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Comparative studies on soil chemical properties and cashew tree growth parameters of sedimentary and basement complex soils

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ABSTRACT: Sixteen soil characteristics associated with cashew (*Anacardium occidentale*) tree growth parameters on two major lithological formations in Niger State, Guinea Savanna area of Nigeria were analyzed using coefficient of correlation and ANOVA. It was observed that differences between the mean soil parameters in the two formations were not significantly marked, except for exchangeable sodium. The paired mean differences with LSD show significant differences for soil pH, organic carbon, total N and available P. the significant positive correlation shown between cashew tree growth parameters and some soil nutrients indicates that such nutrients are essential to the growth and possibly fruits yield of cashew trees. However, there were no significant differences between the tree growth parameters on basement complex soils and sedimentary soils.

Key Words: Cashew farming; Cashew tree growth; Soil characteristics.

Introduction

Cashew fruit tree farming in Niger State, Nigeria, is an old practice. The two major lithological formations for its cultivation are the sedimentary and basement complex soils. The cashew tree growth is a function of certain chemical characters acting singly or in interaction with each other. For a study to improve tree growth and yield to succeed, it is essential to identify the soil chemical characteristics that determine tree height, crown diameter and breast height diameter. Simple correlation and ANOVA have been widely employed to obtain functional parameters that can be used to determine the nature of relationship among variables.

Like other tree crops, cashew (*Anacardium occidentale*) trees need adequate supply of macro- and micronutrients in order to grow and produce good quality fruits. When these nutrients are inadequate, growth is reduced and the quality of the harvested product becomes poor. Although symptoms of the effect of physico-chemical properties are not generally found among cashew growing on site in their natural habitat, this does not mean that these trees, even on better sites, are growing at an optimal rate. These species respond to high levels of soil fertility and many soils are incapable of supplying all the nutrients in sufficient amounts to sustain rapid tree growth.

Earlier studies of soil and tree relationship tended to lay more emphasis on topographic, soil physical and morphological features as indices of tree growth (Ezenwa, 1988). This is because these features have significant effects on other soil factors that affect tree growth. Furthermore, most of those properties are stable factors of the landscape that are relatively undisturbed by human activity. Many workers on site productivity have shown that soil chemical properties are limiting factors to tree growth (Platteborze et al., 1971; Evans, 1976). The present study which is based on the study of soils regarding chemical characteristics in selected tree orchards where there are variability in soils, covered orchards established from two different geological materials in Guinea Savanna area of Nigeria. These soils are developed from sedimentary and basement rocks.

The objectives of the present study are: (1) to identify some chemical characters that determine cashew tree growth, (2) to determine the height, crown diameter and breast diameter of the cashew tree stand in the selected sites within the study area, and (3) to determine the relationship between cashew tree growth parameters and soil chemical characteristics.

Materials and Methods

Orchard Investigation

Three sample plots of not less than 40 trees each were laid in each soil unit per location for similar age stands of cashew in the Guinea Savanna area of Nigeria. A total of 18 plots covering 13-year old trees were marked out for easy identification. The tree heights were measured in metres using Hagar Altimeter and metre tapes. The diameter over back at breast height and crown diameter of every tree was measured with a diameter tape.

Laboratory Studies

Soils from cashew orchards on basement complex and sedimentary lithological formation were used for the study. The soil samples were air-dried under shade and ground to pass through a 2 mm sieve. For organic carbon, total nitrogen, total zinc and copper determinations, the samples were further sieved to pass through a 0.5 mm sieve. Soil pH was determined in 1:2.5 soil/water ratio mechanical analysis was by the hydrometer method of Day (1965). Available P was determined according to the method of Bray and Kurtz (1945). The method of Walkey and Black was used in the determination of organic carbon. Total N was determined by the method of Bremmer (1965). Cation exchange capacity (CEC) was determined by summation of the exchangeable bases and exchangeable acidity (Ea). Total Zn and Cu were extracted after digestion of the soil in HF and a ternary mixture of HNO_3-H_2SO_4-$HClO_4$ according to Jackson (1958) and determined by atomic absorption spectrophotometer. Available Cu and Zn were extracted with 0.01 mol/dm^3 EDTA and 0.1 mol/dm^3 HCl separately and determined by atomic absorption spectrophotometer.

