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Monosaccharide Distribution of Soils on a Toposequence in the Humid Tropical Rainforest, Southeastern, Nigeria

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Abstract

Soil monosaccharide distribution provides useful information about its carbohydrate origin and tendency for carbon sequestration. Monosaccharide (glucose, galactose, mannose, arabinose and xylose) distribution of soils on a toposequence in Mbano, southeastern, Nigeria was estimated by extracting 1g soil with 25 mls of 80% hot alcohol. Experimental design was a 2 x 3 x 5 factorial of horizon, physiography and monosaccharides in a randomized complete block setup with 3 replications. Also monosaccharide contents were correlated and regressed with soil properties. Mean monosaccharide contents averaged over horizons and physiography varied as 0.03, 0.07, 0.68, 0.74 and 0.88% in increasing order of glucose < galactose < mannose < xylose < arabinose. Also, averaged over horizon and monosaccharides, mean values were 0.62, 0.79 and 0.98% in increasing sequence of toe-slope < summit < mid-slope physiographic positions. Averaged over physiographic positions and monosaccharide contents, concentrations of AB (0.670%) was distinctly (LSD 0.05) better than A (0.30%) horizons. Galactose+mannose/arabinose+xylose and mannose/xylose ratios were less than unity indicating that the carbohydrates were of plant origin. Also, mean arabinose/xylose and xylose/mannose ratios were greater than unity, signifying fresh plant tissues with high decomposition rates respectively. Soil monosaccharides correlated ($P < 0.05$) with the bulk density, clay, ECEC, moisture content, pH, total porosity, P and organic carbon with less than 20% of the monosaccharides accounted by the soil properties. In general, the soil carbohydrates originated from fresh rapidly decomposing plant tissues with poor tendency for carbon sequestration.

Keywords: Monosaccharide, toposequence, carbon sequestration, humid tropics and southeastern Nigeria

1. Introduction

Soil organic matter consists of a heterogeneous mixture of interacting polymers from carbon fixed by plants and delivered to the soil in the form of leaves, wood litter, roots and root exudates (Sposito, 1989; Evans et al., 2001). Carbohydrate, a complex polysaccharide mixture of many monosaccharides accounts for about 5-25% of soil organic matter (Stevenson, 1994; Evans et al., 2001). Its roles in the soil include the sustenance of soil microbial activities through the provision of readily available energy, stabilization of soil aggregates, maintenance of soil-water relations and conservation of soil physical properties (Spaccini et al., 2001; Uzoho and Igbojionu, 2014). Concentration of soil monosaccharides varies and depends on the hydrolysis of the polysaccharides especially cellulose and sucrose. For instance, it has been reported that sucrose readily hydrolyzes to glucose and fructose (Salzer and Hager, 1993; Kleinschmidt et al., 1998). Soil monosaccharides include glucose, fructose, mannose, galactose, arabinose, xylose, fucose, ribose and rhamnose amongst others (Evans et al., 2001). Chelsire (1977) reported that five monosaccharides; glucose, mannose, galactose, arabinose and xylose typically represent more than 90% of total hydrolysable carbohydrates. Arabinose, xylose and ribose represent pentoses of plant origin that is not readily synthesized by microbial activities while glucose, galactose and mannose are hexoses that are synthesis products of microorganisms (Evans et al., 2001). Fucose and rhamnose are deoxysugars of microbial origin that are usually present in small amounts in the soil or sediments (Kleinschmidt et al., 1998).

