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PEDOGENIC VARIATIONS IN TRACE ELEMENTS STATUS IN SOILS DEVELOPED ON DIFFERENT LAND USE: SYSTEMS UNDER HYDROMORPHIC CONDITION IN DADIN KOWA, GOMBE STATE, NIGERIA

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ABSTRACT

An assessment was conducted on the status and distribution of Trace elements in soils developed under five different land use systems in Dadin kowa, Gombe State. Two soil profiles pits were dug in each of identified land uses, described and sampled. The physical and chemical properties of the soils were determined. All soil samples collected were analysed using standard Laboratory procedures. Results revealed that, the textural classes for the studied soils were predominantly loamy sand to sandy loam in nature. The Bulk density, particle density and total porosity varied from 1.60 to1.67 g/cm^3, 2.57 to 2.71 g/cm^3 and 35.82 to 40.41% respectively. The soil reaction was slightly acidic to neutral (pH 6.39 – 6.68). The electrical conductivity (EC) of the soils of all the soil mapping units was below the critical limits of 4dSm^{-1}, an indication of the non-saline nature of the studied soils. The values of OC, TN and AP content of the studied soils across land use and horizons is substantial > 10g/kg, and is rated medium to high, 1.1 to 1.40g/kg, rated low to medium and 8.03 to 9.35mg/kg, rated low, respectively. The results further indicated that extractable Iron (2.49 to 5.19mg/kg), Zinc (0.60 to 3.48mg/kg), Copper (0.25 to 1.57mg/kg) and Manganese (1.59 to 2.84mg/kg) were rated high, medium, and medium to high, respectively, in their soil content. It was also observed that differential land management systems had significantly ($p<0.05$) influence the content and distribution of trace elements in the studied soils.

The incorporation of crop residue and addition of organic matter will not only maintain the availability of micronutrients, but at the same time the general physical and chemical properties of the soils, which will in turn enhance sustainable crop production.

Key words: Copper, Extractable, Hydromorphic, Pedogenic, Trace Elements, Zinc

INTRODUCTION

Trace elements are chemical elements that are required for plant growth in small amounts (Mustapha, *et al.*, 2011). This group of elements includes Zinc, Iron, Copper, Manganese, Nickle amongst others, which perform different complex roles in plant nutrition (Havlin, *et al.,* 2012). Although required in minute quantities, however Trace elements have the same agronomic importance as macronutrients and play vital roles in the growth of plants (Morthvedt, *et al.,* 1991). Most Trace elements are associated with the enzymatic systems of plants, Zn is known to promote the formation of growth hormones, starch and seed development, Fe partake in chlorophyll formation, Cu is important in Photosynthesis and Mn activates a number of important enzymes and participate in Photosynthesis and Metabolism (Nazif, *et al.,* 2006)

In recent years large hectares of Arable land in Nigeria have been reported to be deficient in Trace elements, and many of these deficiencies were brought about by the continuous use of inorganic fertilizers particularly nitrogen, phosphorus, and potassium by farmers, limited use of organic manures as well as non recycling of crop residues are some of the other factors contributing towards rapids exhaustion of Trace elements, in soils (Saddiq, *et al.,* 2008; Ibrahim, *et al.,* 2011)

The increasing human and animal population in Nigeria in general and Gombe state in particular, and the current governments derive to diversify the economy towards agriculture and the adoption of more scientific intensive agricultural systems has necessitated the evaluations of nutrient status of soils; most especially the micronutrients which had hitherto been neglected (Mustapha, 2003). Therefore this study was conducted with the aim of evaluating the influence of different land management systems on status of soil micronutrients and suggests management practices for optimum and sustainable cropping systems in the study area.

MATERIALS AND METHODS

The Study Area

The study area is at Dadin kowa in Yamaltu Deba local government area of Gombe State. It is located between latitudes, 10° 29' 00'' N and latitude 10° 30' 12'' E and longitude 11° 50' 35'' N and latitude 11° 53' 07'' E, within the Savannah ecological zone of the country (Klinkenberg and Higgins, 1968). It lies at an elevation ranging from 184-351m above sea level (Ikusemoran *et al.,* 2016) situated about 40km along Gombe – Biu road in the Northern Guinea Savanna Zone of Nigeria. According to Ikusemoran *et al.,* (2018), the geological succession of the Dadin Kowa area is underlain by the upper cretaceous rocks of marine sediments. The sediments are predominantly argillaceous and consist of alternating shale and limestone with sandy mudstones, siltstones and sandstones respectively (Ikusemoran *et al.,* 2018). The climate of the area is that of the semi-arid type characterised by wide seasonal and diurnal temperature ranges with two main seasons: rainy season (April-October) and dry season (November to March) (Abubakar, 2013). The average annual rainfall is put at 1000mm with the greater part falling between July and October (UBRBDA, 2018). April is usually the hottest month (maximum temperature being 39^oC) while December and January has the lowest temperature averaging 16^oC (UBRBDA, 2018).

