

RELATIONSHIP BETWEEN AVAILABLE ZINC AND OTHER SOIL PROPERTIES OF TEACHING AND RESEARCH FARM OF MODIBBO ADAMA UNIVERSITY, YOLA, NORTH EAST NIGERIA

^{*1}Bapetel, U., ²M. L. Bubarai, ¹Tahir A. M., and ³Abdulkadir, N. A.

¹Soil Science Department, Modibbo Adama University, Yola, Adamawa State, Nigeria

²Department of Soil Science and Agricultural Chemistry Samhiggin Bottom University of
Agriculture Science and Technology Prayagraj, India

³Soil Science Department, Kano University of Science and Technology, Wudil, Kano State,
Nigeria

Corresponding Author's email address: usmanubapetel@mautech.edu.ng,

Received 12th August, 2021 Accepted 18th October, 2021

ABSTRACT

A study was conducted to assess the status of available zinc in soil of Teaching and Research Farm, Modibbo Adama University, Yola North East, Nigeria. Ten soil samples were collected from 0 – 20 and 20 – 50 cm depths to reflect the soil of the study area. The soils were analysed following standard laboratory procedures. Result obtained showed that the soils were sandy loam to sandy clay loam, slightly acidic (mean = 6.4 – surface; 6.5 – subsurface soils), very low OC content (mean = 0.35 % – surface; 0.27 % – subsurface soils), low to medium Total N and exchangeable bases. Zinc was generally low to medium (range = 0.18 – 1.71; mean = 1.12 % in surface soils, and range = 0.32 – 2.71; mean = 1.35 % in subsurface soils). Zinc is not correlated with most of the soil properties in both soil depths. In surface soil, a positively correlation with potassium ($r = 0.702^*$) was observed and negative correlation with Total N ($r = -0.634^*$) in subsurface soils. It is recommended that for successful and profitable crop production, application of inorganic fertilizers plus zinc and organic material should be encouraged.

Key words: Zinc, surface soil, subsurface soil, soil properties

INTRODUCTION

Zinc is a metallic micronutrient element that is necessary for plant growth and it is required in extremely small quantity. Even though zinc is required in minute quantity, it has the same agronomic importance as macronutrients and play vital roles in growth of plants (Nazif *et al.*, 2006). Zinc increases yield of crops, functions as an enzyme activator in carbohydrate metabolism and protein formation (Schulte, 2004), plays an important role in auxin production; assist in the utilization of phosphorus and nitrogen in plants; involved in biosynthesis of indole acetic acid (IAA) and tryptophane (Alam and Raza, 2001; FFD, 2002). Studies carried out so far have revealed zinc deficiency in some Nigerian savanna soils (Lombin, 1983). Low level of available Zn was reported by Mustapha *et al.* (2011). On a global study Sillanpaa (1982) reported generally low

to deficient levels of Zn in a number of soils from Nigeria.

In Nigeria with the increasing human and animal population, and policy of the Government to increase food production, farmers have abandoned the traditional practice of shifting cultivation to modern form of agriculture which involved use of high yielding crop varieties that take up many nutrients from the soil and cause deficiency of micronutrients. Similarly, 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 (Oyinlola and Chude, 2010). Therefore, for a successful implementation of scientific agricultural, assessing of nutrient status of the soil including zinc is necessary, hence this study was taken with the following objectives:

(1) To determine the contents of available Zn in the soils, and (2) To investigate the relationship between zinc and soil properties

MATERIALS AND METHODS

Study Area

The study was carried out in Teaching and Research Farm, Modibbo Adama University, Yola North East, Nigeria. It is located on latitude 9°14'N and longitude 12°38' E at an altitude of 158.8 m above sea level. It falls within Northern Guinea Savannah zone that is characterised by high grass land with many shrubs and few trees, it has a distinct wet and dry seasons. Average annual rainfall is 958 mm which is characterised by one peak period usually attained in August. The relative humidity is very low between January and March (20 – 30 %), but with the onset of rainfall in April it starts to increase up to a peak of 80 % in August and September (Musa, 2006).. The temperature is high throughout the year, in dry season the mean daily temperature is about 39.7°C in April, the minimum temperature could go down as low as 15.2°C in January (Adebayo and Tukur, 1999). Soil types of the area are mainly Alfisols and Inceptisols with slightly acidic to neutral in soil pH, low organic carbon, total N, available P, CEC, and low to medium percentage base saturation (Musa, 2006).