Forms of soil monosaccharides could be useful indicators of the nature, utility and origin of soil carbohydrates. For instance, the ratios of galactose plus mannose to arabinose plus xylose and rhamnose plus fucose to arabinose plus xylose have been noted as important indicators of the origin of soil carbohydrate (Guggenberger et al., 1995; Evans et al., 2001). According to Evans et al. (2001), ratio greater than unity of galactose plus mannose to arabinose plus xylose indicates that a soil carbohydrate material is synthesized by microorganisms otherwise it is derived from plant tissues. Hu et al. (1995) suggested that a ratio of mannose to xylose gives a better indicator of the relative contribution of microbially derived sugar to soil carbohydrate. It has also been suggested that ratios of arabinose to xylose could be useful in the evaluation of the replacement of carbohydrates of original forests with those of pastures, since arabinose is the predominant sugar in fresh leaves (Trouve et al., 1996; Glaser et al., 2000). Equally, xylose to mannose ratio has been suggested as indicator of the decomposition of plant residues (Murayama, 1984). Monosaccharide content varies with soil type and depth and between landscapes. Variation with soil type includes high glucose followed by mannose contents in two Ferraltic soils in Congo (Larre-Larrouy and Feller, 1997), glucose followed by galactose, mannose and arabinose in mountain soils of the Alay range in Kyrgzia (Glaser et al., 2000) and galactose followed by glucose, mannose and xylose in margin sediments of Peru (Bergamaschi, et al., 1997). Distribution with profile depth includes an increase, decrease or inconsistencies with depth due to differences in organic matter or carbohydrate concentrations. For instance decreases in organic matter and carbohydrate (Solomon et al., 2000; Li et al., 2007; Chen et al., 2009) and inconsistencies in carbohydrate distribution (Uzoho and Igbojionu 2014) attributable to changes in land use and climatic conditions have been reported with soil depths. Due to the influence of soil forming factors especially topography, monosaccharide concentrations may vary with landscape positions. This could probably be due to the transportation and deposition of sediments by water. It has been reported that due to high erosion, soil organic matter lost from the summit and middle slope was deposited and accumulated at the foot-slope of a landscape (Gregorich et al., 1998). Also, in a study of the effects of landscape position on soil properties of reconstructed prairies in south-central Iowa, high SOM was reported in the summit and toe-slopes than the middle slope (Guzman and Al-Kaisi 2011). Equally, Uzoho and Okechukwu (2014) obtained high SOM at the levee and floodplain than the upland in soils of contrasting landscapes in Egbema, Southeastern Nigeria. Variation in topography may seriously influence soils on a toposequence. Toposequence refers to soils of varying characteristics due primarily to the influence of topography (Akpan-Idiok et al., 2005). It is a succession of sites from the crest to the valley bottom that contains a range of soil profiles which are representative of the landscape and soils (Juo and Moormann, 1981).

Soil properties especially OM, pH, texture, CEC, bulk density and C/N ratio may affect monosaccharide concentrations. Some workers have reported the impact of soil properties on soil organic matter and carbohydrate concentrations (Uzoho and Igbojionu, 2014; Uzoho and Okechukwu, 2014). Magnitude of the influence of soil properties on monosaccharides could be an increase, decrease or lack of impact.

In the humid tropics and southeastern, Nigeria in particular, extensive studies have been undertaken on soil organic matter and carbohydrate concentrations (Spaccini et al., 2001; Uzoho and Igbojionu, 2014; Uzoho and Okechukwu, 2014). However, there appears to be a dearth of information on the monosaccharide distribution of the soils. The objectives of this present study were therefore to evaluate soil monosaccharide distribution and its relationship with selected properties of soils on a toposequence in the humid tropical rain forest, southeastern, Nigeria.

2. Materials and Methods

2.1 Study Location and Site Description

The study area was Isiala Mbano located between latitudes 5^o 39^1 and 5^o43^1N and longitudes 7^o $09^1$and 7^o 13^1E in the humid rainforest zone, southeastern, Nigeria. It has a mean annual rainfall range of 1732.03-2081.15 mm, monthly temperature range of 24.94-29.22°C and mean relative humidity range of 68.8-72.6% (IPEDC, 2006). Soils were underlain by Coastal Plain Sands (Orajiaka, 1975) and varied as Typic Paleudult in the summit and mid-slope and Ruptic Hapludult in the toe-slope of the toposequence (Soil Survey Staff, 1999). The toposequence was of 2% slope and a distance of 39m between the summit and mid-slope and 137m between the mid and toe slopes. Climax vegetation consisted of cassava (Manihot esculentum) in the summit and mid-slope and spear grass (Imperata cylindrica) in the toe-slope. The main economic activities of the area include farming, trading and civil service.

