altered soil properties and function, which pave the way for greater understanding in the direction of improving soil health (Ufinomue, *et al*., 2014). In most of Africa including Nigeria, study on quantification of carbon stored in the soil is proceeding slowly. Thus, data on soil carbon pools are lacking for most common agro-systems. Hence, this study had as its main objectives: (i) to determine the carbon stocking ability of Alagba, Orlu, Kulfor and Ahiara soil series in the study area (ii) identify the specific bacteria/fungi found in the study area.

2. Materials and Methods

The study was carried out in two locations in Edo State namely; (1) Nigerian Institute For Oil Palm Research (NIFOR), Benin City (latitude 06.33'N to 06.47'N; longitude 05.37'E to 05.46'E). 2) Rubber Research Institute of Nigeria (RRIN) Iyanomo, Benin City, Nigeria (latitude 06.08'N to 06.11'N; longitude 05.34'E to 05.38'E).

The mean annual rainfall in NIFOR area ranged from 1560 mm to 1978 mm. Monthly air temperatures for the same period ranged from 27.8^0 -29.4^0 C with an annual mean of 25.7^0 C.

Some vegetation of the area include; Oil Palm (*Elaeis guineesis)*, *Chromolaena odorata, Centrosema pubescens* and *Ageratum conyzoides*. Ogunkunle (1983), classified NIFOR soils into Alagba and Orlu series as Rhodic Paleudult (Ultisol) and Kulfo and Ahiara as Typic Dystrudept (Inceptisol) (Figure 1). The mean annual rainfall for RRIN location ranged from 1720 mm to 2026 mm. The mean monthly temperature range from 27.8 to 32.4^0 C. The climax vegetation of RRIN has been tremendously altered by the impact of uncontrolled forest exploitation and cultivation . Several tropical tree species such as *Chrotalaria exelsa*, *Cieba petandra*, *Chromolaena odorata* e.t.c are present. The soil is part of the Coastal Plain sands of the Niger Delta Basin. Orimoloye and Akingbola (2013), classified the Alagba and Orlu series as Rhodic Paleudult (Ultisol) and Kulfo and Ahiara as Typic Dystrudept (Inceptisol) (Figure 2). Adjacent plots/ nearby plots with the same soils were treated as control plots.

2.1 Soil Sampling

With the aid of soil map (Figure 1 and Figure 2), in each of the soil series and location, random auger samples were collected at a depth of 0-30cm. Similarly, core samples (using core samplers) were taken from the same point where auger boring were made. Each sample was a replicate. The samples were properly labelled, bagged and taken to the laboratory. While, adjacent plots/ nearby plots with the same soil were treated as control plots.

2.2 *Laboratory Studies*

Particle size analysis were determined by hydrometer method as described by Tiessen and Stewart (1983). Bulk density (Bd) was estimated by core procedure (Grossman and Reinsch, 2002). Soil pH was measured using pH meter in a soil water ratio of 1:1. Humic acid (HA) contents and Fulvic acid (FA) contents were analyzed using the method of Steveson (1994) and Swift (1996) respectively. EDTA method was used to determine Exchangeable base outline by Jackson (1962). Soil organic carbon was estimated by wet digestion (Nelson and Summers 1982). Soil organic carbon stock was calculated by multiplying Bulk Density (BD), Clay Fraction (CF) Humic Acid (HA) and Fluvic Acid (FA), that is organic carbon stock = BD (g/ cm^3) X CF X HA X FA (Batjes, 1996).

