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ASSESSMENT OF MICRONUTRIENTS STATUS OF SOILS UNDER MILLET CULTIVATION IN GEIDAM LOCAL GOVERNMENT YOBE STATE, NIGERIA

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ABSTRACT

Micronutrients are metallic chemical elements necessary for plant growth in only extremely small amounts. Although required in minute quantities however, micronutrients have the same agronomic importance as macronutrients and play vital roles in the growth of plants. The transformation from the fallow and shifting cultivation practices prevalent among farmers to intensive continuous cultivation of soils and the use of improved crop varieties which take up many nutrients from the soil are major causes of deficiency of these micronutrients. In addition to this, the current fertilizer recommendation for crops in Northern Nigeria is only for macronutrients; continuous application of one or two macronutrients may in due course deplete the soil reserve of other nutrients and limit the crop performance. A total of 26 composite soil samples were collected at 0-15 and 15-30 cm depths from thirteen different, purposively selected representative locations (Guwalturam, Lawal Bukarti, Tororo, Mobanti, Kukawa India, Shaneneri, Abbati, Kori Fadama, Kiri Kasama, Kalgeri, Gonari Kukawa, Kirjin Tilo and Yalemari) in Geidam LGA of Yobe State, Standard laboratory methods were used to determine the physical and chemical properties of the soil samples. The results of the present study have indicated that the soils were generally sandy to loamy in texture, slightly acidic (Mean = 6.55), low in organic carbon and CEC, low in Ca and K; medium in Na and medium to high in mg contents. The total Nitrogen and the available Phosphorus of the studied sites indicated high and low contents respectively. Generally, Cu was found to be in the medium category while Zn was generally low in both zones. However, the soils contained Fe and Mn above the critical limits for crop production and categorized as "high". This might be a potential environmental problem as they may, upon complex reactions, result in the formation of plinthite / petroplinthite leading to hard pan formation; restricting rooting depth and causing infiltration and drainage problem in the soil. It is suggested that supplementary application of Zn will be required for sustainable arable crop production in the soils studied and application of organic matter to improve the overall fertility of the soil and to reduce the possible development of plinthic / petroplinthic layers.

INTRODUCTION

Micronutrients are metallic chemical elements necessary for plant growth in only extremely small amounts. Although required in minute quantities however, micronutrients have the same agronomic importance as macronutrients and play vital roles in the growth of plants (Nazif *et al.*, 2006). These metallic chemical elements include Zinc (Zn), Iron (Fe), Copper (Cu) and Manganese (Mn), amongst others. Most micronutrients are associated with the enzymatic systems of plants. For instance, Zn is known to promote the formation of growth hormones, starch and seed development, Fe is important in chlorophyll formation, Cu in photosynthesis and Mn activates a number of important enzymes and is important in photosynthesis and metabolism (FFTC, 2001). The transformation from the fallow and shifting cultivation practices prevalent among farmers to intensive continuous cultivation of soils and the use of improved crop varieties which take up many nutrients from the soil are major causes of deficiency of these micronutrients. In addition to this, the current fertilizer recommendation for crops in Northern Nigeria is only for macronutrients; continuous application of one or two macronutrients may in due course deplete the soil reserve of other nutrients and limit the crop performance (Oyinyola and Chude, 2010).

Millet (*Pennisetum glaucum*) cultivation is intensively carried out year round in the study area therefore there is incessant uptake of nutrients especially those that are essential for the growth of millets and other arable crops. This continuous uptake of these nutrients may cause the soil to be deficient in certain nutrients which in turn render the soil to be infertile. In view of the aforementioned reasons, this research is aimed at assessing the micronutrient status of soils under millet cultivation in Geidam so as to boost the production and achieve sustainable and judicious utilization of soils.