2.2 Sample Collection and Analysis

Three profile pits were sunk on each of the three physiographic positions; summit, mid-slope and toe-slope. Duplicate soil samples were collected following natural horizonization from each horizon of the profile pits to avoid contamination. Samples collected were air dried, sieved using a 2mm diameter mesh and the fine earth fractions subjected to laboratory analysis using standard methods. Particle size after dispersion with calgon using the hydrometer method (Gee and Or, 2002), moisture content as a percent fraction of wet and oven dry weights of the soil samples, bulk density (Klute, 1986), pH in 1:2.5 soil/water ratio using the glass electrode of the pH meter, ECEC (Thomas, 1996), total nitrogen (Bremner, 1996) and organic carbon (Nelson and Sommers, 1996). Monosaccharide contents of the soils were determined using the following procedures: Sub sample of the fine earth soil fraction was weighed (1 g) into a boiling tube and 25 ml of 80% hot ethanol added and shaken on a vortex mixer for 45 minutes. The tube was allowed to settle for 30 minutes and the contents filtered into a beaker using Whatman No. 41 filter paper. The above step was repeated three times to ensure complete extraction. The extracts were then evaporated to dispel all the ethanol and 10 ml de-ionized water added to dissolve the contents before transferring into a 100 ml volumetric flask. The beaker was washed three times and transferred into the 100 ml flask and then made up to mark with de-ionized water. The sugars were subsequently determined as follows:

Glucose content was determined using the Anthrone method (Browne and Zerbon, 1981). In this, about

1ml aliquot of the sugar extract was pipetted into a test tube and 6mls of anthrone-sulphuric acid (Prepared by dissolving 1g of Anthrone in 760 ml of concentrated H_2SO_4 and made up to mark using 240 mls of de-ionized water) added and shaken vigorously for 2 minutes on a reciprocating shaker. A blank solution was also prepared as above but using de-ionized water instead of sugar concentration. Standard glucose solution of concentrations10-50µg/ml was prepared. Absorbance of the bluish coloured solutions of sample and the glucose standards were read on a Spectronic 21D Spectrophotometer at a wavelength of 595nm against the blank.

$$\%\ \text{Glucose} = \frac{\text{Absorbance of sample x Av. Gradient factor x Dilution factor}}{\text{Wt of sample x 10000}} \qquad (1)$$

Mannose content was determined using the same method as for the glucose but with the absorbance read at a wavelength of 615nm.

$$\%\ \text{Mannose} = \frac{\text{Absorbance of sample x Av. Gradient factor x Dilution factor}}{\text{Wt of sample x 1000}} \qquad (2)$$

Galactose concentration was determined by reading the absorbance of the standard and raffinose sample at a wavelength of 528 nm on a Spectronic 21D Spectrophotometer.

$$\%\ \text{Galactose} = \frac{\text{Absorbance of sample x Av. Gradient factor x Dilution factor}}{\text{Wt of sample x 10000}} \qquad (3)$$

Arabinose determination was achieved by reading the bluish colour solutions of arabinose standard and sample at a wavelength of 595nm on the 21 D spectrophotometer.

$$\%\ \text{Arabinose} = \frac{\text{Absorbance of sample x Av. Gradient factor x Dilution factor}}{\text{Wt of sample x 10000}} \qquad (4)$$

The Xylose concentration of the sugar extract was determined as the glucose above with the bluish colour solutions of xylose standard and sample read at a wavelength of 595nm.

$$\%\ \text{Xylose} = \frac{\text{Absorbance of sample x Av. Gradient factor x Dilution factor}}{\text{Wt of sample x 10000}} \qquad (5)$$

3. Statistical Analysis

Data generated for the various monosachharides were subjected to analysis of variance (ANOVA) and means separated at 5% confidence interval using the least significant difference (LSD). Correlation and regression analysis were also conducted. All analyses were executed using the Genstat statistical package (Buysse et al., 2004).