Results and Discussion

The results of soil chemical properties for 0 – 40 cm depth and growth data of 13-year old cashew on soil units are shown in Table 1. The soil pH values in both the basement complex and sedimentary soils showed the soils as having a weak acid reaction. Falade (1980) discovered that cashew tree crop is known to grow within a wide range of pH values between 4.1 and 8.4. However, low pH values are known to influence the production of a greater number but smaller leaf sizes in cashew. It could be observed that soil of basement orchards had higher organic carbon contents than the soils of sedimentary origin.

The total nitrogen contents of these lithological sites were very low. The equally low organic matter content and predominantly sandy nature of the soils may have contributed significantly to the content of nitrogen. Also, nitrogen is highly mobile and it is, therefore, not unexpected that the sandy nature of the soils would further aggravate the problem. Jones (1973) has also indicated low values of total nitrogen in an earlier report for well-drained soils in the Savanna region of West Africa. However, as could be observed in the present investigation, orchards of basement complex soils have higher content of total N but lower values of available P than soils on sedimentary material.

Table 1: Soil chemical properties for 0 – 40 cm depth and growth data of 13-year old *Anacardium occidentale* on basement complex and sedimentary soils.

	Basement complex soil		Sedimentary soil	
	Range	Mean	Range	Mean
pH	4.75 – 5.44	4.98	5.08 – 5.69	5.31
Organic C (%)	0.68 – 0.80	0.75	0.55 – 0.78	0.66
Available P (mg/dm3)	2.09 – 2.88	2.45	2.42 – 3.25	2.97
Total N (%)	0.12 – 0.17	0.15	0.08 – 0.22	0.13
C/N	4.51 – 6.74	5.29	3.62 – 7.74	6.33
Na (mmol/kg)	1.50 – 2.10	1.70	1.10 – 1.20	1.20
K (mmol/kg)	1.60 – 2.60	2.10	0.80 – 3.50	2.00
Ca (mmol/kg)	20.0 – 22.0	20.70	16.0 – 26.3	20.4
Mg (mmol/kg)	14.0 – 17.0	15.10	3.00 – 21.0	10.0
Ea (mmol/kg)	26.0 – 38.0	31.30	30.0 – 42.0	35.3
CEC (mmol/kg)	65.0 – 77.5	70.90	56.7 – 91.2	68.8
B/S (%)	50.98 – 59.70	56.13	42.23 – 53.97	47.84
Silt + Clay (%)	19.36 – 30.90	23.86	15.71 – 22.20	19.81
HCl-Zn (mg/dm^3)	0.40 – 7.30	4.33	2.50 – 2.80	2.63
Total Zn (mg/dm^3)	5.47 – 16.60	11.72	8.50 – 9.70	9.07
HCl-Cu (mg/dm^3)	0.39 – 6.73	3.96	2.40 – 2.80	2.67
Total Cu (mg/dm^3)	2.50 – 14.00	9.83	5.70 – 7.10	6.33
CD (m)	4.36 – 7.28	5.83	3.00 – 12.68	6.54
BHD (m)	0.46 – 0.76	0.60	0.36 – 1.49	0.74
H (m)	4.26 – 7.38	5.81	3.80 – 9.14	5.73

The values for exchangeable Ca, Mg, K and Na were low. These cations occur in the order Ca > Mg > K > Na in the two lithological formations. the predominance of Ca over the other bases in those soils is attributed to the fact that Ca is least easily lost from the environment of the soils (Brady, 1974) and also to a greater number of exchangeable sites in soils showing a specific affinity for Ca (Ezenwa, 1988). There are fewer sites showing an affinity for Mg (Beckett, 1965). However, this does not hold where there are sodic or saline soils where Na has been found to be predominant (Lyerly and Congenecker, 1962) and a few volcanic soils where Mg has been found to be the predominant cation (Heilgason, 1968). The low values recorded for K and Na suggest that these cations are easily lost by leaching from the soils at even the lowest range of rainfall (Ezenwa, 1988). It may also be attributed to low levels of these elements in the parent materials.

Data on cation exchange capacity reveal a very low to low range values over all the soils, implying that the soils have a very low capacity to retain cations and may strongly encourage nutrient loss by leaching.

Base saturation (B/S) values ranged from moderate to high in all the orchard soils. This implies that the soil can contribute at least 56.13% and 47.84% of its exchangeable bases for root absorption at the surface level for the orchards on basement complex and sedimentary soils respectively.

