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Variability of micronutrients status along topographic positions and toxicity potential of soils under rice cultivation in Niger State, Nigeria

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ABSTRACT

Micronutrients are important for good crop performance. There is limited quantitative data on the content and distribution of micronutrients in soils under rice cultivation in Niger state, particularly, on the soils of Baddeggi and Makusidi. To achieve this, soil samples were purposively collected along topographic positions (upper-slope, mid-slope, lower-slope and bottomlands) in the two areas. To assess the distribution of iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu), a total of sixty-four composite samples were collected at 0-15 and 15-30 cm depth and were determined by Atomic Absorption Spectrophotometry. The results revealed that the mean values of available Fe, Mn, Zn and Cu were 182.40, 41.90, 7.90 and 6.50 mg/kg for Baddeggi and 254.30, 275.13, 16.25 and 7.88 mg/kg for Makusidi respectively. The very high Fe and Mn in the study sites may lead to toxicity of these elements. The Cu and Zn were also relatively high, and their deficiencies are unlikely to occur in the study area.

Keywords: Soil; micronutrients; toxicity; rice and production

INTRODUCTION

Micronutrients are trace elements or metallic chemical elements essential for plant growth in extremely small quantities (Brady and Weil, 2010). Although required in small quantities, however, micronutrients have the same agronomic importance as macronutrients and also play vital roles in the growth of plants (Nazif *et al*., 2006, Ukabia *et al*., 2021). Report by Ukabiala *et al.* (2021) shows that most micronutrients play a vital role in association with enzymatic system of plants, for instance Zn is known to promote the formation of growth hormones, starch formation and seed development. Iron is important in chlorophyll formation, Cu and Mn activates a number of important enzymes in photosynthesis and metabolism (EFTC, 2001, Ukabiala *et. al*., 2021) these trace elements

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include Zinc (Zn), Iron (Fe), Copper (Cu), Manganese (Mn), Boron (B) and Molybdenum (Mo). Factors affecting the availability of micronutrients are parent material, soil reaction, soil texture, and soil organic matter (Brady and Weil, 2002). According to Tisdale *et al.* (1995), micronutrients were positively correlated with the fine mineral fractions like clay and silt but had negative relationship with coarser- sand particles. This is because their high retention of moisture induces the diffusion of these elements (Tisdale *et al.*, 1995). Brady and Weil (2010) established that the solubility, availability and plant uptake of micronutrient cations are more under acidic conditions (pH 5.0 to 6.5). Micronutrients play a specific role in the growth and development of plants, and these micronutrients are mainly obtained by the plants from the soil reserve. However, the frequent changes in soil management practices alter micronutrient availability. In order to upturn crop productivity of Niger state soils, there is the need to monitor the micronutrients status of the soils. The only available inherent soil fertility information covering the whole state is obtained from the country's soil fertility map, which was developed by the National Programme for Food Security (Chude *et al.,* 2011a). The objective of this research was to assess micronutrient status of soils under rice cultivation in Niger state along topographic positions and determine their toxicity potentials.

MATERIALS AND METHODS

Study Area

The study area falls under zone-1 and zone-3 as classified by Niger state Agriculture and Mechanization Development Authority (NAMDA) which receives most of its annual rainfall from the range of 1200 mm in the north to about 1600 mm in the south spread between the months of May and October. Mean annual temperature is high throughout, about 32 ºC with peaks in the months of March to June. Niger State covers a total land area of about 8.6 million hectares which represent 9.3% of the total land area of Nigeria, out of which seven million is cultivable (85% of the land) and 82 thousand hectares is irrigable for rice cultivation. The State has 110,000 ha of hydromorphic (fadama) soils equivalent to about 3.5 % of its total land area (Lawal *et al*., 2012a). The state is located in the northern Guinea savanna zone of Nigeria. It lies between Latitudes $8^0\ 0^1$ and $13^0\ 30^1$ N and Longitudes $4^0\ 20^1$ and $8^0\ 40^1$ E situated at elevation of 258.5 m above sea level. Niger State shares common boarders to the North-west with Kebbi state, to the North-east with Kaduna state, to the South with Kogi state and to the South-west with Kwara state. It also shares boarder to the South-east with Abuja (FCT) and Republic of Benin in South-west. The State is characterized by sub-humid tropical climate having distinct rainy and dry seasons (Anonymous, 2011). The natural vegetation in Niger state follows the rainfall pattern and other climatic elements. The vegetation of the State is broadly classified as Northern Guinea savanna with dense population of grasses, shrubs and tree (Anonymous, 2011). Makusidi and Baddeggi areas where the research was carried out are located at elevation of 112 and 98 m above sea level.

