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Assessment of Some Micronutrient (Zn and Cu) Status of Fadama Soils under Cultivation in Bauchi, Nigeria

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Abstract
The status of Zn and Cu of two fadama soils under cultivation at Lushi and Federal Low-cost Housing Estate in Bauchi, Nigeria were determined between February and June, 2012. A total of 30 composite soil samples were collected from 0-15cm, 15-30cm and 30-45cm depths from purposively selected representative locations in the study area and analyzed using standard procedures. Particle size distribution of the soils showed clay loam texture. Soil *pH* was strongly acidic with mean values of 5.36 and 5.59 for Lushi and Federal Low-cost soils, respectively. Low levels of organic carbon (OC), available P, and exchangeable bases were observed. Though, soil content of Zn and Cu were low, values increased significantly ($p<0.05$) with soil depths at both Lushi and Federal Low-cost locations. The low mean values of these micronutrients at both Lushi ($Zn=1.36mgKg^{-1}$; $Cu=0.83mgKg^{-1}$) and Federal Low-cost ($Zn=1.32mgKg^{-1}$; $Cu=0.83mgKg^{-1}$) implied that soil amendments of Zn and Cu and/or application of appropriate quantities of key nutrient elements would enhance their availability for optimum yields of crops for the resource-poor farmer in the study area.
Keywords: Micro nutrients, zinc, copper, fadama soils

1. Introduction

Micronutrients, though required in small quantities, are essential for the growth and development of crops. The availability of these elements in correct amounts and proportions play a vital role in the absorption of other nutrient elements, especially nitrogen, phosphorus and potassium. Micronutrients content of soils depends upon the soil types, parent material, soil *pH*, organic matter, clay content, amount of exchangeable bases and phosphate (Macias, 1972). The availability of micronutrients, especially Zn and Cu, is important for the optimum growth of crops.

Zinc and copper alongside other micronutrients were first recognized as limiting factor in crop production in Florida, United States of America during the late 1920s (Tisdale e*t al.*, 1975). The role of both zinc and copper in plants are associated with the functioning of a number of enzymes. Zinc promotes growth hormones, seed production and starch formation. Copper is important in photosynthesis, protein and carbohydrate metabolism as well as nitrogen fixation (Brady, 1990).

Owonobi *et al.* (1990) consider fadamas to be valleys of streams, rivers and lakes, which are traditionally cropped during the dry season. It is usually a site of busy agricultural activities throughout the year owing to its characteristic residual and underground moisture retention within the rhizosphere for most part of the year and the understanding that they are more fertile than their upland counterparts (Mustapha *et al*., 2005; Singh and Babaji, 1990). According to Davey and Johnston (1956) fadama includes only those depressions found in the heavy clay which are filled by the overflowing of the rivers, drainage or rainfall and which retain water and green vegetation for some time after the rest of the countryside is dry and bare. Their good water holding capacity and proximity to water source (streams and/or underground water) for crop insurance against drought and/or for dry season irrigation are the main factors that have lured farmer to fadama lands (Mustapha and Loks, 2005). In the fadamas, the soils are young and highly productive due to the seasonal flooding, which replenishes the soil with active clay fraction, organic matter and nutrient elements.

Studies on soil micronutrients status in Nigeria, in general, and in Bauchi state, in particular, have suffered considerable neglect (Mustapha, 2003). Most of the soil fertility workers in Nigeria did center their works on nitrogen, phosphorus and potassium (Mustapha, 2007; Sadegh-Zadeh *et al*., 2008; Mustapha *et al*., 2011, Daar *et al*., 2013). It is only of recent that work started in Nigeria, and indeed West Africa, on some micronutrients, especially magnesium and aluminum (Jayaganesh *et al*., 2011).

In Nigeria today, the quest for high food production in order to meet up with the food need of the ever-increasing population has brought about the need to harness the fertility of fadama soils that were hitherto neglected. This is evidenced in the initiation of the National Fadama Development Projects (Fadama I, Fadama II and Fadama III projects) by the Federal Government of Nigeria. The sustainable exploitation of the fadama lands is, however, currently hindered by the lack of site-specific information on these soils (Mustapha and Loks, 2005) thereby rendering them vulnerable to abuse and mismanagement. In order to achieve Nigeria's goal of food sufficiency through the agricultural transformation agenda (ATA), a proper knowledge on the physical and chemical properties of fadama soils, especially of some neglected, but important, micronutrients becomes imperative. Similarly, the continuous cultivation of fadama soils, owing to its better crop production potential informed the likelihood that the soil may be depleted of plant micronutrient elements.