Field Methods

Five (5) extensively cultivated farms/orchards were identified and mapped as soil mapping units; they are tomato (TMT), amaranth (AMR), mango (MNG), millet (MLT) and rice (RCE). To achieve objectives of the study, two soil profile pits were dug on each of the 5 mapping units identified and soil samples from each recognizable pedogenic horizon from each of the dug profile pits were collected in a well labelled polythene bags and stored ready for laboratory analyses.

Laboratory analysis

In the laboratory, each sample was separately air dried ground and passed through a 2mm sieve for laboratory analysis as described by Agbenin (1995). Particle size analysis was determined using the Bouyoucos hydrometer method, after dispersing the soil samples with 5% Sodium hexametaphosphate. The bulk density was determined by the clod method (Black and Hartge, 1986). Porosity was calculated mathematically from bulk density (Db) and standard particle density (Dp) data as described by Anderson and Ingram (1998). Soil pH was determined in 1:1 water ratio using a glass electrode pH metre (Page *et al.,* 1982). Determination of Organic carbon, and Total nitrogen were done by the wet oxidation method and regular micro-kjeldal method respectively. Available phosphorus was determined using the Bray 1 method. The extractable Trace Elements: Zn, Cu, Fe and Mn were extracted with 0.1M HCl solution as described in IITA, (1982) manual, and their respective concentrations determined by atomic absorption spectrophotometer (AAS) model VGP210 (Bulk Scientific)

Data Analysis

Descriptive statistics were used to assess the normal distribution of data for parameters analyzed in the laboratory (Agbenin, 1995). Data collected from the laboratory analysis were also subjected to Analysis of variance (ANOVA) using GenStat Statistical Software 17th edition. Means that are significant were separated using LSD at 5% level of probability.

Results and Discussion

Soil physical properties

The particle-size distribution mean data for the various land use systems (LUS) is presented in Table 1. The total mean sand content across LUS ranged from 73.38-84.8%, and is the predominant soil particle. This observation of sand fraction predominance in this study is consistent with the findings of Askira *et al.* (2019). Onweremadu *et al.* (2011), attributed the high sand content to the nature of parent material. Such deposits are commonly found covering the surfaces of underlying soils that may be formed from other parent materials such as the alluvial deposits common in fadama areas as it were in this study. The highly significant ($p<0.01$) variation in mean sand distribution across land use could be related to the secondary products of weathering (Brady and Weil, 2013). Silt particle values ranged from 7.8-16.7% across the different land uses. A notable feature in all the soils studied is their high silt content. Ogbodo (2011) and Nsor and Uhie (2016) all reported higher silt content in their various studies. This high silt content obtained in this study could be attributed to the nature of parent material and stage of soil development (Maniyunda, 1999). There was a highly significant ($p<0.001$) difference in silt content between the different land uses (Table 1). The high mean content of silt recorded in soils under rice, tomato and amaranth could be attributed to the received fine colluvial and alluvial sediments from the upper slope positions through erosion and deposition (Maniyunda and Gwari, 2014). Clay content ranged from 6.58- 9.91% across the different land uses. The result for particle size distribution showed that percentage clay content was lowest when compared to sand and silt, in all the studied soils. Such low values of clay content obtained in this study, agreed with the findings of Akintoye *et al.* (2012) and Akpan *et al.* (2017), who worked on similar soils. The significant ($p<0.05$) variation in clay distribution obtained in this study could be related to the pedogenic processes such as lessivage, eluviations and illuviation (Usman *et al.,* 2017). The mean bulk density (BD) values across the different land uses ranged from 1.60-1.67g/cm^3. The obtained BD values in this study are within the range reported in earlier findings by Ande *et al.,* (2016) who recorded values of 1.11 to 1.98g/cm^3 while working on floodplain soils in Southern Guinea Savanna of North Central Nigeria. Soils under mango cultivation recorded a significantly ($p<0.05$) higher BD values than other land uses. This variation in soils under mango could be attributed to high intensity livestock grazing (Raji *et al.,* 1996). High soil bulk density pose a great challenge, such as resistance to root penetration, poor aeration, slow movement of nutrients and water and build up of toxic gases and root exudates (Sharu *et al.,* 2013). However the values obtained in these studies are generally considered safe for root penetration. Root penetration is usually hindered in soils having bulk density value >1.75g/cm^3 (Esu, 2005; Ashenafi *et al*., 2010). Donahue *et al*. (1990) did report that good plant growth is best at bulk densities below 1.40 g/cm^3 for Clay, and 1.60 g/cm^3 for sandy soils. The mean Particle density values across the different land uses ranged from 2.57-2.71 g/cm^3, indicating that quartz, feldspar, micas and the colloidal silicates with densities between 2.60- 2.75 g/cm^3 forms the major portion of minerals in the study area as earlier stated by Brady and Weil (2013).