MATERIAL AND METHODS

The study area

The study was conducted in 2014 in Geidam Local Government Area (LGA), Yobe state. It is situated between latitude 12^0 20^1 N and longitudes 11^0 20^1 E, 289 meters elevation above the sea level and falls within the Sahel savanna agro-ecological zone of Nigeria. Its geomorphology comprises of quaternary deposits of the chad formation made up of consolidated sand and clays. The climate regime is characterized by high temperatures and seasonal rainfall. The mean temperature ranges from 36 to 38 ^{0}C. The rainfall pattern is unimodal, ranging from 250 mm to 500 mm and is characterized by distinct dry (October – May) and rainy (June - September) seasons. The soils are grouped on the basis of parent materials into Aeolian deposits, lacustrine, alluvial deposits, sedentary sandstone (Nwaka, 2012). Vegetation in the Sahel is very scanty consisting of thorny bushes and small trees which grow under dry condition. The largest trees are usually thorny acacias, balanite and adonsonia digitata while the most commonly cultivated crop in the studied area is Millet (*Pennisetum glaucum*)

Soil sampling and handling

A total of 26 composite soil samples were collected at 0-15 and 15-30 cm depths from thirteen different, purposively selected representative locations (Guwalturam, Lawal Bukarti, Tororo, Mobanti, Kukawa India, Shaneneri, Abbati, Kori Fadama, Kiri Kasama, Kalgeri, Gonari Kukawa, Kirjin Tilo and Yalemari) in Geidam LGA of Yobe State, Nigeria. Each soil sample was a composite of five sub-samples. The collected soil samples were properly labeled and stored in polythene bags and taken to the laboratory. In the laboratory, each sample was separately dried in air, ground using porcelain pestle and mortar and passed through a 2 mm mesh sieve. The sieved fine earth fractions were collected in separate bags and used for all laboratory analyses.

Laboratory analyses

Standard laboratory methods were used to determine the physical and chemical properties of the soil samples. Particle size distribution was determined using hydrometer method after dispersing in sodium hexametaphosphate solution as outlined by Anderson and Ingram (1993). The soil pH was determined in 1:1 soil / water suspension using a glass electrode pH meter while Organic carbon in the soil was determined by the wet combustion method of Walkely-Black as outlined by Anderson and Ingram, (1993). Total N was determined by Modified Kjeldahl method as described by Anderson and Ingram, (1993). Available P was determined using Mehlich-3 extraction procedures as described by Anderson and Ingram,

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(1989). Exchangeable bases (Ca, Mg, K and Na) were extracted with 1N Ammonium acetate (NH_4OAC) (Anderson and Ingram, 1993); Ca and Mg were determined using atomic absorption spectrophotometer while K and Na was determined using flame photometer. The extractable micro nutrients: Zn, Cu, Fe and Mn were extracted using 0.1M HCL solution. (Osiname *et.al.*, 1973) and determined on an atomic absorption spectrophotometer (Model 210) at appropriate wave length.

Data analysis

Data obtained were subjected to statistical analysis using the analysis of variance (Harry and Steven, 1995). Means that were significantly different were separated using the Least Significant Difference (L.S.D.) as reported by Steel and Torrie (1985).

Results and Discussion

The particle size distributions of the soils are shown in table 1. The results indicated that the soils have relatively high sand with a mean value of 815.02 g kg^{-1} and a mean clay content of 126.58 g kg^{-1} giving the soils, a generally sandy texture in all the locations and depths. This is expected and further ascertained by Jones and Wild (1975), who reported that most savanna soils are sandy in nature which is associated with low water holding capacity (WHC). Clay content increases with soil depth in all locations. However, sand fraction decreased while silt fraction was irregularly distributed. This might be attributed to removal of the fraction by surface run-off and also by alluviation. Voncir *et. al*., (2008) reported this to be a common phenomenon in soil in this agro-ecology.