It is against this back drop that this research work seeks to ascertain the fertility of two fadama soils by investigating the status of zinc and copper, with a view to recommending soil amendments to improve the crop yield of the resource poor farmer in the study area.

2. Materials and Methods

2.1 The Study Area

The study was carried out between February and June, 2012 at fadama areas of Lushi and Federal Low-cost housing estate in Bauchi metropolis, northern guinea savanna zone of Nigeria. The area is located between longitudes 9^0 00' and 10^0 30'N and latitudes 9^0 30' and 10^0 30'E. The climate of the area is characterized by high temperature and seasonal rainfall with a maximum temperature of up to about 32^0C and an annual mean rainfall range of between 1000-1250mm. Mustapha *et al*. (2003a) had described the fadama soils of this area as Haplic Plinthaquults.

2.2 *Soil Sampling and Handling*

A total of 30 composite samples were collected according to the pedogenic horizons at the two locations (Lushi and Federal Low-cost fadama areas) and kept in labeled polythene bags for easy identification. The collected samples were air-dried in the laboratory until a constant weight was obtained. The samples were then ground using porcelain pestle and mortar and sieved through a 2mm stainless steel sieve. The fine ground soil samples, collected in separate polythene bags, were used for analyses at the Soil Science Laboratory of the Abubakar Tafawa Balewa University, Bauchi.

2.3 Laboratory Analyses

The processed soil fractions were subjected to laboratory analyses according to the procedure outline by Page *et al*. (1982). Particle size distribution and micro aggregate stability, which involved the determination of the amounts of silt and clay in calgo-dispersed as well as water-dispersed samples using the Bouyoucos hydrometer method of particle size analyses, was done according to the procedure described by Gee and Or (2002). Soil *pH* was determined in water at a 1:1soil to water ratio using glass electrode *pH* meter. Organic carbon was determined using the wet oxidation method (Walkley and Black, 1934). Micro-Kjeldhal digestion method (Juo, 1979) was used to determine total N and available P was extracted by sodium bicarbonate solution (Olsen and Summers, 1982). Exchangeable bases (Ca, Mg, K and Na) were extracted in 1NNH4AC (1 normal ammonium acetate) and Ca and Mg in the extracts were determined using Atomic Absorption Spectrophotometer while K and Na were determined using flame photometer (Thomas, 1982). The CEC was determined by saturating the soil with 1NNH4AC solution, and all the cations displaced into the soil solution were summed up. The available Zn and Cu were extracted using 0.1 MHCL solution and the elements in the soil solution were determined by atomic Absorption Spectrophotometer.

2.4 Data Analyses

The data obtained were analyzed using GenStat Discovery edition 4.2. Significantly different means were separated using the least significant difference (LSD). Simple descriptive statistics including mean and range were also used.

3. Results and Discussion

Particle size distribution and organic matter content of the soil at the study area, Lushi and Federal Low-cost, are presented in Table 1. The particle size distribution of the soils indicated a clay loam texture with the mean value of sand, silt and clay content being 29.0 (range=21.5-37.5), 33.1 (range=24.8-43.2) and 33.2 (range=29.2-37.2), respectively for Lushi soils and 22.3 (range= 19.5-26.3), 25.4 (range=15.5-37.2) and 52.3 (range=43.5-65.2), in that order, for federal Low-cost soils. At both locations, silt content significantly ($p<0.05$) decreases with soil depth. Conversely, the amount of clay increases significantly ($p<0.05$) down the soil profile (Table 1). Mustapha (2007) in an earlier study of fadama soils at five locations reported the predominance of silt in most of the surface soils and the author attributed it to annual deposition through seasonal flooding. The increase in clay down the soil profile may be as a result of the removal of the fraction by surface run-off and also by illuviation (Mustapha *et al*., 2011) which is a common phenomenon in soil in the northern guinea savanna agro-ecology (Voncir *et al.*, 2008). The high silt and clay contents may be due to seasonal flooding which transports and deposits these fine soil fractions, giving these fadamas the characteristic of clay loam domination. This agrees with Davey and Johnston (1956) who described fadamas as depressions with heavy clay.