Soil Sampling

Soils were purposively sampled from Baddeggi in Katcha local Government Area which had 35 hectares of land and 20 hectares in Makusidi in Wushishi Local Government Area which were under rice cultivation. Soil samples were taken from 0-15 and 15-30 cm depths. Four transects at intervals of 100 m apart were cut along topographic positions of the sites, from which composite soil samples were collected at upper-slope (US), mid-slope (MS), lower-slope (LS) and bottomlands (BL). Each composite sample then consisted of samples taken from the sampling point on transect. In each sampling point, samples were taken from 0-15 and 15-30 cm depths. Thirty-two (32) composite samples were collected, 16 each for 0-15 and 15-30 cm depth, giving a total of 64 composite samples (Table 1).

Table 1: The layout for collection of soil sample at Baddeggi and Makusidi surface and subsurface layers (0-15 cm and 15-30 cm)

BADDEGGI	UPPER-SLOPE	MID-SLOPE	LOWER-SLOPE	BOTTOMLAND
Transect	A	A	A	A
Transect	B	B	B	B
Transect	C	C	C	C
Transect	D	D	D	D
MAKUSIDI				
Transect	A	A	A	A
Transect	B	B	B	B
Transect	C	C	C	C
Transect	D	D	D	D

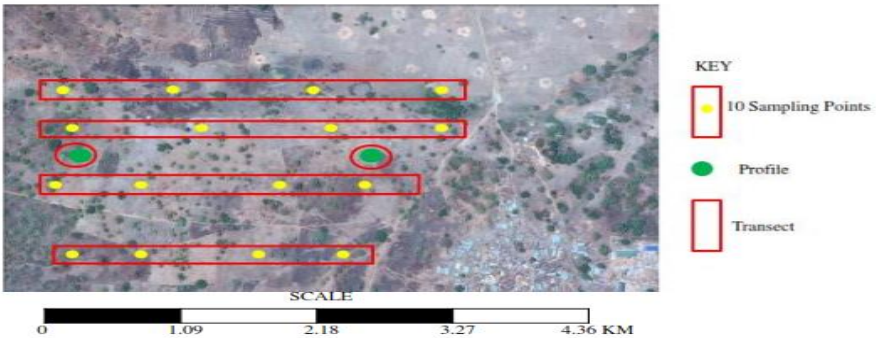

Plate 2: Google Earth View Makusidi Study Site

Soil Sample preparation and analysis

The soil samples were air-dried, gently crushed using a mortar and pestle, and passed through a 2mm-seive to obtain a fine earth separates. Soil analyses were carried out in the laboratory following the procedures outlined by the International Soil Reference and Information Centre and Food and Agriculture Organization (ISRIC/FAO 2002). The available micronutrients iron, manganese, zinc and copper (Fe, Mn, Zn and Cu) were extracted with 0.01 *N* hydrochloric acid (HCl) and the concentrations in the extract were determined using Atomic Absorption Spectrophotometer (AAS).

Classification for Micronutrients in Soils

Table: 2 Critical limits for interpreting micronutrients levels of Nigerian soils

Parameter*	Low	Medium	High
Micronutrients:			
Cu ($mg\ kg^{-1}$)	<0.2	0.2 - 1.0	>1.0
Zn ($mg\ kg^{-1}$)	<0.8	0.8 - 2.0	>2.0
Fe ($mg\ kg^{-1}$)	<4.5	4.5 - 10.0	>10.0
Mn ($mg\ kg^{-1}$)	<5	5 – 10	>10

Source: Esu (1991); The toxicity reference value are >1.0, >2.0, >10.0 and >10 ($mg\ kg^{-1}$) for (Cu, Zn, Fe and Mn) respectively.

