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TEXTURE AND CHEMICAL PROPERTIES OF SOME SOILS UNDER MANGO (MANGIFERA INDICA) ORCHARD AND ADJOINING GRASSLAND IN NIGER STATE

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ABSTRACT

Physicochemical analysis was carried out on soil samples collected from mango orchards and their corresponding adjoining grasslands on basement complex and sedimentary sandstone lithological formations in some parts of Niger State in the Nigerian southern guinea savanna zone. The mango orchard soils and those of the adjoining grasslands exhibited significantly marked differences in their organic C, available P, exchangeable Ca and Mg, C.E.C., Base saturation, extractable Zn, extractable and total Cu values. On sedimentary sandstone, the orchard soils mean values for organic C, available P, exchangeable Ca and Mg, C.E.C, base saturation, extractable Zn and Cu were 6.30 gkg^{-1}, 2.71 mgkg^{-1}, 1.83 mmolkg^{-1}, 1.47 mmolkg^{-1}, 6.79 mmolkg^{-1}, 51.80 %, 2.55 mgkg^{-1} and 2.8 mgkg^{-1} respectively, while the mean values in grassland soils were 2.63 gkg^{-1}, 1.59 mgkg^{-1}, 1.32 mmolkg^{-1}, 0.28 mmolkg^{-1}, 5.03 mmolkg^{-1}, 35.33%, 7.37 mgkg^{-1} and 1.24 mgkg^{-1} respectively. The mean values in orchard soils on basement complex for organic C, exchangeable Ca and Mg, base saturation and total Cu were 8.30 gkg^{-1}, 2.02 mmolkg^{-1}, 1.43 mmolkg^{-1}, 54.47 % and 10.93 mgkg^{-1} respectively, while in grassland soils the mean values were 2.77 gkg^{-1}, 1.25 mmolkg^{-1}, 0.33 mmolkg^{-1}, 37.56 % and 3.92 mgkg^{-1} respectively. The higher amounts of most nutrient elements in the orchard soils than in those of the adjoining grasslands could be due to nutrient recycling by the mango orchard trees. These findings suggest that local farmers may spend less on the use of inorganic fertilizers and maintain the soil in a better condition for higher yields if they are encouraged to employ farming practices that enhance nutrient recycling.

Keywords: Texture, Chemical properties, Mango orchard, adjoining grassland, basement complex and sedimentary sandstone.

INTRODUCTION

The Nigerian guinea savanna zone is commonly associated with low and highly variable rainfall pattern. Thus, the resultant vegetation is usually made up of vast grassland interspersed with few short to medium-sized shrubs and trees (Laurie, 1974). Also, the fertility status of soils in this zone is generally quite low probably due to the low organic matter content arising from rapid humification as observed in the tropical region (Ojanuga, 1971) and the types of clay minerals that dominate in this region. Lal and Kang (1982) reported that, tropical soils undergo rapid decline in fertility when they are cleared and cultivated.

In sustaining soil productivity, organic matter status plays a vital role. Traditional farming systems in Africa rely on bush fallow systems to restore soil fertility. Unfortunately, population pressure or scarcity of labour to clear the fallow land has led to an appreciable reduction in the length of fallow. This has resulted in decreased soil productivity. Improved and new technologies designed as alternatives to the shifting cultivation and bush fallow system include mechanisms that can replenish the soil organic matter (Mulongoy et al., 1993). Some farmers selectively retain a few woody species during land clearing, while others establish trees and shrubs which have the