Table 1: Particle Size distribution and Texture of some soils in Geidam LGA, Yobe State, Nigeria

	Sand	Silt	Clay	Texture
	←	g kg-^{1}	→	
Location				
Guwalturam	870.40	24.28	105.04	Sandy
Lawal Bukarti	730.40	45.28	170.04	‘’ ‘’
Tororo	800.40	19.56	180.04	‘’ ‘’
Mobanti	780.40	75.56	140.04	‘’ ‘’
Kukawa India	830.40	30.56	105.04	‘’ ‘’
Shaneneri	830.40	55.56	110.04	‘’ ‘’
Abbati	830.40	50.56	115.04	‘’ ‘’
Kori Fadama	825.40	55.56	115.04	‘’ ‘’
Kiri Kasama	770.40	80.56	145.04	‘’ ‘’
Kalgeri	790.40	65.56	140.04	‘’ ‘’
Gonari Kukawa	820.40	70.56	105.04	‘’ ‘’
Kirjin Tilo	845.40	50.56	100.04	‘’ ‘’
Yalemari	870.40	10.56	115.04	‘’ ‘’
Mean	815.02	48.82	126.58	
SE±	23.95	14.06	9.69	
Depth (cm)				
0-15	832.71	38.87	113.12	Sandy
15-30	789.63	62.43	140.04	‘’ ‘’
Mean	811.17	50.65	126.58	
SE±	53.31	26.83	32.19	

Source: Laboratory work, 2014

The chemical reaction of the studied sites showed that, soil pH ranged from 6.22 in Kirjin Tilo to 6.90 in Kori Fadam (Mean = 6.55) indicating slightly acidic reaction (Table 2). Between the depths considered, the pH varied significantly ($P < 0.05$) with a mean value of 6.54. This could be attributed to the removal of basic cations from the surface of the soil to the lower depths (Mustapha and Locks, 2005; Voncir *et. al.*, 2008; Kolo *et. al.*, 2009) and or the use of acid –forming fertilizer such as urea for agricultural purposes.

Results (Table 2) show that the organic carbon (O.C) contents ranged from 2.55 g kg^{-1} in Kiri Kasamma to 4.20 g kg^{-1} in Gonari Kukawa with a mean value 3.46 g kg^{-1}. Significant ($P < 0.05$) differences were observed across surface (0-15 cm) and subsurface (15-30 cm) in all locations; with mean value of 3.48 g kg^{-1} organic carbon content. These values fell within the "low" category (Esu, 1991) of fertility classes for Northern Nigeria Savanna soils. This would suggest that the soils would be prone to leaching of nutrients. Similar low organic carbon values have been reported by Yaro *et .al*. (2006) for the Nigeria savanna soils. Other reports indicated low organic carbon content for soils in the northern guinea savanna zone of Nigeria. (Mustapha and Nnalee, 2007, Mustapha *et. al.*, 2007). The low organic carbon content of the soils is characteristics of the savanna due to partly to rapid decomposition and mineralization of organic matter and to poor management sometimes by burning of crop residues by farmers (Lawal *et. al.*, 2012). Greenland, (1995) attributed decline in soil organic matter content to intensification of agricultural activities through clearing and clean cultivation of soils for annual cropping. Thus, the farmers within the study area need to adopt cultural practices that will encourage the return and incorporation of plant/crop residues in to these soils in order to beef up the soil organic carbon level (Lawal *et. al.*, 2012). The total Nitrogen across the locations and depth ranged from 0.05 – 0.08 g kg^{-1} with a mean value of 0.06 g kg^{-1} (Table 2). These values fell within the "low" category (Esu, 1991) of fertility classes.

Available P contents in the soil ranged from 2.88 -7.11 mg kg^{-1} (mean = 4.22) across the locations and a mean value of 4.62 mg kg^{-1} across the depths considered. These ranges fell within the "low" fertility class (Enweazor et. al., 1990, Esu, 1991).

Table 2: pH, O. C., T/N and Av-P distribution of some soils in Geidam LGA, Yobe State, Nigeria

	pH (H_2O) (1:1)	O. C. ← g kg^{-1}	T/Nitrogen →	Av-P mg kg^{-1}
Locations				
Guwalturam	6.45	3.79	0.05	3.46
Lawal Bukarti	6.65	3.19	0.08	4.24
Tororo	6.70	3.24	0.04	6.99
Mobanti	6.73	2.99	0.05	7.11
Kukawa India	6.55	3.22	0.07	5.97
Shaneneri	6.60	3.95	0.06	3.88
Abbati	6.53	3.25	0.06	5.21
Kori Fadama	6.90	2.95	0.05	4.62
Kiri Kasamma	6.38	2.55	0.05	3.68
Kalgeri	6.59	3.50	0.08	2.88
Gonari Kukawa	6.45	4.20	0.08	4.35
Kirjin Tilo	6.22	4.11	0.06	3.87
Yalemari	6.40	4.02	0.07	3.84