Statistical Analysis

The data collected on the soil micronutrient elements were subjected to analysis of variance (ANOVA) using the statistical analysis system (SAS, 2002). The means were separated using Duncan Multiple Range Test (DMRT). Correlation analysis was done to show the relationship between micronutrients and physical and chemical properties of soils.

RESULTS AND DISCUSSION

Effect of Topographic Position and Soil Depth on the Distribution of Available Micronutrients

The results of the effect of topographic position and soil depth on the distribution of available micronutrients are presented in Table 3.

Available Mn was significantly ($P<0.05$) affected by topographic position at Baddeggi, while in Makusidi, topographic position had no significant ($P>0.05$) effect. The effect of topographic position at Baddeggi gave the highest mean value of Mn (71.50 mg/kg) on the bottomland and the lowest value (13.40 mg/kg) on the upper slope.

Table 3: Effect of topographic position, soil depth and toxicity potentials of available micronutrients (Mn, Fe, Cu and Zn) at Baddeggi and Makusidi

Treatment	Mn Baddeggi	Mn Makusidi	Mn Combined	Fe Baddeggi	Fe Makusidi	Fe Combined	Cu Baddeggi	Cu Makusidi	Cu Combined	Zn Baddeggi	Zn Makusidi	Zn Combined
						mg/kg						
Slope (S)												
Upper-Slope	13.40^{b}	275.13	144.30	128.90^{b}	254.30	191.60	3.60	6.83	5.21^{b}	5.70^{b}	16.25	10.95
Mid-Slope	41.90^{ab}	226.63	134.30	181.13^{ab}	237.40	209.30	4.53	6.85	5.70^{ab}	6.53^{ab}	14.53	10.53
Lower-slope	28.00^{ab}	209.38	118.70	174.50^{ab}	253.00	213.80	6.50	7.65	7.06^{a}	7.10^{a}	14.30	10.70
Bottomland	71.50^{a}	198.75	135.13	182.40^{a}	245.13	213.80	4.10	7.88	5.96^{ab}	7.90^{a}	14.10	10.99
SE	17.98	29.50	15.10	18.10	17.80	10.94	1.13	0.70	0.63	0.70	1.70	0.86
Significance	*	Ns	Ns	*	Ns	Ns	Ns	Ns	*	*	Ns	Ns
Depth D(cm)												
0-15	42.00	251.30	146.63	171.70	263.94	217.81	3.99	7.20	5.60	7.10	16.03	11.54
15-30	35.38	203.69	119.53	161.80	230.94	196.34	5.34	7.41	6.40	6.54	13.60	10.04
SE	12.71	20.90	10.70	12.80	12.60	7.73	0.80	0.50	0.5	0.50	1.20	0.61
Significance	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Interaction												
S X D	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

Means followed by the same letter(s) within a treatment column are not significantly different at 5% level of probability using Duncan multiple range test (DMRT), Ns – not significant * - significant ($P< 0.05$).

Table 4: Fertility classes of the micronutrients on the transects (Upper-slope, Mid-slope, Lower-slope and Bottomland) at Baddeggi and Makusidi

Treatment	Mn Baddeggi	Mn Makusidi	Mn Combined	Fe Baddeggi	Fe Makusidi	Fe Combined	Cu Baddeggi	Cu Makusidi	Cu Combined	Zn Baddeggi	Zn Makusidi	Zn Combined
						mg/kg						
Slope (S)												
Upper-Slope	High	High	High	High	High	High	High	High	High	High	High	High
Mid-Slope	High	High	High	High	High	High	High	High	High	High	High	High
Lower-slope	High	High	High	High	High	High	High	High	High	High	High	High
Bottomland	High	High	High	High	High	High	High	High	High	High	High	High
Depth D (cm)	High	High	High	High	High	High	High	High	High	High	High	High
0-15												
15-30	High	High	High	High	High	High	High	High	High	High	High	High
Interaction												
S X D	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns

Ns –not significant at 5%level of significance.