Table 1: Ranking of the means of soil physical properties across different land uses

	Sand	Silt	Clay	BD	PD	TP
	→	% ←		→ g/cm^3 ←		%
Land Uses						
Amaranth	77.36bc	14.00a	8.64ab	1.61b	2.71a	40.41a
Millet	83.12ab	7.80b	9.07a	1.61b	2.57ab	37.14ab
Mango	84.80a	8.62b	6.58c	1.67a	2.64a	36.76ab
Rice	73.38c	16.70a	9.91a	1.60b	2.48b	35.82b
Tomato	78.36bc	14.04a	7.60ab	1.63b	2.66a	38.70ab
LSD (p<0.05)	*5.23*	*4.07*	*1.95*	*0.04*	*0.12*	*2.72*
LOS	**	***	*	*	*	*

LOS (Level of significant) (p): NS (Not Significant) > 0.05, * < 0.05, ** < 0.01, *** < 0.00,
BD= bulk density, PD= particle density, TP= total porosity
Note: Means followed by the same letters in the column are not significantly different at 5% LOS

The mean value of PD differed significantly ($p<0.05$) across the different land uses. Generally, the values of particle density recorded in this study were considered satisfactory (Kachinskii, 1965). Total porosity values recorded in this study falls within the range of 35.82 to 40.41%. Therefore, porosity is not a limiting factor in this present study (Kachinskii, 1965). Similar values were also reported for some studied soils by Ogban and Utin, (2015) and Akpan *et al.,* (2017) while working on wetland and coastal plain soils, respectively, in Calabar, Cross River State, Nigeria. Land use under *Amaranth* cultivation recorded a significant ($p<0.05$) higher mean value of 40.41% when compared to the other land uses. The higher mean porosity value recorded in the *Amaranth* land use may be attributed to loosening of soil materials by plant roots and regular cultivation of soil (Ahukaemere and Akpan 2012). Brady and Weil (2013) stated that the optimum total pore space value for crop production should be at least 50%. According to Kachinskii (1965), soils under amaranth cultivation could be classed as satisfactory soils, while millet, mango, rice and tomato are classed as unsatisfactory soils. Incorporation of organic manure to the soils will decrease the soil bulk density and ultimately increase the percentage pore distribution thereby enhancing the soil physical condition for optimum crop production and food security (Hassan and Shuaibu, 2006).

Soil chemical properties

The mean data for chemical properties across the various land use systems (LUS) is presented in Table 2. Generally, pH is regarded as a major driver of soil fertility (Brady and Weil, 2013). The mean soil pH values determined in water [pH (H_2O)] of the soils across land uses ranged from 6.39 to 6.68 which is rated as slightly acidic to neutral in reaction (Malgwi, 2007). The low pH values recorded in this study are similar to those earlier reported by Abagyeh, *et al.,* (2017); Okoli *et al.,* (2017); Fekadu *et al.,* (2018). The acidic condition of the soils under study could be attributable to greater oxidation of anions like sulphides and nitrites leading to soil acidification (Ahukaemere *et al.,* 2014). There was no observed significant ($p>0.05$) variation in mean pH values across the different land uses. The electrical conductivity (EC) of a soil solution is a good indicator of the degree of salinity of the soil (Brady and Weil, 2013). The mean EC values across LUS ranged from 0.12-0.22 d/sm. The obtained range of EC values were found to be below the critical limits of $4dSm^{-1}$ and are therefore classified as non-saline (Malgwi, 2007).