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potential to maintain soil fertility (Kang and Wilson, 1987). In recent times, because of rapid population growth, much attention has been directed towards the need for increased food production through a more intensive cultivation practice on a continuous basis. The result is the problem of deficiency of both major and minor soil nutrients. The soil becomes increasingly impoverished and even when nutrients are applied as inorganic fertilizers, it is mostly the major elements that are replaced. However, farming practices that enhance nutrient recycling by providing plant leaf litter or plant residue will go a long way to reduce the problems of nutrient element deficiency. The quality and quantity of plant materials and litter returned to the soil largely determines the levels of organic matter (Yamoah et al, 1986). Brady and Weil (1999) noted that after a long period, regrowth vegetation will at least partially rejuvenate the quality of the soil by adding organic residues and recycling nutrients from deep in the profile. Even when the underlying parent material is rich in exchangeable bases, it would be relatively impossible for the soil to maintain indefinitely a high fertility status in the guinea savanna zone. This is because the savanna vegetation is burned regularly and also grazed extensively by domesticated animals. Hence, the plant material which would have otherwise, abstracted or taken up nutrients from the soil and return them in nutrient-rich humus when they decay and decompose would have been lost (Eyre, 1982).

Considering the problems stated above, one may not be left with any choice other than man-made plantations of fast growing and drought tolerant tree species through orchard establishment (Evans, 1976). This kind of vegetation dominated by trees generally encourage substantial nutrient recycling mainly through the decay of plant residues from leaf-fall, especially where there is absence of bush burning and controlled grazing. The objective of this work, therefore, is to determine the texture and chemical characteristics of soils of 13-year old mango orchards and their corresponding adjoining grasslands in the study area for the purpose of comparative analysis of the physicochemical properties of the two soils.

MATERIALS AND METHODS

The study area stretches from Suleja to Mokwa in Niger State, Nigeria. It is located in the Southern guinea savanna zone (Sanford and Isichei, 1980) between latitudes 8° 40' and 9° 45' N and longitudes 4°40' and 7°25' E. It has a mean rainy season length of 180-200 days, and a mean annual rainfall of 1,300-1,400mm. The maximum temperature (38 °C) occurs between March and April, while the minimum temperature (14 °C) is observed between December and January. The geology of the area under study consists of two different geological materials, namely, sedimentary sandstone and basement complex. The sedimentary sandstone location comprises of three sites (Bida, Doko and Mokwa), while the basement complex location also consists of three sites (Suleja North, Suleja South and Suleja West), making a total of six different sites. The soils derived from sedimentary sandstone are hydromorphic, mostly coarse sands, sandy loam and loamy sand, whereas, well-drained sandy loam and sandy clay loam are the dominant soils derived from the basement complex rocks.

Field studies were carried out on soils under 13-years old mango orchards and their corresponding adjoining grasslands, 15m apart, located in each of the six sites on the two different lithological formations. Each of the mango orchards had over 30 tree stands of similar age. Seven bulked soil samples each were collected from four orchards ($3500m^2$ each) and their corresponding adjoining grasslands, while eight bulked samples were collected from each of the slightly larger remaining two orchards ($3700\ m^2$ each) and their adjoining grasslands. Hence, a total of 88 bulked soil samples were collected (i.e. 44 from the mango orchards + 44 from their corresponding adjoining grasslands) from the six different sites under study. The bulked soil samples were collected with a soil auger from 0-40cm depth, air-dried and passed through a 2mm sieve. The choice of 0-40cm soil depth was informed by the fact that this depth is usually considered as being closely related to the effective depth for tree growth.

Sub-samples were used for physicochemical analysis. Soil samples used for total N, organic C, total and available Zn and Cu determinations were further ground to pass through a 0.5mm sieve. Soil pH was determined in 0.01M $CaCl_2$ (1:2.5, soil/solution ratio) using a pH meter with a glass electrode (IITA, 1979). Particle size distribution was determined by hydrometer method (Bouyoucos, 1951). Organic C was determined by Walkey-Black method (Allison, 1965). "Available" P was extracted by the Bray No.1 method (Bray and Kurtz, 1945). Total N was determined by the Macro-Kjedhal method (Bremner, 1965). Exchangeable Na, K, Ca, Mg, Al and H were extracted with 1N neutral Ammonium acetate solution (IITA, 1979). Exchangeable Na and K were determined using the flame photometer (Black, 1965), while exchangeable Ca and Mg were determined by the Versenate (Na_2 E.D.T.A.) titration method (Jackson, 1970). Exchangeable acidity ($H^+ + Al^{3+}$) was determined following the titration method employed by McLean (1965). Cation Exchange Capacity (C.E.C.) was obtained by summation. Percent base saturation was calculated by dividing the sum of the exchangeable bases by C.E.C. and multiply by 100. Extractable Zn and Cu were extracted with 0.1N HCl and 0.01N Na_2 – EDTA, while total Zn and Cu were extracted with digestion acid (1 volume of $HClO_4$ + 4 volumes of HNO_3) and 6N HCl (IITA, 1979). The extractable (available) and total Zn and Cu were determined by atomic absorption spectrophotometry (Jackson, 1970). The results obtained from the physicochemical analysis of soil samples from the two different soils were subjected to statistical analysis by employing T-test for the purpose of comparative analysis.