4. Results

4.1 Soil Characterization

Mean sand, silt, clay and silt/clay ratio of soils of the toposequence ranged from 796.40-802.40, 40.10-49.52, 145.44-157.50g kg^{-1} and 0.25-0.34 respectively (Table 1). In each physiographic position; summit, mid-slope and toe- slope, sand content decreased, clay increased while silt and silt/clay ratio were irregular with profile depths.

Table 1.Selected Physical Properties of Soils along the Toposequence Studied

Horizon	Soil Depth	Bd	TP	MC	Sand	Silt	Clay	Silt/Clay ratio	TC
	cm	g cm^{-3}	%			g kg^{-1}			
				Summit					
A	0-22	1.10	52.70	13.60	822.40	34.40	143.20	0.24	LS
AB	22-38	1.21	57.00	13.20	842.40	27.20	130.40	0.21	LS
Bt1	38-57	1.29	50.00	15.60	782.40	34.40	183.20	0.19	SL
Bt2	57-71	1.32	48.40	14.80	762.40	64.40	173.20	0.37	SL
	Mean	1.23	52.03	14.30	802.40	40.10	157.50	0.25	LS
				Mid-Slope					
A	0-18	1.08	57.80	10.20	842.40	34.40	123.20	0.28	LS
AB	18-31	1.19	53.50	12.50	822.40	54.40	123.20	0.44	LS
Bt1	31-52	1.26	50.80	13.60	782.40	40.00	134.40	0.30	S
Bt2	52-68	1.34	47.70	13.80	772.40	64.40	163.20	0.39	SL
Bt3	68-79	1.40	45.30	15.20	762.40	54.40	183.20	0.30	SL
	Mean	1.25	51.02	13.06	796.40	49.52	145.44	0.34	SL
				Toe-Slope					
A	0-20	1.04	59.40	12.20	842.40	54.40	103.20	0.53	L
Bt1	20-33	1.22	52.30	14.30	782.40	34.40	183.20	0.19	SL
Bt2	33-47	1.32	48.40	16.60	782.40	34.40	183.20	0.19	SL
	Mean	1.19	53.37	14.37	802.40	41.07	156.53	0.30	SL

Bd = Bulk density, TP = Total porosity, MC = Moisture content, TC = Textural class, LS = Loamy sand, SL = Sandy loam, S = Sand

Texture varied as sand, sandy loam, loamy sand and loam amongst soil depths with sandy dominating for the toposequence. Mean moisture content, total porosity and bulk density ranged from 13.06-14.37%, 51.02-53.37% and 1.19-1.25g cm^{-3} respectively, with pattern of distribution down soil depth for each physiographic position being a decrease for moisture content, increase for bulk density and irregular for total porosity. For all physical attributes, the least values were in the mid-slope exception being the silt/clay ratio and bulk density.

Mean soil pH, total N, OC and available P ranged from 5.83-6.26, 3.33- 4.27g kg^{-1}, 0.30-0.33g kg^{-1} and 2.41-3.39 mg kg^{-1} respectively (Table 2), with distribution pattern for the various physiographic positions being a decrease for total N, OC and available P and inconsistencies with soil pH down profile depths. Mean Ca, Mg, K and ECEC ranged from 0.30-0.97, 0.72-1.56, 0.48-0.52 and 2.99-4.68 cmol (+) kg^{-1} respectively and decreased with depth for the various physiographic positions. Mid-slope had the least concentration of most chemical parameters as was for physical properties.

4.2 Monosaccharide Content of Soils of the Toposequence

Monosaccharide distribution of soils of the toposequence is shown in Table 3. Averaged over soil horizons and monosaccharide forms, mean monosaccharide content was significantly (LSD 0.05) higher in the mid-slope (0.98%) than the summit (0.79%) and the toe-slope (0.62%). Mean monosaccharide forms averaged over horizons and physiographic positions decreased in the order arabinose > xylose > mannose > galactose > glucose. Also, mean monosaccharide contents averaged over monosaccharide forms and physiographic positions was distinctly (LSD 0.05) higher in the AB (0.67%) than the A (0.30%) horizons. Amongst various monosaccharides, arabinose content was significantly (LSD 0.05) higher than the others in the various horizons and physiographic positions exception being mannose in the A horizon of the toe-slope.