Mean	6.55	3.46	0.06	4.22
SE±	0.08	0.05	0.02	0.40
Depth (cm)				
0-15	6.67a	3.69c	0.35	4.00
15-30	6.40b	3.21c	0.32	5.24
Mean	6.54	3.45	0.34	4.62
SE±	0.43	1.98	0.16	1.40

Source: Laboratory work, 2014

Table 3: Amount of Exchangeable Bases and CEC of some soils in Geidam LGA, Yobe State, Nigeria

	Ca	Mg	K	Na	CEC
	←	Cmol (+) kg^{-1}			→
Location					
Guwalturam	1.06	1.16	0.09	0.21	3.49
Lawal Bukarti	1.00	1.05	0.l1	0.25	3.04
Tororo	1.21	1.00	0.10	0.24	3.94
Mobanti	1.19	0.90	0.11	0.24	3.67
Kukawa India	1.35	1.03	0.13	0.22	3.70
Shaneneri	1.45	0.99	0.12	0.22	3.80
Abbati	1.39	1.07	0.11	0.22	3.48
Kori Fadama	1.29	1.92	0.14	0.23	3.65
Kiri Kasamma	1.16	0.92	0.14	0.23	3.80
Kalgeri	1.15	0.99	0.12	0.22	2.99
Gonari Kukawa	1.14	1.08	0.11	0.19	2.96
Kirjin Tilo	1.16	0.89	0.15	0.25	2.90
Yalemarin	1.02	1.02	0.11	0.19	2.59
Mean	1.19	1.08	0.12	0.22	3.39
SE±	0.24	0.68	0.04	0.02	0.43
Depth (cm)					
0-15	1.29	1.17	0.13	0.21	3.55
15-30	1.09	0.82	0.10	0.21	3.23
Mean	0.19	1.00	0.12	0.21	3.39
SE±	0.18	0.04	0.01	0.01	0.40

Source: Laboratory work, 2014

Across both locations and depths considered, the exchangeable bases were rated low for Ca and K, medium to high for Mg and medium for Na respectively (Esu, 1991). This reflects the low Cation exchange capacity (CEC) of the soils across locations and the depth. This is in line with the findings of Oyinyola and Chude (2010) in Northern Nigeria Savanna.

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Table 4: Critical limits for interpreting levels of soil fertility, Salinity and Sodicity Analytical Parameters

Parameter	**Low**	**Medium**	**High**
Ca^{2+} (cmol $_{(+)}$ kg^{-1})	< 2	2 – 5	> 5
Mg^{2+} (cmol $_{(+)}$ kg^{-1})	< 0.3	0.3 – 1	> 1
K^{+} (cmol $_{(+)}$ kg^{-1})	< 0.15	0.15– 0.3	> 0.3
Na^{2+} (cmol $_{(+)}$ kg^{-1})	< 0.1	0.1 – 0.3	> 0.3
CEC (cmol $_{(+)}$ kg^{-1})	< 6	6 – 12	> 12
Org. C (g kg^{-1})	< 10	10-15	> 15
Total N (g kg^{-1})	< 0.1	0.1 – 0.2	> 0.2
Avail. P (mg kg^{-1})	< 10	10 – 20	> 20
Cu (mg kg^{-1})	< 0.2	0.2 - 2.0	> 2
Zn (mg kg^{-1})	< 0.8	0.81 - 2.0	> 2
Fe (mg kg^{-1})	< 0.2.5	0.2.5 - 5.0	> 5
Mn (mg kg^{-1})	< 1.0	1.1 - 5.0	> 5

Source: Esu (1991)