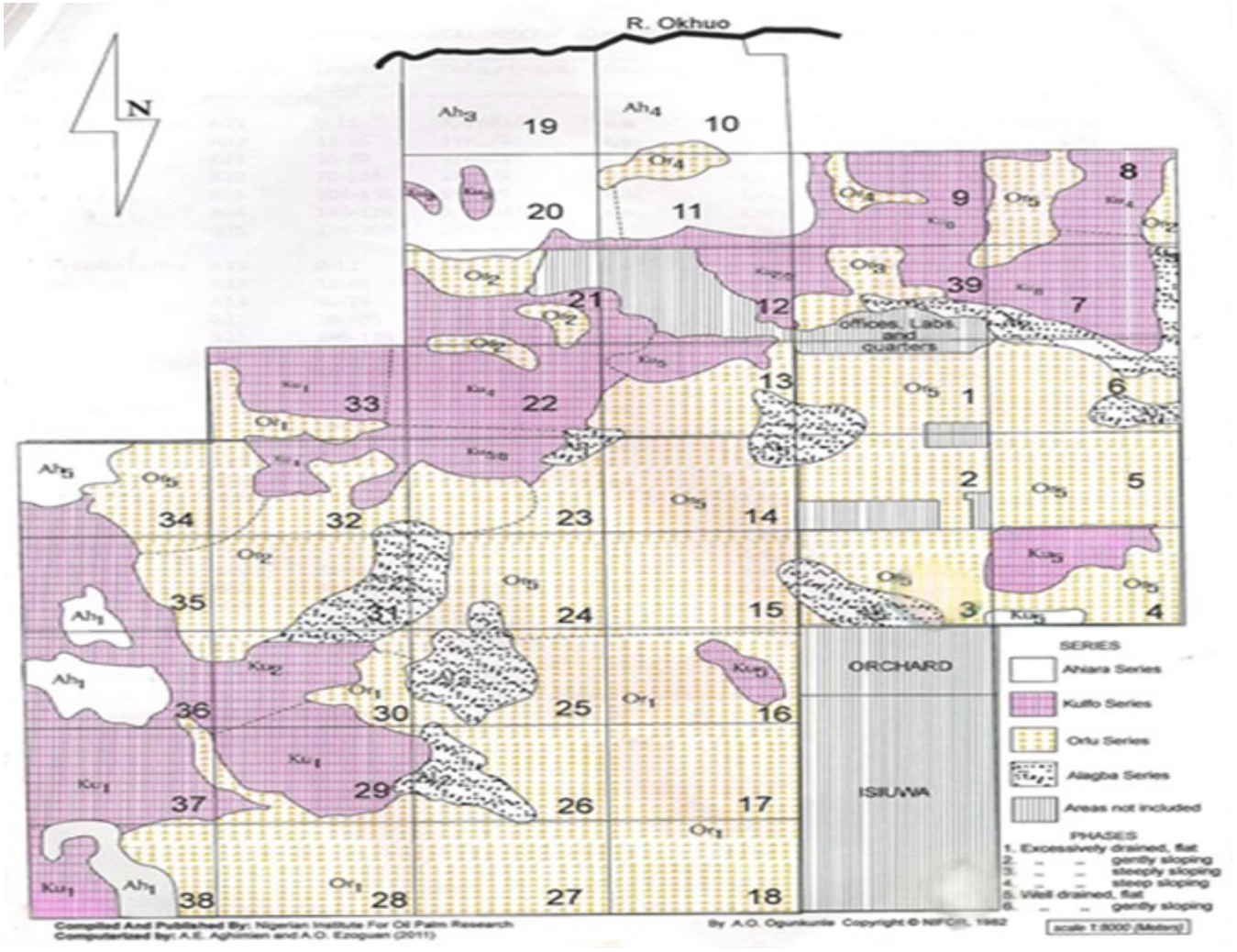


Fig. 1: Soil Map of NIFOR Main station

Table 1: The Mean Rainfall Data of NIFOR and RRIN locations (mm)

Locations	NIFOR	RRIN
Year	2015	2015
January	0	0
February	75.7	57.5
March.	38.7	25.10
April	219.9	205.5
***May**	**215.4**	**259.4**
June	194.6	177.2
July	277.8	252.8
August	262.1	282.9
September	282.3	297.5
October	323.8	363.4
November	109	123
December	57.0	21.1
Total	**2094.9**	**1816.5**

Source: NIFOR Meteorological Station and RRIN Meteorological station.

3. Results and Discussion

The results obtained on various soil organic carbon stocks (SOCS) attributed in relation to important soil characteristics and nature of parent materials are presented and discussed below:

3.1 Soil Organic carbon Stock (SOCS)

As evident from Figure 3, results of Soil organic carbon stocks in soils varied greatly with type of parent materials. The soils within NIFOR location had mean values ranging from 14.76 g/kg to 86.16 g/kg while that of RRIN ranged from 26.28 g/kg to 104.6 g/kg. The highest Soil organic carbon stock recorded (104.6 g/kg) (Alagba series) in RRIN location, whereas lowest soil organic carbon contents was observed in Ahiara series in both location studied. Results of the study indicated that there were differences in total quantity of carbon stocks in the different soil series in the study area. These differences were confirmed by the high variation between the SOCs contents of the different soil series. The highest quantities of SOCs were observed in Alagba soil type having a value of 104.63 g/kg (RRIN location) as presented in Figure 3. Orlu followed Alagba series with a value of 86.157 g/kg (NIFOR) respectively.