RESULTS AND DISCUSSION

The soils from the mango orchards and their corresponding adjoining grasslands on the two different lithological formations (sedimentary sandstone and basement complex) were analysed for particle size distribution, pH, organic C, available P, total N, exchangeable cations (Na, K, Ca, Mg, Al and H), cation exchange capacity, base saturation, extractable and total (Zn and Cu). The results of the soil analysis are displayed in Table 1.

The results of the T-test analysis employed to compare the texture and chemical properties of mango orchards and their corresponding adjoining grassland soils on sedimentary sandstone (Table 2) and on basement complex (Table 3) soil units are shown below.

Particle Size Distribution

The T-test analysis results show that the difference in average silt + clay content between the orchard soils and those of their adjoining grasslands located on both sedimentary sandstone and basement complex soil units was not significant. Ezenwa (1988) reported that soil texture is one of the stable factors of the landscape that are relatively undisturbed by man's activities. Also, since soils of the mango orchards and their adjoining grasslands originate from the same geological material in the respective lithological formations, the grain size of their particles are not expected to differ considerably. Young (1976) observed that the grain size of a parent material was the main determinant of soil texture.

Soil pH

The results of T-test analysis show that none of the mean pH values for orchard and grassland soils in the two geological formations (locations) compared were significantly different from each other. Brady and Weil (1999) noted that forest soils produce higher acidity (lower pH) than grassland soils due to production of organic and inorganic acids from breakdown of organic residues concentrated on the soil surface. However, the authors reported that the expected difference in pH between the two soils is masked by the higher buffering capacity of the forest soils arising from higher organic matter content and higher C.E.C. This renders the difference in pH negligible. This may also be a reflection of the absence of significant difference in the exchangeable acidity of the soils under study.

Organic Carbon

The mean organic C content of orchard soils on both sedimentary sandstone and basement complex were significantly (P=0.05) higher than those of the soils under grassland. This could be attributed to occasional destruction of leaf-litter by wild fires and animal grazing on grasslands in the guinea savanna region (Ezenwa, 1985). Another reason could be the higher degree of leaf-litter shedding by mango orchard trees. The quality and quantity of plant materials and litter returned to the soil will, to a great extent, determine organic matter levels according to Yamoah *et al.* (1986).

Available Phosphorus

The average available P content of mango orchard soils was observed to be significantly (P=0.05) higher than that of their corresponding adjoining grasslands on sedimentary sandstone location. This is attributed to nutrient recycling by the orchard trees. This finding agrees with the report of Eyre (1982). Also, annual bush fires and animal grazing may have led to reduction and/or removal of grasses in the soils of the adjoining grasslands, thus reducing the extent of nutrient recycling. Brady and Weil (1999) reported that soil quality is positively affected if a significant proportion of crop residues are returned to the soil.

In the basement complex soil unit, no significant difference in average available P value was observed between the mango orchard soils and their adjoining grassland soils. It is probable that appreciable amounts of available P were still locked up in the leaf-litter of the orchard trees, or tied up in the soil.