Mean galactose+mannose/ xylose+arabinose and mannose/xylose ratios averaged over the various horizons and physiographic positions were less than unity (0.055-0.594) while those of arabinose/xylose and xylose/mannose were above unity (1.095-1.500 and 0.889-4.674 respectively). Distribution of ratios of the various monosaccharides amongst horizons and physiographic positions included less than unity for the galactose+mannose/xylose+arabinose and mannose/xylose ratios and greater than unity of arabinose/xylose and xylose/mannose in the A and AB horizons of the summit and mid-slopes. It also included a greater than unity of arabinose/xylose in the A and AB horizons, mannose/xylose in only the A and xylose/mannose in only the AB horizons of the toe-slope of the toposequence. Monosaccharide contents correlated with selected soil properties (Table 4). For instance, Arabinose content was none significantly ($P \leq 0.05$) correlated with bulk density (r = -0.21), clay (r = -0.14), ECEC (r = 0.28), moisture content (r = -0.24), total porosity (r = 0.21), pH (r = -0.11), total P (r = 0.12) and organic carbon (r = 0.12). A regression model showed that Clay, ECEC and OC/ pH accounted for only 2, 8 and 1% respectively of the Arabinose content (Table 5). Also galactose content was not seriously ($P \leq 0.05$) related with the bulk density (r = -0.12), clay (r = 0.10), ECEC (r = 0.34), moisture content (r = 0.09), total Porosity (r = 0.04), pH (r = -0.12), available P (r = 0.23) and organic carbon (r = 0.08). Besides ECEC with about 12%, the regression model predicted less than 10% of the galactose to be due to other soil properties. Relationship between glucose and bulk density (r = 0.01), pH (r = 0.25), available P (r = 0.11), organic carbon (r = 0.13), clay (r = -0.27), ECEC (r =-0.34), moisture content (r = -0.42) and total porosity (r = -0.01) was not distinct ($P \leq 0.05$). Only ECEC account for more than 10% of the glucose content of the soil. Equally, mannose was not significantly correlated with bulk density (-0.18), clay (r = -0.24), moisture content (r = -0.34), pH (r = -0.11), ECEC (r = 0.18), total porosity (r = 0.19), available P (r = 0.28) and organic carbon (r = 0.18). A predictive equation indicated that the soil properties (pH, OC, P, ECEC and clay) were poor predictors of soil mannose with each accounting for less than 10%. Relationship between xylose and ECEC (r = 0.25), total porosity (r = 0.21), available P (r = 0.27) and organic carbon (r = 0.12), bulk density (r = -0.20), clay (r = -0.15), moisture content (r = -0.27) and pH (r = -0.09) was not distinct. As with mannose, soil properties were poor predictors of soil xylose. Relationship between arabinose/xylose ratio was not distinct with bulk density (r = 0.10), clay (r = 0.36), moisture content (r = 0.40), pH (r = 0.08), ECEC (r = -0.05), total porosity (r = -0.10), available P (r = -0.29) and organic carbon (r = -0.25). Besides clay content (r = -0.44), correlation between mannose/xylose ratio and bulk density (r = 0.05), ECEC (r = -0.24), moisture content (r = -0.40), total porosity (r = -0.04), pH (r = -0.11), available P (r = 0.14) and organic carbon (r = 0.32) was non distinct. Correlation between xylose/ mannose ratio with clay (r = 0.45) and moisture content (r = 0.44) were significant while that with bulk density (r = 0.06), ECEC (r = 0.03), total porosity (r =-0.07), pH (r = 0.15), available P (r = -0.28) and organic carbon (r = -0.33) was not. Finally, there was significant relationship between galactose+mannose/xylose+arabinose