The difference in carbon stocks between all soil series with the highest carbon stock and lowest values may be either because of differences in plantation type, presence of soil microorganism and soil types (soil series). This agrees with the finding of Ogboghodo (2017) that higher soil organic matter observed were strongly associated with microbial population. Difference in SOCs pool under different soil series were statistically significant ($P<0.05$).

More, possible explanation for the increase of RRIN location of Soil Organic Stocks towards Oil Palm location include; the quantity and quality of leaf fall and field layers, different temperature condition and site production capacity and different atmospheric nitrogen (N) deposition and soil management.

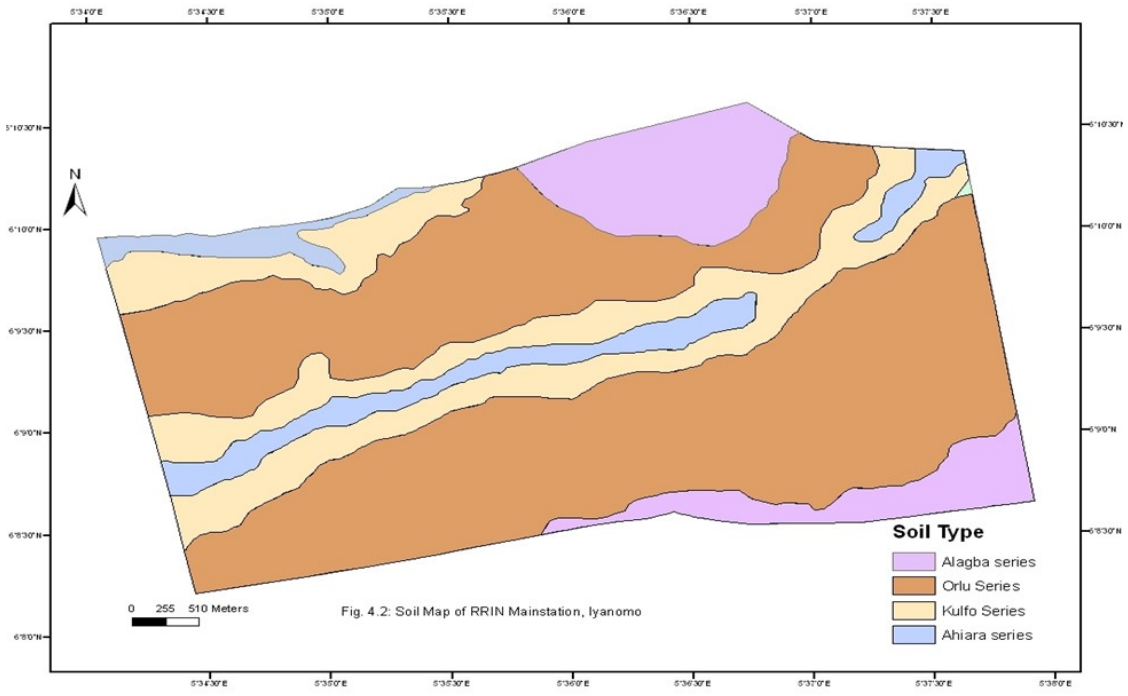


Fig. 2: Soil Map of RRIN **Source: Orimoloye and Akingbola (2013).**

Juma (1999), stated that organic matter content, particularly the more stable humic substances increases the capacity of the soil to store water and stock organic carbon from the atmosphere.