Total Nitrogen

T-test analysis results indicate an insignificant difference in mean total N content between the orchard and grassland soils located on the two different geological formations. This may be due to the generally low N levels (as low as 0.008 to 0.029gkg^{-1}) in savanna soils, arising from the predominantly sandy nature of the soils and relatively low rainfall in this region (Jones, 1973). Also, nitrogen is highly mobile, and it is therefore, expected that the sandy

Table 1: Average soil (0-40 cm) texture and chemical properties of 13-year old mango orchards and their adjourning grassland on sedimentary sandstone basement complex soil units in Niger State

Plot No	PH ($CaCl_2$)	Org.C (gkg^{-1})	Avail. P ($mgkg^{-1}$)	Total N (gkg^{-1})	Na	K	Ca ($mmolkg^{-1}$)	Mg	Ea	C.E.C	B/S (%)	Silt + Clay (%)	EDTA Zn	Total Zn ($mgkg^{-1}$)	EDTA Cu	Total Cu
Sedimentary Soil Unit																
Mango Orchard Soil																
1	5.03	6.80	3.00	0.90	0.13	0.16	1.80	1.30	3.60	6.99	48.50	15.43	3.90	10.4	2.50	6.70
2	4.73	5.10	2.38	0.80	0.11	0.08	1.80	1.70	3.20	6.89	53.56	25.45	2.07	7.70	2.70	6.30
3	4.50	7.00	2.75	1.00	0.09	0.09	1.90	1.40	3.00	6.48	53.70	15.20	1.69	7.00	3.20	7.90
Mean	4.75	6.30	2.71	0.90	0.11	0.11	1.83	1.47	3.27	6.79	51.92	18.69	2.55	8.37	2.80	6.97
Adjoining Grassland Soil																
1	5.25	2.30	1.68	0.40	0.09	0.09	1.30	0.23	3.33	5.04	33.93	18.58	7.40	10.01	1.10	4.30
2	5.35	2.80	1.56	0.50	0.09	0.09	1.35	0.32	3.31	5.16	35.85	14.91	7.78	10.17	1.20	4.52
3	5.18	2.80	1.52	1.20	0.10	0.08	1.32	0.29	3.13	4.92	36.38	15.42	6.93	9.73	1.43	3.17
Mean	5.26	2.63	1.59	0.70	0.09	0.09	1.32	0.28	3.26	5.04	35.39	16.30	7.37	9.97	1.24	4.00
Basement Complex Soil Unit																
Mango Orchard Soil																
1	4.51	9.70	2.13	1.80	0.12	0.13	2.07	1.30	2.60	6.22	58.20	21.03	1.50	6.90	4.20	9.80
2	4.64	8.90	1.87	1.50	0.11	0.13	2.00	1.59	4.60	8.43	45.43	33.97	3.80	10.30	5.90	12.00
3	5.44	6.30	2.88	1.10	0.21	0.27	2.00	1.40	2.60	6.48	59.88	21.69	6.70	16.66	6.43	11.00
Mean	4.86	8.30	2.29	1.47	0.15	0.18	2.02	1.43	3.27	7.04	54.50	25.56	4.00	11.29	5.51	10.93
Adjoining Grassland Soil																
1	5.67	2.70	1.44	0.55	0.12	1.13	1.22	0.32	3.61	6.40	43.59	36.06	1.2	1.99	2.23	3.95
2	5.47	2.90	1.31	1.50	0.12	0.16	1.24	0.30	3.61	5.43	33.52	30.28	3.07	4.17	1.53	3.20
3	4.93	2.70	1.28	0.20	0.11	0.14	1.30	0.37	3.47	5.39	35.62	28.25	2.37	5.17	1.50	4.60
Mean	5.36	2.77	1.34	0.75	0.12	0.48	1.25	0.33	3.56	5.74	37.58	31.53	2.21	3.77	1.75	3.92

nature of these soils would further aggravate the problem. Considerable amounts of N may still remain locked up in the orchard leaf-litter or in an unmineralized form.