Adopted from Mustapha *et. al*. (2011) and Adamu *et. al*. (2014)

	pH#	Saline soil*	Sodic soil*
Ultra acid	< 3.5	ECe > 4.0 dS/m^2	ECe < 4.0dS/m^2
Extremely acid	3.5 – 4.4	ESP < 15 %	ESP > 15 %
Very strongly acid	4.5 – 5.0	pH < 8.5	pH > 8.5
Moderately acid	5.5 – 6.0		
Slightly acid	6.1 – 6.5	# = Source: Esu (1991) * = Source: Landon (1991)	

Adopted from Omar, 2011

Cupper (Cu) status. The contents of available Cu ranged from 0.19 mg kg^{-1} in Lawan Bakarti to 0.45 mg kg^{-1} in Gonari Kukawa, with mean value of 0.31 mg kg^{-1} in the studied locations and a mean value of 0.31 mg kg^{-1} across the depth (Table 5). Based on Esu (1991) nutrients fertility ratings (Table 4), the values fell within the "medium" categories. These values are similar to values (mean= 0.36 mg kg^{-1}) obtained by Biwe (2012) in a study conducted in Gubi but, above the values reported by Mustapha and Singh (2003) for soils elsewhere in Galambi, both in Bauchi state; Nigeria in similar agro-ecology. Between the depths considered, Cu varied significantly (P < 0.05). The upper surface (0-15 cm) in all locations contained more Cu than the lower (15-30 cm) surface ranging from 0.28 mg kg^{-1} to 0.34 mg kg^{-1} (mean = 0.31 mg kg^{-1}) and both fell within the "medium" fertility rating (Esu 1991) categories. Thus, it could be predicted that the deficiency of Cu would not occur in these soils in the nearest future. Copper deficiencies are common in sandy soils or soils with high pH (Enwezor *et al.*, 1990). Lombin (1983) had earlier reported that the contents of available Cu in soils of Northern Nigeria savanna are adequate and poses no fertility problem.

Zinc (Zn) status: The contents of available Zn in the locations ranged from 0.72 mg kg^{-1} in Abbati to 1.05 mg kg^{-1} in Lawal Bukarti with a mean value of 0.85 mg kg^{-1}. Based on the critical limits of Esu (1991), all the soils fell in the category of "low" Zn status and would require Zn fertilization for a better crop production except; Lawal Bukarti. Zn distribution in surface (0-15cm) was significantly (P < 0.05) more than the Zn content in subsurface (15-30 cm) and values ranged from 0.06 mg kg^{-1} to 1.03 mg kg^{-1} (mean = 0.55 mg kg^{-1}), falling in

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"low" to "medium" fertility rating (Esu 1991) category. The values obtained in the present study are indeed similar to 0.58 mg kg^{-1} (mean) obtained by Mustapha *et. al.*, (2010) in a study carried out in Gombe, Nigeria. However, as Zn decreases with depths, its implication here is that plants may not have a Zn "store "in the lower surface. Similar decrease with depth was also observed by Singh (1985) and Bassirani *et. al.*, (2011). This is also in line with the findings of Mustapha *et. al.*, (2011) in soils of Gombe, Nigeria.

Iron (Fe) status: The soils are rich in available Fe contents which varied from 2.70 mg kg^{-1} in Abbati to 9.00 mg kg^{-1} in Yalemari with a mean of 5.78 mg kg^{-1} and it falls within the "High" category of Esu (1991) micronutrients fertility rating. These values are below the ones reported by Mustapha *et. al.*, (2010) for soils elsewhere in Gombe state (range = 18.40-21.91 mg kg^{-1}; mean= 19.96 mg kg^{-1}) but similar to Mustapha *et. al.*, (2011) for soils in Akko local government area of Gombe state (range = 5.7 to 14.9 mg kg^{-1}; mean = 10.80 mg kg^{-1}). Between the depths considered, Fe significantly ($P < 0.05$) ranged from 4.05 to 7.47 to mg kg^{-1} with a mean of 5.77 mg kg^{-1}. The high Fe contents in soil (above the critical limits of 2.5 mg kg^{-1} crop production) means that the Fe deficiency is not likely for crops grown on these soils. This is especially so when viewed against the backdrop of reports (Mengel and Geurtzen,1986) that Fe deficiency is very unlikely in acid soils; as it is known to be soluble under relatively acid and reducing conditions (Chestworth, 1991). However the presence of Fe in high concentrations in soils could lead to its precipitation and accumulation and upon complex chemical reactions lead to the formation of Plinthite (Laterite). This upon alternate wetting and drying could irreversibly form hard indurated material (Petroplintite or ironstone) which could restrict root penetration and drainage. This observation is similar to that of Mustapha *et. al.*, (2010).