Table 2: Ranking of means of soil chemical properties across different land uses

	pH(1:2)	EC	OC	TN	AP
		d/sm →	(g/kg) ←	(mg/kg)	
Land Uses					
Amaranth	6.68	0.22a	16.02a	1.4a	9.35a
Millet	6.39	0.12b	12.25b	1.1b	8.86ab
Mango	6.47	0.20a	12.57b	1.1b	8.36bc
Rice	6.53	0.15ab	15.20ab	1.3ab	8.03c
Tomato	6.64	0.18ab	13.55ab	1.2ab	8.43bc
LSD (p<0.05)	*0.22*	*0.05*	*0.24*	*0.02*	*0.50*
LOS	NS	*	*	*	***

LOS (Level of significant) (P): NS (Not Significant) > 0.05, * < 0.05, ** < 0.01, *** < 0.001,
EC=electrical conductivity, OC=organic carbon, TN=total nitrogen, AP=available phosphorus,
Note: Means followed by the same letters in the column are not significantly different at 5% LOS

Such low EC values obtained in this study is in line with the earlier findings by Egwu *et al.*, (2018); Imadojemu *et al.,* (2018). Imadojemu *et al.,* (2018), attributed the low EC values recorded in the study area to the sandy nature of the parent materials. The EC mean values showed that soils under amaranth and mango cultivation recorded a significantly ($p<0.05$) higher values when compared to the other land uses. The mean organic carbon content across LUS ranged from 12.25-16.02 g/kg. The mean value of organic carbon (OC) content of the soils across land use is substantial > 10g/kg and is rated medium to high (Malgwi, 2007). This finding is contrary to earlier findings by Salem, *et al.* (2018) and Askira *et al.* (2019) who obtained low OC content for soils in the Savanna Zones of Nigeria. Soils under amaranth cultivation is observed to be statistically ($p<0.05$) higher in mean OC content when compared to the other land uses. The high content of organic matter in soils under amaranth may be attributed to short growing season and regular addition of farm yard manure and plant residue after every harvest which causes a relative accumulation of organic matter, a reduced microbial activities and less frequent and less severe translocation of mineralised products at the start of the rains (Esu, 1982). The mean total nitrogen (TN) values for the studied soils, across the different land uses ranged from 1.1 to 1.4g/kg and are rated low to medium as per Malgwi (2007). Similar range of total nitrogen values have been reported by Pantami (2017) and Egwu *et al.* (2018) for soils in the Northern Guinea Savanna Zone of Nigeria. Also, low total nitrogen in soils has been reported by Salem *et al.* (2017a). The low to medium level of TN obtained in this study could be attributed to TN been mobile in soils, as a result its losses through various mechanism like ammonia volatilization, succeeding denitrification, chemical and microbial fixation, leaching and runoff all results in residual/available N to be poor in soils (*Akpan et al.* 2017). Soils under amaranth cultivation is statistically ($p<0.05$) higher in mean TN content compared to other land uses. The higher TN recorded in soils under amaranth may be attributed to the relatively higher content of organic matter. Lawal *et al.* (2012) stated that organic matter accounts for between 90 and 98 % of soil nitrogen. The available phosphorus (AP) mean content of the soils across land uses ranged from 8.03 to 9.35mg/kg and was substantially found to be low (Malgwi, 2007). Such low AP values were earlier reported by Osujieke *et al.,* (2017) in their various findings. This low AP mean values could be due to fixation, as a result of the acidic condition of the soils (Fekadu *et al.,* 2018). The mean values of available P recorded in soils under amaranth cultivation is highly significantly ($p<0.001$) higher from values obtained under millet, mango, rice and tomato cultivations. This higher AP values recorded in soils under amaranth cultivation could be attributed to addition of phosphorous containing fertilizer and high organic matter content (Sai Kumar *et al*., 2013).

Trace Elements

Trace elements considered in this study include zinc, copper, iron and manganese. Of the four extractable Trace elements determined, iron (Fe) content was highest in the soil, followed by manganese (Mn), zinc (Zn) and copper (Cu). The mean data for Trace elements determined in the studied soils are presented in Table 3.