Table 2. Selected Chemical Properties of Soils along the Toposequence Studied

Horizon	Soil Depth	pH (H_2O)	pH (1N KCl)	OC	TN	Av. P	Ca	Mg	K	Na	Al	H	ECEC
	cm			g kg^{-1}		mg kg^{-1}				Cmol(+)kg^{-1}			
					Summit								
A	0-22	5.12	4.58	5.80	0.51	5.69	4.80	2.83	0.22	0.57	-	3.12	11.53
AB	22-38	5.12	4.60	4.20	0.40	2.84	1.60	2.50	0.74	0.52	0.40	1.16	6.57
Bt1	38-57	6.27	5.62	3.40	0.30	2.53	0.20	0.17	0.27	0.56	0.36	1.40	2.97
Bt2	57-71	6.09	5.58	3.20	0.30	1.86	0.20	2.00	0.82	0.48	-	0.92	4.42
	Mean	5.83	5.27	3.60	0.33	2.41	0.67	1.56	0.61	0.52	0.38	1.16	4.65
					Mid-Slope								
A	0-18	6.20	5.92	5.60	0.50	5.72	1.20	0.83	0.19	0.48	-	0.84	3.54
AB	18-31	5.08	4.86	6.00	0.50	3.63	0.10	0.33	0.25	0.48	0.24	1.04	2.38
Bt1	31-52	6.33	5.72	3.60	0.30	2.87	0.30	0.17	0.33	0.43	0.36	1.28	2.88
Bt2	52-68	6.27	5.96	4.40	0.40	2.04	0.40	0.50	0.17	0.52	-	0.92	2.42
Bt3	68-79	6.19	5.75	2.00	0.20	1.96	0.20	1.50	0.24	0.48	0.24	0.96	3.66
	Mean	6.26	5.81	3.33	0.30	2.29	0.30	0.72	0.25	0.48	0.30	1.05	2.99
					Toe-Slope								
A	0-20	6.07	5.86	7.40	0.60	6.82	1.20	1.83	0.74	0.48	-	0.96	5.21
Bt1	20-33	6.04	5.73	2.60	0.20	2.16	1.50	2.33	0.22	0.52	0.72	1.64	6.93
Bt2	33-47	6.08	5.69	2.80	0.20	1.19	0.20	0.08	0.19	0.52	-	0.92	1.91
	Mean	6.06	5.76	4.27	0.33	3.39	0.97	1.41	0.38	0.51	0.72	1.17	4.68

Table 3. Monosaccharide Contents (%) and Ratios in the Summit, Mid-slope and Toe-Slope of A and AB Horizons of the Toposequence

Physiography	Horizon	Glu	Gal	man	xyl	ara	Mean	g+m/x+a	man/xyl	ara/xyl	xyl/man
Summit	A	0.01	0.20	0.83	0.95	1.06	0.75	0.52	0.88	1.13	1.13
	AB	0.07	0.09	1.15	1.24	1.31	0.82	0.49	0.93	1.06	1.08
	Mean	0.04	0.15	0.99	1.10	1.19	**0.79**	0.50	0.91	1.10	1.11
Mid-Slope	A	0.01	0.01	0.02	0.14	0.23	1.16	0.07	0.12	1.64	8.24
	AB	0.02	0.04	1.02	1.13	1.54	0.80	0.04	0.90	1.36	1.11
	Mean	0.01	0.03	0.52	0.64	0.89	**0.98**	0.06	0.51	1.50	4.67
Toe-Slope	A	0.04	0.02	0.38	0.25	0.31	0.57	0.71	1.52	1.24	0.66
	AB	0.05	0.08	0.69	0.77	0.85	0.67	0.48	0.90	1.09	1.12
	Mean	0.05	0.05	0.54	0.51	0.58	**0.62**	0.59	1.21	1.17	0.89
	Grand mean	**0.33**	**0.73**	**0.68**	**0.75**	**0.88**	**0.79**	**0.38**	**0.88**	**1.25**	**2.22**

LSD's (0.05): Fact A(Physiographic position) = 0.019
Fact B (Horizon) = 0.014
Fact C (Monosaccharide) = 0.016
Fact A x Fact B = 0.022
Fact A x Fact C = 0.030
Fact B x Fact C = 0.024
Fact A x Fact B x Fact C = 0.042