The organic C content of the soils at the both Lushi and Fedaral Low-cost fadama soil did not differed significantly (P>0.05) with soil depths (Table 1) and ranged from 2.5-3.8 (mean=3.1). The mean values of the organic C were generally low according to the ratings of Esu (1991). Lombin (1983) and Mustapha and Nnalee (2007) reported similar low values of organic C for soils in the guinea savanna zones of Nigeria. Otisi (1996) reported that soils with high accumulation of Ca, Mg and Na salts have low organic matter, and invariably organic carbon.

The chemical properties of the fadama soils at the two study sites (Table 2) showed that soil *pH* ranged from 5.23-6.40 (mean= 5.36) and 4.80-6.49 (mean= 5.59) at the Lushi and Federal Low-cost fadama areas, respectively. Though generally acidic, the *pH* values did not differed significantly (p>0.05) with soil depths at both locations. The higher *pH* reaction (Lushi=5.23; Federal Low-cost=4.80) at the upper part of the profile (0-15cm) at both locations may be attributed to the removal of basic cations from the surface of the soil to lower depths and probably the use of acid-forming fertilizers such as urea (Voncir *et al*., 2008; Mustapha *et al*., 2011).

Mean values for P and Ca (Table 2) did not differed significantly (p>0.05) with soil depths at both Lushi (P=6.45mg Kg^{-1}; Ca=2.26mg Kg^{-1}) and Federal Low-cost (P=6.61mgKg^{-1}; Ca=2.31mgKg^{-1}). According to the ratings of Esu (1991) the P and Ca content of the soils were rated as low and medium, respectively. Mg, K, and Na recorded mean values of 3.65cmol Kg^{-1}, 0.47cmol Kg^{-1}, and 0.28cmol Kg^{-1}, respectively at the Lushi fadama soils; which were also similar to the mean values of Mg (3.36cmol Kg^{-1}), K (0.38cmol Kg^{-1}) and Na (0.26cmol Kg^{-1}) obtained at the Federal Low-cost fadama soils (Table 2). These nutrient elements were rated as high (Esu, 1991). A relatively medium to high contents of K and Mg was reported by Mustapha *et al*. (2011) in a similar study.

Zinc content increased significantly (p<0.05) from the upper part of the soil (0-15cm) down the subsoil (30-45cm) and rated as low (Appendix 1) at both Lushi fadama soils (range=0.52-2.42mg Kg^{-1}; mean=1.36mg Kg^{-1}) and Federal Low-cost fadama soils (range=0.84-2.02mg Kg^{-1}; mean=1.36mg Kg^{-1}) (Table 2). Copper contents of the studied soils were also low and values differed significantly with soil depth. The mean value of Cu were 0.35 mg Kg^{-1} (range=0.52-0.84 mg Kg^{-1}) and 0.83 mg Kg^{-1} (range=0.50-1.28 mg Kg^{-1}) at Lushi and federal Low-cost fadama soils, respectively. Fagbami, *et al.* (1985) reported that clay content is positively related to Zn and Cu availability; that is, Zn and Cu are most abundant where clay is high. Macias (1973) also linked Zn and Cu availability to exchangeable bases.

4. Conclusion

The levels of the micronutrients (Zn and Cu) in the two fadama soils investigated were low. The availability or deficiencies of other nutrient elements in the soil are related to Zn and Cu availability in the soils under study. Soil amendments of Zn and Cu and/or application of recommended quantities of other key nutrient elements would enhance the availability of these micronutrients for optimum yields of crops for the resource-poor farmer in the study area.