Although no critical range for Zn and Cu have been established for cashew trees in Nigeria, the values obtained in this study could not be sufficiently adequate to sustain tree crops growing on them at present. The low amount of available Zn in these soils may be attributed to the strong relationship between available Zn and soil organic matter and most Zn-containing rock minerals are easily weathered (Chude and Obigbesan, 1982) and thus likely to form fine textured soils. This finding is similar to the observation of Kang and Osiname (1972) who reported low levels of Zn and Cu status on sandy inceptisols from the forest savanna zones of Western Nigeria.

The relationships that were observed between cashew tree growth and soil chemical properties are shown in Tables 2 and 3. In both cases, although generally non significant relationships were found to exist between some soil properties and the tree growth parameters, it is noteworthy that some quality in terms of its composition and textural class has great influence on the cashew tree growth. The influence of Zn and Cu on crown diameter (CD) is more pronounced in basement complex than in soils of sedimentary origin. Tree height (H) and breast diameters (BHD) were influenced one way or the other by the soil properties determined.

Table 2: Correlation coefficients between 13-year old *Anacardium occidentale* growth parameters and basement complex soil chemical characteristics.

	H	BHD	CD
pH	0.6 ns	0.679 ns	– 0.411
Organic C	– 0.95**	0.913**	0.732**
Available P	– 0.63 ns	0.705 ns	0.377 ns
Total N	– 0.329 ns	0.23 ns	– 0.986**
C/N	0.377 ns	– 0.279 ns	0.993*
Na	0.00 ns	– 0.1 ns	– 0.876*
K	– 0.86*	0.908*	0.32**
Ca	0.859*	– 0.801*	0.863*
Mg	0.639 ns	– 0.715*	– 0.36 ns
Ea	0.797*	– 0.73*	0.914**
CEC	0.962**	– 0.929**	0.703 ns
B/S	0.908**	– 0.859*	0.806*
Silt + Clay	0.274 ns	– 0.372 ns	– 0.71*
HCl-Zn	– 0.999*	0.998**	0.45 ns
Total Zn	– 0.470 ns	– 0.377 ns	1**
HCl-Cu	0.028 ns	0.075 ns	0.889*
Total Cu	0.695 ns	– 0.62 ns	0.965**
CD	0.483 ns	– 0.39 ns	1
BHD	0.995**	1	
H	1		

*Significant at 0.05 level; **Significant at 0.01 level

Table 3: Correlation coefficients between 13-year old *Anacardium occidentale* growth parameters and sedimentary soil chemical characteristics.

	H	BHD	CD
pH	– 0.98++	– 0.931**	0.38 ns
Organic C	0.317 ns	0.781*	0.611 ns
Available P	0.757*	0.281 ns	– 0.964**
Total N	– 0.15 ns	0.411 ns	0.904**
C/N	– 0.176 ns	– 0.682 ns	– 0.719*
Na	– 0.421 ns	0.139 ns	0.988**
K	0.991**	0.758*	– 0.665 ns
Ca	– 0.59 ns	– 0.934**	– 0.341 ns
Mg	– 0.665 ns	– 0.153 ns	0.991**
Ea	0.314 ns	– 0.252 ns	– 0.963
CEC	– 0.821*	– 0.99**	– 0.016 ns
B/S	– 0.593 ns	– 0.935**	– 0.337 ns
Silt + Clay	– 0.593 ns	– 0.061 ns	0.999**
HCl-Zn	0.956**	0.962**	– 0.291 ns
Total Zn	– 0.642 ns	0.955**	– 0.278 ns
HCl-Cu	– 0.408 ns	0.153 ns	0.985**
Total Cu	– 0.685 ns	– 0.971**	0.223 ns
CD	– 0.558 ns	– 0.018 ns	1
BHD	0.84*	1	
H	1		

*Significant at 0.05 level; **Significant at 0.01 level

the positive correlation between tree height, breast height diameter and crown diameter growth and some of the chemical characteristics indicates that application of the nutrients as fertilizer will be very important to the establishment, growth and survival of cashew in different guinea savanna zones of Nigeria.

A comparative study of the effect of soil properties in the two formations (sedimentary and basement complex) as indicated in Table 4 shows that F statistics did not show any marked significant difference among mean tree growth parameters. It was also observed that differences between the mean soil properties in the two formations were not significantly marked except for exchangeable sodium in the soil and tree growth parameters. The paired mean differences with LSD did not show any marked differences except for soil pH, organic carbon, total nitrogen and available phosphorus. This variation is attributed to the fact that parent materials have strong influence on soil formation in Nigerian guinea savanna. Chude and Obigbesan 91982) as well as Udo et al. 91979) have reported similar findings for soils of igneous, metamorphic and sedimentary rocks of Western Nigeria.