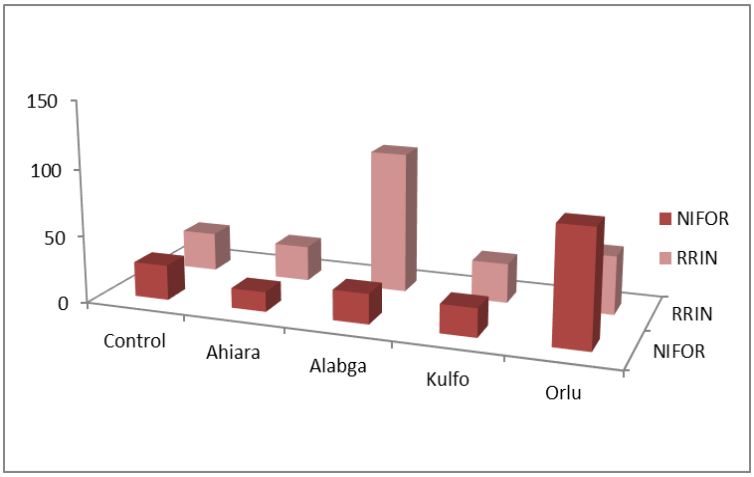


Figure 3. Soil Organic Carbon Stocks (SOCS) affected by Soil types in g/ kg

3.2 Soil Physical Properties

The mean values for Bulk density (Bd), sand, clay fraction (CF), Humic acid (HA), and Fulvic acid (FA) are presented in Table 2 are as follows: 1.07 g/kg (control), 1.32 g/cm^3 (Orlu), 1.25 g/cm^3 (Kulfo) 1.25 g/cm^3 (Ahiara), 1.23 g/km^3 (Alagba) respectively in NIFOR location. Orlu series had the highest mean value in bulk density and correlated positively with silt fraction, Humic acid, Fulvic acid and Organic carbon. The mean sand values is distributed as follows: 871 g/kg (control), 918 g/kg (Orlu), 874 g/kg (Kulfo), 901 g/kg (Ahiara) and 873 g/kg (Alagba). Clay fraction values ranged from 61.93 g/kg (Alagba) to 77 g/kg (Kulfo). The texture of the soils was mainly sandy loam. Soil texture affects soil organic carbon stock due to its influence on soil microbial population and soil respiration (Davidson *et al*., 1998). Clay fraction were higher in RRIN location compared to NIFOR location. The results indicated that there was significant difference ($P<0.05$) in clay fractions between the two locations and among the soil series studied. The physical, chemical and microbial properties of RRIN location studied are presented in Table 3. Results of the analysis showed that the soil texture is sandy loam with the sand fraction accounted for more than average of 87% while, soil pH was strongly acidic (5.42). The organic matter contents in both location were generally low to medium (< 20 - 42 g/kg). Bacterial, fungi and most living things in soils, depend on soil organic matter for nutrient and energy. The low level of nutrient status in the study could also be attributed to the predominant sandy soil texture of the area. The results obtained from this study showed that organic matter content was greater in soils of Ultisol than in Inceptisol soils.

Phyical properties of RRIN soils

The mean values for Bulk density (Bd), sand, clay fraction (CF), Humic acid (HA), and Fulvic acid (FA) are presented in Table 3 are as follows: 1.02 g/kg (control), 1.21g/cm^3 (Orlu), 1.13 g/cm^3 (Kulfo) 1.16 g/cm^3 (Aharia), 1.25g/km^3 (Alagba) respectively in NIFOR location. Alagba series had the highest mean value in bulk density and also correlated positively with silts fraction, Humic acid, Fulvic acid and Organic carbon. The mean sand values is distributed as follows: 859 g/kg (control), 774.4 g/kg (Orlu), 971.6g/kg (Kulfo), 854.6 g/kg (Aharia) and 834.6 g/kg (Alagba). Clay fractionsvalues ranged from 91.5 g/kg (Control) to 177.4g/kg (Orlu).

3.3 Soil chemical properties

Results of the mean values of soil pH, organic carbon (OC), and C:N ratio is shown in Table 2. Soil pH ranged from 5.40 (strongly acid) to 6.44 (slightly acidic) in NIFOR location. Organic carbon and carbon nitrogen ratio is ranged as follows; 15.43 g/kg to 18.93 g/kg, and 5.51 carbon/nitrogen ratio. While, soil pH, organic carbon, and C/N ratio are ranged as follows; 4.25 (extremely acidic) to 5.25 (strongly acidic), 21.4 g/kg to 32.4 g/kg and 14.26 to 22.77 for carbon nitrogen ratio respectively.