The highest mean value (275.13 mg/kg) on the upper-slope and lowest (198.75 mg/kg) on the bottomland were obtained at Makusidi. The results also indicated that the content of Mn was higher at the surface layer than in the subsurface layer (Table 3). In the combined sample, the highest (144.30 mg/kg) and lowest mean (118.70 mg/kg) were recorded on the upper and lower-slopes respectively. Esu (1991) indicated that the critical limits for Mn were <5 as low, 5-10 as medium and >10 mg/kg as high. From that critical limit ranges, Mn was high in Baddeggi and very high in Makusidi. Similar results were reported by (Atefah 2013 and Kabata Pendias, 2001) of Mn concentration in Argillaceous sediments (400-800 mg/kg) and Sandstones (100-500 mg/kg). Similar study was carried out at Baddeggi by Gbade (1990) and the value of Mn obtained was 2.28 to 20.88 ppm. The result is relatively lower than the one obtained in the current study. this may be due changes as a result of natural weathering processes over time and or addition of Mn containing materials naturally through the agent of wind or water, as due to direct addition of organic materials in the study site.

The content of available Fe was significantly ($P<0.05$) affected by topographic position at Baddeggi but was not significantly affected at Makusidi. However, across all soil depths at Baddeggi and Makusidi. There was no significant difference in the result obtained (Table 3). The result revealed that, the highest (182.40 mg/kg) and lowest mean (128.90 mg/kg) values were recorded on bottomland and upper-slope respectively. However, statistical analysis from Table 3 shows that there was no significant ($P>0.05$) difference in Fe content across the soils of upper-slope, mid-slope, lower-slope and bottomland at Makusidi. The results of Mn and Fe obtained indicated that all the soils of the two studied sites were generally high.

The copper (Cu) content was not significantly affected ($P>0.05$) by topographic position and soil depths at Baddeggi and Makusidi. Cu content at Baddeggi was well above the high critical limit, the highest mean value (6.50 mg/kg) at the mid-slope and the lowest (3.60 mg/kg) at the upper-slope were obtained. At Makusidi, the highest (7.88 mg/kg) and lowest mean (6.83 mg/kg) values were obtained at the bottomland and upper-slope respectively. According to Esu (1991), the critical class limits for Cu were given < 0.2 as low, 0.2-1.0 as medium and >1.0 mg/kg as high. The values of the two studied areas were well above high critical limit indicating sufficient quantity of copper in the soil, which may be attributed to parent materials and accumulation of clay content was on the subsurface layer. This agrees with the findings by Reaves and Berrow (1984) that copper content increased with increase in depth and decreased with increasing sand content. Considering the combined sample, the highest (7.06 mg/kg) and lowest mean value (5.21 mg/kg) were recorded at lower-slope and upper-slopes respectively. The two soil depths had the highest mean (6.40 mg/kg) at the subsurface layer and lowest mean (5.60 mg/kg) value at surface layer. Similar results was also reported by (Atefah 2013 and Kabata Pendias 2001) of Cu concentration in Argillaceous sediments (40-60 mg/kg) and Sandstones (5-30 mg/kg) The values compared favourably to those reported for Nigerian hydromorphic soils and higher than the general values reported for Nigerian soils (Kparmwang *et al*., 1994; Kparmwang *et al*., 2000; Mustapha and Singh, 2003).

The available Zn content was significantly ($P<0.05$) affected by topographic position at Baddeggi but, at Makusidi there was no significant ($P>0.05$) effect. However, soil depth had no significant ($P>0.05$) effect on the available Zn in the study area. Considering the effect of topographic position at Baddeggi, the highest mean value of 7.90 mg/kg was obtained at the bottomland and the lowest mean value of 5.70 mg/kg at the upper-slope. While at Makusidi, the highest (16.25 mg/kg) mean was obtained at the upper-slope and lowest (14.10