Table 4: Analysis of Variance (ANOVA) of growth data of 13-year old *Anacardium occidentale* and soil characteristics of guinea savanna sedimentary and basement complex soil.

	Source of Variation	DF	SS	MS	F	Sedi-mentary	Basement Complex	LSD	Differ-ences
pH	BT	1	0.160	0.160	1.185	5.310	4.980	0.235	0.33*
	WT	4	0.540	0.135					
	Total	5	0.700						
Organic C (%)	WT	1	0.012	0.012	1.413	0.660	0.750	0.015	0.09*
	WT	4	0.034	0.009					
	Total	5	0.047						
Available P (mg/dm^3)	BT	1	0.441	0.411	2.11	2.970	2.450	0.339	0.52*
	WT	4	0.779	0.195					
	Total	5	1.189						
Total N (%)	BT	1	0.001	0.001	0.167	0.130	0.150	0.006	0.02*
	WT	4	0.014	0.004					
	Total	5	0.015						
C/N	BT	1	1.612	1.612	0.455	6.330	5.290	6.166	1.040
	WT	4	14.169	3.542					
	Total	5	15.781						
Na (mmol/kg)	BT	1	0.005	0.005	9.011*	0.120	0.170	0.009	0.05*
	WT	4	0.002	0.001					
	Total	5	0.007						
K (mmol/kg)	BT	1	0.000	0.000	0.014	0.200	0.210	0.018	0.010
	WT	4	0.044	0.011					
	Total	5	0.044						
Ca (mmol/kg)	BT	1	0.001	0.001	0.006	2.040	2.070	0.256	0.030
	WT	4	0.588	0.147					
	Total	5	0.589						
Mg (mmol/kg)	BT	1	0.390	0.390	0.815	1.000	1.510	0.833	0.510
	WT	4	1.915	0.479					
	Total	5	2.305						
Ea (mmol/kg)	BT	1	0.232	0.232	0.619	3.530	3.130	0.652	0.400
	WT	4	1.499	0.375					
	Total	5	1.731						
CEC (mmol/kg)	BT	1	0.064	0.064	0.031	6.880	7.090	3.616	0.210
	WT	4	8.311	2.078					
	Total	5	8.375						
B/S (%)	BT	1	103.171	103.171	3.714	47.840	56.130	48.356	8.290
	WT	4	111.115	27.779					
	Total	5	214.285						
Silt + Clay (%)	BT	1	24.523	24.523	0.964	19.810	23.860	44.300	9.050
	WT	4	101.794	25.449					
	Total	5	126.317						
HCl-Zn (mg/dm^3)	BT	1	4.335	4.335	0.687	2.630	4.330	10.990	1.700
	WT	4	25.253	6.313					
	Total	5	29.588						
EDTA-Zn (mg/dm^3)	BT	1	1.707	1.707	0.344	2.930	4.000	8.637	1.070
	WT	4	19.847	4.962					
	Total	5	21.553						
Total Zn (mg/dm^3)	BT	1	10.587	10.587	0.646	9.070	11.720	28.500	2.650
	WT	4	65.508	16.377					
	Total	5	76.095						
HCl-Cu (mg/dm^3)	BT	1	2.432	2.432	0.462	2.670	3.940	9.170	1.270
	WT	4	21.071	5.268					
	Total	5	23.503						
EDTA-Cu (mg/dm^3)	BT	1	3.435	3.435	0.660	2.850	4.370	8.997	1.520
	WT	4	20.673	5.168					
	Total	5	24.108						
Total Cu (mg/dm^3)	BT	1	18.375	18.375	0.894	6.330	9.830	35.761	3.500
	WT	4	82.173	20.543					
	Total	5	100.548						
CD (m)	BT	1	0.742	0.742	0.048	6.540	5.830	26.681	0.710
	WT	4	61.308	15.327					
	Total	5	62.050						
BHD (m)	BT	1	0.023	0.023	0.103	0.740	0.620	0.387	0.120
	WT	4	0.889	0.220					
	Total	5	0.912						
H (m)	BT	1	0.010	0.010	0.002	5.730	5.810	9.740	0.080
	WT	4	22.381	0.590					
	Total	5	22.391						

*Significant at 0.05 level; **Significant at 0.01 level

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