3.3.1 Humic acid and fulvic acid

The result of humic acid (HA) and fulvic acid (FA) are shown in Table 2 and 3. The mean value for humic acid ranged from 46.7 g/kg (Ahiara) to 465.3 g/kg (Orlu) recorded for NIFOR location. While, RRIN location ranged from 16.7 g/kg (Aharia) to 564.0g /kg (Alagba) the highest mean. Fulvic acid had the following mean value which ranged from 26.37 g/kg (Aharia) to 321.1 g/kg (Orlu) in NIFOR location. While, RRIN location ranged from 29.00 g/kg (Kulfo) to 286.2 g/kg (Alagba). Fulvic acid correlated positively with humic acid. Humic substances serve as the main source of nutrient in most soils, especially in higher weather tropical soils (Olayinka 2009). The results revealed that there were significant difference ($P<0.05$) in the contents of Humic acid and fulvic acid studied. Krieger (1975), indicated that greater quantities of humic acid than fulvic Acid fraction and attributed this possibly to the greater percentage of nitrogen (protein) is humic acid than fulvic acid. Bohn *et a*l. (2001), reported that the low molecular weight of fulvic acid. of the former (Humic acid).

3.3.2 Microbial population

Table 2 shows the mean for Total bacterial counts during the period of study in NIFOR location. The order of dominance is as follows; Alagba > Ahiara > Orlu > Kulfo series. RRIN location follows similar pattern; Alagba > Ahiara > Orlu > Kulfo respectively.

The mean results for Total fungi counts is shown in Table 3. Alagba and Ahiara had the same mean value of 15.00 cfu/g x 10^3 while, Kulfo and control had the same mean value (11.00 cfu/g x 10^3) in NIFOR location. The specific bacterial species present in various soils were: *Staphylococcus aureus, Pseudomonas aeruginosa, Micrococcus cereus, Bacillus substilis* and *Klebsiella pneumoniae* were observed to be present in NIFOR location.

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However, the specific bacterial species present in various soils were: *Staphylococcus aureus, Pseudomonas aeruginosa, Micrococcus cereus, Bacillus substilis* and *Klebsiella pneumoniae* were observed to be present in NIFOR location. *Staphylococcus aureus* was present in Ahiara, Alagba series and Orlu but absent in Kulfo series in NIFOR location. *Micrococcus cereus* was observed to be absent in ll soil series with the exception of Alagba series. *Bacillus substilis* follows the same trends as *Micrococcus cereus.*
Five fungal species were identified from the study including: *Aspergillus niger, Aspergillusf umigatus, Aspergillus flavus, Penicillium notatum a*nd *Geotrichum spp* in respectively. *Aspergillusniger* was present in Ahiara, Alagba andOrlu series (NIFOR), but observed to be absent in Kulfo series. Fungi species followed this order of dominance; Orlu>Alagba>Kulfo>Ahiara

Table 2: Some Physical, Chemical and Microbial properties of Ahiara, Alagba, Kulfo and Orlu soils in NIFOR location

Soil properties	Series				
	Control	Ahiara	Kulfo	Alagba	Orlu
		Mean Values			
Bulk density (g/cm ^{3})	1.02	1.25	1.23	1.23	1.32
Sand (g/kg^{-1})	871	901	874	901	918
Silt (g/kg^{-1})	63.10	32.00	49.00	32.00	20.00
Clay (g/kg^{-1})	65.9	67.00	77.00	67.00	62.00
Textural Class	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Soil pH	6.40	5.43	5.72	5.43	6.23
Organic Carbon (g/kg^{-1})	15.43	17.1	17.87	18.93	18.23
Total Nitrogen (g/kg^{-1}	1.10	1.73	1.50	1.88	1.37
Carbon/Nitrogen Ratio (CNR)	5.51	6.47	21.53	6.46	16.13
Humic Acid (g/kg^{-1})	110.8	46.7	66.2	98.8	465.3
Fulvic Acid (g/kg^{-1})	63.9	26.4	57.2	52.1	321.2
Total Bacteria Count (cfu/g) x 10^3	16.00	23.00	18.00	26.00	21.00
Total fungi Count (cfu/g) x 10^3	11.00	15.00	11.00	15.10	12.00

3.3.3 Relationship between soil properties

Correlation matrix analysis of the soils physical, chemical and microbial properties indicated that certain soil properties were related significantly (Table 4). Correlation analysis were done to determine the level of association among some of the soil properties. The positive correlation that existed between soil organic Carbon and Total bacteria counts suggests that the transformation of soil organic matter is supported by bacteria and fungi present in soils. Weigand *et al.* (1995), observed a significant positive correlation between soil organic carbon and soil pH, total bacterial counts and available phosphorus. Positive correlation existed between organic carbon and Fulvic acid in both plantations. However, negative correlation existed between clay and organic carbon but this was not significant.