mg/kg) at the bottom-slope. In the study area, Zn content followed a decreasing order of concentration: Upper-slope >Middle-slope >Lower-slope >Bottomland. With regards to soil depth, the highest mean value of 7.10 mg/kg was obtained at the soil surface layer (0-15 cm) of Baddeggi. This result corroborate Lawal *et al*. (2012a) who recorded high content of Zn (7.40 mg/kg) on soil surface layer (0-50 cm) in hydromorphic soils derived from sedimentary rocks in the same agroecological zone. Esu (1991) reported the critical limits for Zn: <0.8 mg/kg as low, 0.8-2.0 mg/kg as medium and >2.0 mg/kg as high. In Makusidi, the relatively high values in all the soils may be partly attributed to the relatively high clay content in all the soils. Soils with high clay content have been reported to be rich in Zn (Lombin, 1983b). Availability of zinc is usually enhanced by the pH range of the soil (Lake, 2000; Brady and Weil, 2002). Zinc had been reported to be generally of low mobility in soils (Chesworth, 1991) and has a tendency of being adsorbed on clay size particles (Sims and Johnson, 1991; Alloway, 2008).

CONCLUSION

The findings of the present study revealed that iron (Fe) and manganese (Mn) were very high in the two areas which may lead to toxicity of these elements. Copper (Cu) and zinc (Zn) were also relatively high, and their deficiencies are unlikely to occur in the study area soon. In view of the findings of this study, liming alongside application of organic materials will help in addressing the potential toxicity due high Fe and Mn as well as avoiding the projected deficiency of Cu and Zn in the study sites.

REFERENCES

Alloway, B.J. (2008). *Zinc in Soils and Crop Nutrition*. Second edition, published by IZA and IFA, Brussels, Belgium and Paris, France. 139pp.

Anonymous (2011). Niger State and Its Geology, Ministry of Information and Communication Minna. 9-10 pp.

Atefeh, R.B. (2013). Influence of soil amendments and soil properties on macro and micronutrient availability to microorganisms and plants. PhD. Thesis, Swedish University of Agricultural Science, Uppsaa, Sweden. Pp 61.

Brady, N.C. and R.R. Weil. (2002). *The Nature and Properties of Soils*. 13th ed. Printice-Hall Inc. Upper Saddle River, New Jersy. 960p.

Chaudhari, P.R., D.V. Ahire and D.A. Vidya (2012). Correlation between physico-chemical properties and available nutrients in sandy loam soils of Harid war. *Journal of Chemical, Biological and Physical Sciences*, 2 (3): 1493-1500

Chesworth, W. (1991). *Geochemistry of Nutrients. Micronutrients in Agriculture*. 2nd Edition, Mortredt, J.J., L.M. Shuman and R.M. Welch (Eds). *Soil Science Society of America* Inc. Madison, Wisconsin, U S. A, 427 – 476.

Elbordiny, M.M. and Y. C. El-Dewiny (2008). Effect of some salt affected soil properties on micronutrients availability. *Journal of Applied Science and Research*, 4(11):1569 – 1573.

Esu, I.E. (1991). *Detailed Soil Survey of NIHORT Farm at Bunkure, Kano State, Nigeria*. Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. 72 pp.

Gbade, O. (1990). Characterization and classification of soils of the farmland opposite National Cereals Research Institute's Headquarters Badeggi, Bida. p96.

Ibrahim, A.K., A. Usman, B. Abubakar and H.U. Aminu (2011). Extractable micronutrient status in relation to other soil properties in Billiri Local Government Area. *Journal of Soil and Environmental Management*, 3 (10): 282-285.

ISRIC/FAO (2002). Procedures for Soil Analysis**.** Sixth edition L.P. van Reeuwijk (ed.). International Soil Reference and Information Centre/Food and Agricultural Organis ation.119 pp.

Iyaka, Y.A. and S.E. Kakulu (2009). Copper and zinc contents in urban agricultural soils of Niger State, Nigeria. *An International Multi-Disciplinary Journal,* 3 (3): 23-33.

Kabata-Pendias, A. and H. Pendias (1989). *Trace Elements in Soils and Plants.* CRC press, Boca Raton, FL.

Kparmwang T., I. E. Esu and V.O. Chude (1994). Properties, classification and agricultural potential of basaltic soils in semi-arid Nigeria. *Journal of Arid Environments*, 38: 117-128.