Manganese (Mn) status: Mn in the studied soils ranged from 5.96 mg kg^{-1} in Mobanti to 13.74 in mg kg^{-1} in Gonari Kukawa (mean = 10.23 mg kg^{-1}). These values are rated "High" according to Esu (1991) fertility rating. This implies that the soils contain sufficient Mn for successful agriculture in the area studied as they are above the critical limits of 1- 4 mg kg^{-1} (Sims and Johnson, 1991) and 1-5 mg kg^{-1} reported by Esu (1991). The values obtained are higher than the 7.89-12.00; means= 9.10 mg kg^{-1} obtained by Mustapha (2003) for the Ustults in Bauchi state, Nigeria. The surface (0-15 cm) soil had less Mn content than the sub surface (15-30 cm) and it ranged from 12.30 to 15.86 mg kg^{-1} with a mean value of 14.08 mg kg^{-1}. Though not significantly different, the high Mn content may not be unconnected to the acidic nature of the soils. These figures suggest that Mn content of the soils is high and cannot be a limiting factor to successful crop production in the area. Although, the high contents of Mn in the soils studied could lead to the formation of complexes, which could lead to serious drainage and infiltration problems (Mustapha *et. al.*, 2011).

Table 5: Distribution of Micronutrients of some soils in Geidam LGA, Yobe State, Nigeria

	Cu	Zn	Fe	Mn
	←	mg kg^{-1}	→	
Location				
Guwalturam	0.20	0.75	4.29	12.14
Lawal Bukarti	0.19	1.05	4.74	8.70
Tororo	0.26	0.97	5.39	7.76
Mobanti	0.31	0.90	5.77	5.96
Kukawa India	0.21	0.82	4.06	10.15
Shaneneri	0.27	0.80	5.52	12.16
Abbati	0.39	0.72	2.70	9.30
Kori Fadama	0.28	0.55	6.26	11.03
Kiri Kasamma	0.40	0.79	6.63	12.03
Kalgeri	0.42	1.02	7.60	7.67
Gonari Kukawa	0.45	0.90	8.00	13.74
Kirjin Tilo	0.41	0.82	5.20	10.50
Yalemari	0.21	0.93	9.00	11.83
Mean	0.31	0.85	5.78	10.23
SE±	0.04	0.03	0.73	2.69
Depth (cm)				
0-15	0.34c	1.03a	7.47c	12.30
15-30	0.28c	0.06b	4.08c	15.86
Mean	0.31	0.55	5.77	14.08
SE±	0.24	0.38	6.80	1.21

Source: Laboratory work, 2014

CONCLUSION AND RECOMMENDATIONS

The results of the present study have indicated that the soils were generally sandy to loamy in texture, slightly acidic (Mean = 6.55), low in organic carbon and CEC, low in Ca and K; medium in Na and medium to high in mg contents. The total Nitrogen and the available Phosphorus of the studied sites indicated high and low contents respectively. Generally, Cu was found to be in the medium category while Zn was generally low in both zones. However, the soils contained Fe and Mn above the critical limits for crop production and categorized as "high". This might be a potential environmental problem as they may, upon complex reactions, result in the formation of plinthite / petroplinthite leading to hard pan formation; restricting rooting depth and causing infiltration and drainage problem in the soil.

In view of the above observations, it is suggested that supplementary application of Zn will be required for sustainable arable crop production in the soils studied and application of organic matter to improve the overall fertility of the soil and to reduce the possible development of plinthic / petroplinthic layers.

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