Glu = Glucose, Gal = Galactose, Man = Mannose, Xyl = Xylose, ara = Arabinose, g + m = Galactose + Mannose, x + a = Xylose + Arabinose

Table 4. Simple Correction Coefficient (r) between Selected Soil Properties and Monosaccharide

Soil Properties	Monosaccharide/Monosaccharide ratios								
	Arabinose	Galactose	Glucose	Mannose	Xylose	Ara/Xyl	Man/Xyl	Xyl/Man	G+M/X+A
Bulk Density	-0.21	-0.12	0.01	-0.18	-0.20	0.10	0.05	0.06	0.01
Clay	-0.14	0.10	-0.27	-0.24	-0.15	0.36	-0.44	0.45	-0.45
ECEC	0.28	0.34	-0.34	0.18	0.25	-0.05	-0.24	0.03	-0.14
Moisture Content	-0.24	0.09	-0.42	-0.34	-0.27	0.40	-0.40	0.44	-0.40
Total Porosity	0.21	0.04	-0.01	0.19	0.21	-0.10	-0.04	-0.07	0.003
pH	-0.11	-0.12	0.25	-0.11	-0.09	0.08	-0.11	0.15	-0.18
Available P	0.28	0.23	0.11	0.28	0.27	-0.29	0.14	-0.28	0.19
Organic Carbon	0.12	0.08	0.13	0.18	0.12	-0.25	0.32	-0.33	0.35

Ara = Arabinose, Xyl = Xylose, Man = Mannose, G = Galactose, Mannose, X = Xylose and A = Arabinose.

Table 5. Regression Equation and r^2 of Selected Monosacchaides and Soil Properties

Parameters	Regression Equation	Coefficient of Determination (r^2)
Arabinose vs. Clay	Ya = 1.11 - 0.002clay	0.02
' vs. ECEC	Ya = 0.53 + 0.050 ECEC	0.08
' vs. OC	Ya= 0.61 + 0.035OC	0.01
' vs. pH	Ya = 1.36 - 0.103 pH	0.01
Galactose vs. pH	Yg = 0.30 - 0.022pH	0.01
vs. P	Yg = 0.043 + 0.011P	0.06
vs. ECEC	Yg = 0.028 + 0.011 ECEC	0.12
' vs. OC	Yg = 0.060 + 0.004 OC	0.01
Glucose vs. OC	Ygl = 0.027 + 0.002OC	0.02
' vs. P	Ygl = 0.030 + 0.002 P	0.01
' vs. ECEC	Ygl = 0.050 - 0.003 ECEC	0.12
' vs. Clay	Ygl = 0.074 - 0.0003 Clay	0.07
' vs. pH	Ygl = 0.014pH - 0.047	0.06
Mannose vs. pH	Ym = 1.19 - 0.097 pH	0.01
' vs. OC	Ym = 0.405 + 0.050 OC	0.03
' vs. ECEC	Ym = 0.485 + 0.029 ECEC	0.03
' vs. Clay	Ym = 1.174 - 0.004 Clay	0.06
' vs. P	Ym = 0.396 + 0.069 P	0.08
Xylose vs. pH	Yx = 1.19 - 0.087 pH	0.01
' vs. OC	Yx = 0.525 + 0.035 OC	0.01
' vs. ECEC	Yx = 0.471 + 0.045 ECEC	0.06
' vs. Clay	Yx = 1.05 - 0.002 Clay	0.02
' vs. P	Yx = 0.443 + 0.072 P	0.07

ratio and clay content (r = -0.45) but not with bulk density (r = 0.01), ECEC (r = -0.14), moisture content (r = -0.40), total porosity (r = 0.003), available P (r = 0.19) and organic carbon (r = 0.35).