This further indicates that availability of Humic acid, Fulvic acid, exchangeable Magnesium, exchangeable Calcium, available Phosphorus, Cation exchange capacity and Total Nitrogen, depends to some extent on the status of mineral associated soil organic carbon. The content of Humic acid was significantly influenced by soil types. This could be attributed to the presence of humic substances in soil organic matter which has strong affinity for divalent element. Hence, the ability of soils to provide long term carbon stock and the nutrients necessary for plant productivity are largely dependent on soil organic matter dynamics (Billings and Ziegler, 2005).

Table 3: Some Physical, Chemical and Microbial properties of Ahiara, Alagba, Kulfo and Orlu soils in RRIN location

Soil properties			Series		
	Control	Ahiara	Kulfo	Alagba	Orlu
			Means		
Bulk density (g/cm $^{-3}$)	1.02	1.16	1.13	1.25	1.21
Sand (g/kg^{-1})	859	854.6	971.6	834.6	774.4
Silt (g/kg^{-1})	49.3	47.2	28.9	33.9	48.3
Clay (g/kg^{-1})	91.5	98.2	99.5	131.5	177.4
Textural Class	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam
Soil pH	5.40	5.63	5.66	5.15	5.30
Organic Carbon (g/kg^{-1})	27.2	25.3	21.4	32.4	31.20
Total Nitrogen (g/kg^{-1}	1.10	1.73	1.50	1.88	1.37
Carbon/Nitrogen Ratio (CNR)	14.56	14.59	14.27	17.35	22.77
Humic Acid (g/kg^{-1})	113.0	76.7	113.3	564.0	197.0
Fulvic Acid (g/kg^{-1})	64.0	34.1	29.1	286.2	125.0
Total Bacteria Count (cfu/g) x 10^3	17.00	16.00	22.00	28.00	22.00
Total Fungi Count (cfu/ g) x 10^3	10.00	10.00	14.00	16.00	14.00

Table 4: Correlation matrix of some physical and chemical with microbial properties of soils studied

	Sand	Silt	Clay	Bd	HA	FA	Org.C	TN	TFC	TBC
Sand										
Silt	0.541*									
Clay	0.462	0.661*								
Bd	-0.483	0.526*	0.661*							
pH	0.378	0.369	0.496	0.652*						
HA	0.66*	0.650*	0.450	0.576*						
FA	0.477	0.476	0.393	0.567*	0.694*					
Org.C	-0.220	0.271	0.596*	0.619*	0.596*	0.570*				
TN	0.363	0.564*	0.728*	0.539*	0.311	0.622*	0.881*			
TFC	-0.690*	-0.687*	0.597*	0.792*	0.697*	-0.523*	0.597*	0.692*		
TBC	0.130	0.278	0.373	0.385	0.328	0.276	0.571*	0.446	0.636*	

* - Significant at $P < 0.05$

Key: Bd = Bulk density; CN =Carbon/Nitogen Ratio; FA= Fulvic Acid: HA= Humic Acid; Org. C = Organic Carbon; pH= Soil acidity; TN= Total Nitogen; TBC= Total bacteria counts; TFC= Total fungi counts

4. Conclusion

Results obtained indicated that Nigeria Institute For Oil Palm Research and Rubber Research Institute of Nigeria, soils were sandy in nature and it can be concluded that the soils were predominantly sandy loam considering, their texture. There were significant variations in the Microbial population. The study revealed that *Bacillus substilis,* a bacteria species and *Penicillium notatum,* a fungi species were predominant in both locations studied. The Microbial population varied from soil to soil in the studied area in the order of magnitude: Alagba > Orlu > Ahiara > Kulfo.

Nutrient status varied from soil to soil with Orlu having the highest mean value followed by Alagba, Ahiara and Kulfo in a decrease order. The soil pH was strongly acidic in Study ll (RRIN soils). Thus, it could be concluded that the soil microbial distribution are controlled largely by the nature of soil characteristics within the same parent materials.

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