Table 2: Comparative analysis (t-test) of mean soil (0–40 cm) texture and chemical characteristics of 13-year old mango orchards and their corresponding adjouning grassland on sedimentary sandstone in Niger State

Variation	Mango Orchard Soil	Adjoining Grassland Soil	Standard Error	T-ratio
PH (cacl$_2$)	4.75	5.26	0.145	-3.51^{NS}
Org.C (gkg^{-1})	6.30	2.63	0.689	5.323^{*}
Avail. P (mgkg^{-1})	2.71	1.59	0.154	7.294^{*}
Total N (gkg^{-1})	0.90	0.70	0.208	0.961^{NS}
Na	0.11	0.09	0.021	0.803^{NS}
K	0.11	0.09	0.025	0.951^{NS}
Ca (mmolkg^{-1})	1.83	1.32	0.038	13.456^{**}
Mg	1.47	0.28	0.098	12.171^{**}
Ea	3.27	3.26	0.130	0.077^{NS}
C.E.C	6.79	5.04	0.160	10.937^{**}
B/S (%)	51.92	35.39	0.988	16.732^{**}
Silt + Clay (%)	18.69	16.30	4.162	0.574^{NS}
EDTA -Zn	2.55	7.37	0.672	-7.166^{*}
Total Zn (mgkg^{-1})	8.37	9.97	1.000	-1.604^{NS}
EDTA -Cu	2.80	1.24	0.111	14.075^{**}
Total Cu	6.97	4.00	0.898	3.307^{NS}

Exchangeable Bases

Mango orchards and their adjoining grassland soils exhibited no significant difference in their mean Na and K content both in the sedimentary sandstone and the basement complex soil units (locations). This may be attributed to the very low Na and K values arising from the fact that these cations are easily lost by leaching from the soils at even the lowest range of rainfall (Ezenwa, 1988). The significantly (P=0.01) higher amounts of Ca and Mg observed in the mango orchard soils than in their adjoining grassland soils in the two different locations could be due to higher organic matter content and higher level of nutrient recycling in the orchard soils. Ca has been reported to be the least easily lost cation from the soil, especially in the presence of considerable amount of organic matter (Brady and Weil, 1999).

Exchangeable Acidity (Ea)

The average Ea (Al + H) values observed in the orchards and their adjoining grassland soils on sedimentary sandstone did not differ significantly. Similarly, the mean Ea values for the mango orchards and their adjoining grassland soils on basement complex showed no significant difference. This may be attributed to the mineralogical composition of the parent materials from which these soils were derived and their capacity to release Al^{3+} ions during weathering (Pritchett, 1979). Another reason may be resistance to changes in soils pH by the better buffered mango orchard soils because of higher organic matter content and higher base saturation (Brady and Weil, 1999).

Table 3: Comparative analysis (t-test) of mean soil (0-40cm) texture and chemical characteristics of 13-year old Mango orchards and their corresponding adjoining grassland on Basement complex in Niger state

Variation	Mango Orchard Soil	Adjoining Grassland Soil	Standard Error	T-ratio
PH (cacl$_2$)	4.86	5.36	0.511	0.966^{NS}
Org.C (gkg^{-1})	8.30	2.77	1.009	5.485*
Avail. P (mgkg^{-1})	2.29	1.34	0.327	2.903^{NS}
Total N (gkg^{-1})	1.47	0.75	0.372	1.925^{NS}
Na	0.15	0.12	0.035	0.855^{NS}
K	0.18	0.48	0.353	0.845^{NS}
Ca (mmolkg^{-1})	2.02	1.25	0.044	17.661**
Mg	1.43	0.33	0.096	11.446**
Ea	3.27	3.56	0.645	0.460^{NS}
C.E.C	7.04	5.74	0.924	1.410^{NS}
B/S (%)	54.50	37.58	3.749	4.516*
Silt + Clay (%)	25.56	31.53	5.412	1.103^{NS}
EDTA -Zn	4.00	2.21	1.278	1.398^{NS}
Total Zn (mgkg^{-1})	11.29	3.77	2.021	3.716^{NS}
EDTA -Cu	5.51	1.75	0.908	4.138^{NS}
Total Cu	10.93	3.92	0.906	7.747*