5. Discussion

Texture of the soils was predominantly sandy indicating that they are of the same origin. According to Orajiaka (1975), soils of the area are derived from Coastal Plain Sands. Increased clay content with depth could be due to clay eluviation or migration as a result of leaching losses (Enwezor, et al., 1990). Moisture content increased with soil depth as the clay due to the tendency of clay to hold moisture. Bulk density decreased in a reverse order while total porosity increased with soil organic matter. Similar observations have been reported by others (Madrid et al., 2006; Uzoho et al., 2007). Values of the bulk densities were below critical limit of 1.63 g cm^{-3} required for crop production (Noma et al., 2005). Silt/clay ratios of the soils were below unity indicating that they are highly weathered. It has been reported that a silt/clay of less than unity indicates low values, signifying that the soils are pedogenetically ferrallitic in nature (Essoka and Esu, 2000). According to Ahn (1993), low values indicate that soils are highly weathered and pedologically matured. Nwaka and Kwari (2000) noted that high silt/clay ratios may be related to the coarse nature of parent materials and youthfulness of profiles.

Ranges of soil pH indicated that they are acidic and could be due to the leaching of basic cations (Enwezor et al., 1990; Uzoho et al., 2007). Soil organic carbon, exchangeable bases, total N, available P and ECEC were below critical limits for soils of southeastern Nigeria (Enwezor et al., 1990). Soils had ECEC values below 16 cmol kg^{-1} indicating that they have low clay activity (Uzoho et al., 2007). Low nutrient status, coarse texture and acidity of the soils indicate that they are low in fertility and associated with Ultisols of Southeastern, Nigeria (Enwezor 1990). Monosaccharide forms of the soils varied and dominated by arabinose contrary to high concentration of glucose reported in most soils (Larre-Larrouy and Feller, 1997; Glaser et al., 2000; Solomon et al., 2001; Evans et al., 2001; Dedosz et al., 2002). In marine margin sediments in Peru, high concentration of galactose followed by glucose, mannose and xylose have been reported (Bergamaschi, et al., 1997). Variability in monosaccharide distribution in the landscapes suggests that they could be of different carbohydrate origins. High content of arabinose in the soils suggests that the carbohydrate could be of fresh plant tissue origin. It has been noted that arabinose is the dominant sugar in fresh plant leaves ((Trouve et al., 1996; Glaser et al., 2000). Equally, ratios of less than unity of galactose+mannose/xylose+arabinose and mannose/xylose in almost all horizons of the physiographic positions and mannose/xylose in the A horizon of the toe-slope suggests that the carbohydrates are of plant origin. It has been reported that ratios greater than one (>1) of galactose + mannose/arabinose + xylose indicates that a carbohydrate material is synthesized from microorganisms whereas those less than one (<1) signifies that they are derived from plant tissues (Evans et al., 2001). According to Hu et al. (1995), Mannose/xylose ratios of greater than unity have been suggested as a better indicator of the relative contribution of microbially derived sugars to the soil carbohydrate. Furthermore, ratios greater than unity of arabinose /xylose could be useful in the evaluation of the replacement of carbohydrates of forest origin with those of pastures (Trouve et al., 1996; Glaser et al., 2000). According to Murayama, (1984) xylose/mannose ratio has been used to evaluate the decomposition of plant residues. Therefore, the greater than unity of arabinose/xylose ratio in all horizons of the physiographic positions suggests the existence of a high concentration of fresh relative to forest vegetations. This thus confirms the high concentration of arabinose in the soils since they are mostly present in fresh vegetations. Also high xylose/mannose ratios in almost all the soils indicate a rapid decomposition of the plant tissues, most of which are fresh and with no lignified materials. Thus rate of decomposition could be said to be exceptionally high in the A horizon (8.24) of the mid-slope with the highest fresh vegetation (1.64).

Monosaccharide (glucose, galactose, mannose, arabinos and xylose) contents were poorly correlated and predicted by the soil physical and chemical properties. This suggests that biological factors especially microbial population and litter accumulation could have the most effective influence on the soil monosaccharide concentration.

6. Conclusion

It could be concluded that soil properties varied with profile depths of the various physiographic positions of the topoasequence but generally sandy, acidic with low OM, ECEC and nutrient composition. Arabinose constituted the dominant while glucose was the least monosaccharide concentration of the soils. Soil carbohydrate was of plant origin and included the fresh and highly degradable tissues. Soil properties did not relate highly and accounted poorly for the monosaccharide content of the soils.

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