Zinc (Zn)

The mean values of extractable Zn, between land uses ranged from 0.60 to 3.48mg/kg, and were substantially found to be medium as per Malgwi (2007) rating scale. The levels of Zn obtained in this study are contrary to those obtained by Oviasogie *et al.* (2017) who reported low Zn content in their respective studies. FAO, (1998), indicated that the critical levels for plant available Zn is 1.0mg/kg. There Zn content was significantly ($p<0.05$) higher in soils under rice cultivation, when compared to the other four land uses. The obtained value could be attributed to the oxidation of Fe in the soils causing acidification, thereby increasing Zn solubility (Brady and Weil, 2017), which was facilitated by high degree of weathering, and subsequent release of iron in the soil.

Copper (Cu)

The mean soil Cu content obtained from all the studied soils ranged from 0.25 to 1.57mg/kg and were rated medium to high (Malgwi, 2007). Similar results were earlier reported by Gabasawa *et al.,* (2016). The mean Cu content under rice cultivation was significantly ($p<0.01$) higher when compared to amaranth, millet, mango and tomato. The higher Cu content obtained in soils under rice cultivation, could be attributed to the pH condition of the soil (Dan'Azumi *et al.,* 2017). Indeed, Cu appeared to be having the lowest value of micronutrient in all the soils studied though it is the most important micronutrient from the livestock point of view. Brady and Weil (2017) pointed out that factors affecting the soils ability to provide Cu to plants include pH, humus content and proportion of sand to clay.

Iron (Fe)

Generally, the mean soil Fe content across land uses ranged from 2.49 to 5.19mg/kg and were substantially rated high as per Malgwi (2007) rating scale. The high level of Fe obtained in this study were contrary to the earlier reports by Shobayo (2010) who recorded low values for soil Fe content. Soils under rice cultivation is highly significantly ($p<0.01$) higher in mean Fe content compared to other land uses. The findings could be attributed to a higher degree of weathering, and subsequent accumulation of iron in the soils under rice cultivation. Also, environmental conditions such as distinct wetting-drying cycles and associated with alternation among reduction-oxidation provide the best conditions for the pedogenic formation of iron oxides (Parisa *et al*., 2010).

Manganese (Mn)

The mean concentration of manganese (Mn) in soils of the study area ranged from 1.59 to 2.84mg/kg which is rated medium to high as per Malgwi, (2007) rating scale. Salem *et al.,* (2012) earlier reported high Mn soil content, while investigating the content and distribution of micronutrients in soils of the research and Training Farm of Federal College of Horticulture, Dadin kowa Gombe state. One of the main factors that determine Mn availability in soils is pH (Brady and Weil, 2017). According to Harmsen and Vlek (1985) a pH value below 6.0 favors reduction of Mn and the formation of the more available divalent form of manganese (Mn^{+2}).

Table 3: Ranking of means of soil micronutrients across different land uses

	Zn	Cu	Fe	Mn
	→	(Mg/kg)	←	
Land Uses				
Amaranth	1.03b	0.36b	2.49b	1.59c
Millet	0.60b	0.25b	4.76a	2.46ab
Mango	1.47b	0.50b	5.07a	2.84a
Rice	3.48a	1.57a	5.19a	2.68a
Tomato	1.55b	0.40b	4.19a	1.88ab
LSD (p<0.05)	*1.64*	*0.65*	*1.25*	*0.46*
LOS	*	**	**	***

LOS (Level of significant) (P): NS (Not Significant) > 0.05, * < 0.05, ** < 0.01, *** < 0.001, Zn= zinc, Cu= copper, Fe= iron, Mn= manganese
Note: Means followed by the same letters in the column are not significantly different at 5% LOS

The soils under mango and rice cultivations are statistically similar and highly significantly ($p<0.001$) higher in Mn content than soils under millet, tomato and amaranth cultivation. Dan'Azumi, *et al.,* (2017), reported that variation may be caused by pedogenic processes such as weathering, erosion and mass washing of soil materials, and processes that include physical and chemical decomposition, rate of leaching and type of vegetation at the surface.

Conclusion and Recommendations

From the above results, physical and chemical properties of the studied soils had very little differences between the five agricultural areas in which the study was undertaken. The results further indicated that extractable Iron, Zinc, Copper and Manganese were rated high, medium, and medium to high, respectively, in their soil content. It was also observed that differential land management systems had significantly ($p<0.05$) influence the content and distribution of trace elements in the studied soils. The close monitoring of soil pH, Fe, Cu and Mn content is also necessary so as to avoid toxic contamination and nutrient inbalance overtime. Finally, the incorporation of crop residue and addition of organic matter will not only maintain the availability of micronutrients, but at the same time general physical and chemical properties of the soils, which will in turn enhance sustainable crop production.

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