Kparmwang, T. and W.B. Malgwi (1997). Some available micronutrients in profiles of Ultisols and Entisols developed from sandstone in north-west Nigeria. *In*: B.R. Singh (ed.) *Management of Marginal Land in Nigeria.* Proceedings of the Soil Science Society of Nigeria. Usmanu Danfodiyo University, Sokoto. pp 245-255.

Kparmwang, T., V.O. Chude, B.A. Raji and A.C. Odunze (2000). Extractable micronutrients in some soils developed on sandstone and shale in Benue Valley, Nigeria. *Nigerian Journal of Soil Research*, 1: 42-48.

Lake, B. (2000). Understanding Soil pH. Leaflet No. 2. Yanco Agricultural Institute, New South Wales. 4pp.

Lawal, B. A., M.K.A. Adeboye, P.A. Tsado, M.I.S. Ezenwa, and O. Bayode (2012a). Extractable zinc and copper in hydromorphic soils developed on basement complex rocks and sedimentary rocks in Niger State, Nigeria. *Savannah Journal of Agriculture,* 7(1): 130-136.

Mustapha, S. and A.S. Fagam (2007). Influence of parent material on the contents and distribution of B and Zn in upland soils of Bauchi State, Nigeria. *International Journal of Environmental Science and Technology*, 4(3): 359 - 362.

Mustapha, S. and B.R. Singh (2003). Available Zinc, Copper, Iron and Manganese Status of the Basement Complex rock-derived Ultisols in Bauchi State A case study. *Nigeria Journal of Soil Research*, 4: 35-40.

Nazif, W., P. Sajida and I. Saleem (2006). Status of micronutrients in soils of districts Bhimber (Azad Jammu and Kashmir). *Journal of Agriculture and Biological Science*, 1(2): 35 - 40.

Patiram, R., C. Upadhyaya, C. S. Singh, R. Munna and M. Ram (2000). Micronutrient Cation Status of Mandarin (*Citrus reticulate* Blanco) Orchard of Sikkim. *Journal of Indian Society of Science*, 48(2): 246 – 249.

Saddiq A. M., D. T. Gungula, S. Mustapha and A. M. Chiroma (2008). Mironutrient status in some soils of selected Local Government Areas of Adamawa state, Nigeria. *Soil and Water Resources Management for Sustainable Environment and Economic Empowerment*. In: Singh, L., B. H. Usman, A. M. Saddiq, H. Musa and S. O Ojeniyi (eds) Proceeding of the 32 Annual Conference of Soil Science Society of Nigeria, held at Federal University of Technology, Yola, March 10th-14th 2008, Nigeria. 196-214 pp.

Samndi, M. A, B. A. Raji and T. Kparmwang (2007). Long-term effects of exotic tree species (*Tectona grandis* Linn. F) on the status of extractable micronutrients in the Southern

Guinea Savanna of Nigeria. *Nigeria Journal of Soil and Environmental Research,* 7: 15 – 22.

Sharma, S.S., K.L. Totawat and R.L. Shyampura (1996). Characterization and classification of soils of toposequence over basaltic tarrain. *Journal of Indian Society of Soil Sci*ence, (45): 480-485.

Tisdale, S.L., W.L. Nelson, J.D. Beaton and J.L. Havlin (1995). *Soil Fertility and Fertilizer,* 5th Ed. Prentice-Hall of India, New Delhi. 684p.

Ukabiala, M.E., Uzoh I.M, Kolo J., Ezeaku P.I. and Akamigbo F.O.R (2005). Variability of micronutrient status and hazard potentials in soils of six mapping units within Eastern part of Kogi state, Nigeria. *Nigeria Journal of Soil Science*, 31(2): 55 – 63.

Verma, V.K., R.K. Setia, P.L. Sharma, S. Charanjit and A. Kumar (2005). Pedospheric variations in distribution of DPTA - extractable micronutrients in soils developed on different physiographic units in central parts of Punjab, *Indian International Journal of Agriculture and Biology*, 7(2): 243 – 246.