*significant at 0.05 probability level, **Significant at 0.01 probability level; NS = not significant

Cation Exchange Capacity (C.E.C.) and Base Saturation (B/S)

Mango orchard soils had significantly (P=0.01) higher mean C.E.C. value than the grassland soils on sedimentary sandstone location. In the basement complex location, the mean C.E.C value for orchard soils was also higher, but not significantly. The higher organic matter content observed and nutrient recycling could be said to be responsible for the higher mean C.E.C. value of the orchard soils. Brady and Weil (1999) reported that returning a substantial proportion of crop residues to the soil will have a positive impact on soil quality. It is for this same reasons enumerated above that significantly (P=0.01) higher mean percent base saturation was observed in the mango orchard soils than in their corresponding adjoining grassland soils in the sedimentary sandstone soil unit. In the basement complex location, the significant difference was observed at P=0.05.

Extractable and Total Zn

The adjoining grassland soils had significantly (P=0.05) higher mean extractable Zn content than the orchard soils on sedimentary sandstone, while on basement complex, the difference between means for the two soils was not significant. Macleen and Langille (1976) reported a decrease in extractable Zn with decreasing organic matter content. It is probable that appreciable amounts of extractable Zn may be fixed or locked up in the unmineralized organic matter in the mango orchard soils, hence, a lower extractable Zn content may be expected. Lombin (1983a) also noted that extractable Zn was highly correlated with organic matter.

The orchard and grassland soils did not differ significantly in their mean total Zn content in the two geological locations under study. Fagbami *et al.* (1985) reported that total Zn was weakly correlated with organic matter, but strongly associated with clay content. Unfortunately, the mean silt + clay content of the soils under study were not significantly different; therefore, a significant difference in mean total Zn between the two soils may not be expected.

Extractable and Total Cu

Mango orchard soils exhibited a significantly (P=0.01) higher mean extractable Cu content than the grassland soils on sedimentary sandstone. Also, mango orchard soils had a significantly (P=0.05) higher mean total Cu content than grassland soils on basement complex. Higher organic matter content and nutrient recycling are responsible for the higher mean values so obtained. Lombin (1983a) reported a strong relationship between Cu levels and organic matter levels.

Mango orchards and their corresponding grassland soils had no significant difference in mean total Cu in the sedimentary location. No significant difference was also observed in mean extractable Cu values between mango orchard and grassland soils in the basement complex location. These results indicating no significant differences between mean values could be due to adsorption of the total and extractable Cu by clay minerals in the orchard soils on the sedimentary sandstone and basement complex locations (Tisdale *et al.*, 1985) respectively. They may also be locked or tied up probably in the organic matter in the orchard soils according to these authors.

SUMMARY AND CONCLUSION

This research was carried out with the aim of comparing the soil texture and chemical properties of 13-year old mango orchards and their corresponding adjoining grasslands located on two geological formations (sedimentary sandstone and basement complex) in the guinea savanna zone of Nigeria.

The results of the comparative study indicate significantly marked differences among most of the average soil properties, which include organic C, available P, exchangeable Ca and Mg, C.E.C., base saturation, extractable Zn and Cu, and total Cu. The higher amounts of most of the nutrient elements in the mango orchard soils than in those of the adjoining grasslands could be attributed to nutrient recycling in the orchard soils, and reduction and/or removal of grasses in those of their adjoining grasslands arising from annual bush burning and animal grazing commonly observed in this ecological zone.

Local farmers are often faced with the problem of soil structure deterioration due to intensive use of farmlands and continuous use of inorganic fertilizers, the high cost and unavailability of these fertilizers. Thus, farming practices that will enhance nutrient recycling and controlled grazing should be encouraged in the Nigerian Guinea Savanna. Farmers would spend less on the procurement of inorganic fertilizers and also maintain better soil condition that would guarantee higher yields and productivity.

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