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Table 1: Physical Properties and Organic Matter Content of Soils at (a) Lushi Fadama and (b) Federal Low-cost Fadama

Depth(cm)	Sand	Silt	Clay	Organic C	Textural class
(a)	**Lushi**	**Fadama**	**soils**		
0-15	21.5	43.2	33.2	3.0	Clay loam
15-30	37.5	31.2	29.2	2.5	Clay loam
30-45	28.0	24.8	37.2	2.1	Clay loam
Grand Mean	**29.0**	**33.1**	**33.2**	**2.5**	
LSD(p<0.05)	**ns**	**5.26**	**2.85**	**ns**	
(b)	**Federal**	**Low-cost**	**Fadama Soils**		
0-15	19.5	37.2	43.5	3.8	Clay loam
15-30	26.2	23.5	48.2	2.9	Clay loam
30-45	21.2	15.5	65.2	2.5	Clay
Grand Mean	**22.3**	**25.4**	**52.3**	**3.1**	
LSD(p<0.05)	**ns**	**7.52**	**4.32**	**ns**	

Key: CL=clay loam; C =Clay; ns=not significant

Table 2: Chemical Properties of soil at (a) Lushi Fadama and (b) Federal Low-cost Fadama areas

Depth (cm)	pH (1:1)H_20	P ($mgKg^{-1}$)	Ca ($mgKg^{-1}$)	Mg $cmolKg^{-1}$	K $cmolKg^{-1}$	Na $cmolKg^{-1}$	Zn $mgKg^{-1}$	Cu $mgKg^{-1}$
			Lushi	**Fadama**	**Soils**			
0-15	5.23	7.64	2.57	3.84	0.52	0.21	0.52	0.52
15-30	5.44	5.43	2.08	3.60	0.45	0.25	1.14	0.82
30-45	6.40	6.27	2.14	3.51	0.45	0.38	2.42	1.18
Grand Mean	**5.36**	**6.45**	**2.26**	**3.65**	**0.47**	**0.28**	**1.36**	**0.84**
LSD(p<0.05)	ns	ns	ns	ns	ns	ns	0.51	0.35
		Federal	**Low-cost**	**Fadama**	**soils**			
0-15	4.80	6.15	2.35	2.58	0.42	0.25	0.84	0.50
15-30	5.47	5.93	2.54	4.21	0.40	0.21	1.11	0.72
30-45	6.49	7.74	2.05	3.28	0.32	0.31	2.02	1.28
Grand Mean	**5.59**	**6.61**	**2.31**	**3.36**	**0.38**	**0.26**	**1.32**	**0.83**
LSD(p<0.05)	ns	ns	ns	ns	ns	ns	0.54	0.43

ns =not significant

Appendix 1: Ratings for soil fertility classes

Parameter	Very low	Low	Medium	High	Very high	Units
Zn	<1.0	1.0-1.5	1.6-3.0	3.1-5.0	>5.0	Mg Kg^{-1}
Cu	<1.0	1.0-2.0	2.1-4.0	4.1-6.0	>6.0	Mg Kg^{-1}
Fe		<2.5	2.5-5.0	>5.0		mg Kg^{-1}
Mn	<1.0	1.0-2.0	2.1-3.0	3.1-5.0	>50	mg Kg^{-1}
N		<1.5	1.5-2.0	>.2.0		g Kg^{-1}
P		<10	10-20	>20		g Kg^{-1}
K		<0.15	0.15-0.30	>0.30		cmol Kg^{-1}
Ca		<2	2-5	>5		cmol Kg^{-1}
Mg		<0.3	0.3-1.0	>1.0		cmol Kg^{-1}
Na		<0.2	0.2-0.3	>0.3		cmol Kg^{-1}
O.C.		<10	10-15	>15		g Kg^{-1}

Source: Esu (1991)

Appendix 2: Soil Reaction (*pH*) and CEC Ratings

Soil reaction (*pH*)		**Cation Exchangeable Capacity (C E C)**	
Extremely acid	4.5	Very low	<6.0 $cmol.kg^{-1}$
Very strongly acid	4.6-5.0	Low	6.0-11 $cmol.kg^{-1}$
Strongly acid	5.1-5.5	Moderate	12-25 $cmol.kg^{-1}$
Moderately acid	5.6-6.0	High	26-40 $cmol.kg^{-1}$
Slightly acid	6.1-6.5	Very High	>40 $cmol.kg^{-1}$
Neutral	6.6-7.3		
Slightly Alkaline	7.4-7.8		
Moderately Alkaline	7.9-8.4		
Strongly Alkaline	8.5-9.0		
Very strongly Alkaline	> 9.0		

Source: Black (1965)