Soil Sampling

Sampling locations were selected to reflect the soil of the study area, Random soil sampling method was used to collect ten soil samples in both surface (0 – 20) and subsurface (20 – 50 cm) soil depths. Soil auger was used to collect soil samples from each of the sampling point. The soil samples collected were properly labelled and stored in new plastic polythene bags and taken to the laboratory. Each sample was separately dried in air inside the laboratory and the ground using porcelain pestle and mortar, sieved with 2 mm sieve and the fine soil fraction was used for laboratory analysis

Laboratory Analysis

The soil samples were analysed for some physical and chemical properties of soil including zinc using standard laboratory procedures. Particle size analysis was determined using the Bouyoucous hydrometer method (Gee and Bauder, 1986). Soil pH was

measured in 1:2.5 soil/water suspension using glass electrode pH meter. Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black (Nelson and Sommers, 1982). Total nitrogen was determined by Micro-kjeldah digestion technique method (Bremner, 1996). Available P was determined by Bray 1 method (Bray and Kurtz, 1945). Exchangeable bases were extracted by the neutral ammonium acetate procedure buffered at pH 7.0 (Grant, 1982). The amount of K and Na in the extract were determined using flame photometer with appropriate filters while Mg and Ca were determined by EDTA titrimetric method, exchangeable acidity (Al + H) was determined using 1N KCl method (Grant, 1982). Effective CEC was the summation of total exchangeable bases (CEC) and total exchangeable acid. Available zinc was extracted with 0.01M HCl solution (Osiname *et al.*, 1973) and determined on atomic absorption spectrophotometer (AAS) model BGP – 210 Buck Scientific at wavelength of 213.9nm

Statistical Analysis

Data obtained were subjected to simple descriptive statistic including minimum, maximum, and mean, of some of the physical and chemical properties of soil. SAS Statistics software package Version 9.4 was used to analyze the correlation between zinc and physical and chemical properties of soil

RESULTS AND DISCUSSION

Results of some physical properties of soils studied are presented in Table 1. Particle size distribution of the soils indicated that the textural class ranged from sandy loam to sandy clay loam. Sand ranged from 55.4 to 80.2 %. Silt ranged from 6.0 to 17.4 %, while clay ranged from 18.3 to 28.7 %. The soils have relatively high sand (mean = 68.5 %) in surface soils while clay was relatively high (mean = 19.8 %) in subsurface soil. Sand content decreased with soil depth while silt and clay content increased with soil depth. Malgwi *et al.* (2000) reported that in Northern Nigeria the dominance of sand is as a result of sorting of materials by clay eluviations. The increase with depth in clay may be as a result of removal of the fraction by surface run-off and also by illuviation (Voncir *et al.*, 2008).

The soils are slightly acidic, the pH in water ranged from 6.0 to 6.9 with a mean of 6.4

in surface soil (Table 2), while in subsurface soil, the pH ranged from 5.9 to 6.8 with a mean of 6.5 (Table 3). Earlier studies by Zata *et al.* (2005), also reported a slightly acidic pH values in the same environment.

The electrical conductivity ranged from 0.05 to 0.22 dSm⁻¹ in surface soil (Table 2) and 0.07 to 0.17 dSm⁻¹ in subsurface soils (Table 3). There was no regular trend with change in soil depth. The soils are non saline (< 4.0 dSm⁻¹), which implies that the dissolved salts are low and pose no danger to the growing crops.

The organic carbon (OC) contents ranged from 0.19 to 0.60 % with a mean of 0.35 % in surface soil, while in subsurface soil, OC ranged from 0.17 to 0.35 % with a mean of 0.27 %, these values of OC fell within the very low to low fertility classes for Northern Nigerian savanna soils. Earlier, Kparamwang *et al.* (2001), pointed out that the low OC content in soil could be partly attributed to rapid mineralization of organic matter due to high temperature in the tropical environment, and to annual bush burning. The low OC content in the soil also suggest that the soils would be prone to leaching of nutrients (Oyinlola and Chude, 2010).

The total N contents of the soils vary from 0.08 – 0.14 % in surface, and from 0.08 – 0.12 % in subsurface soil depth with a corresponding mean of 0.11 and 0.12 % respectively, indicating total N varies from low to moderately low fertility class. Isa (2017) also reported low total N content in the area with mean total N content of 0.07 % in both surface and subsurface soils. The very low N content recorded in the soil could be attributed to continuous cropping and land use intensity. Similarly, the low level of nitrogen content could be attributed to the low level of organic carbon content of the soil (Zata *et al.* 2005).

Available P contents in the soils vary from 5.6 – 42.0 mg kg⁻¹ in surface soil and from 6.0 – 19.0 mg kg⁻¹ in subsurface soil. Oyinlola and Chude (2010) also reported available P content in Northern Nigeria savannah soil which ranged from 3.9 to 19.0 mg kg⁻¹. Result from this study indicated low to medium available P fertility classes (Enwezor *et al.*, 1990). Musa (2006) also reported low available P content in the same area, similarly Bapetel *et al.* (2021) also reported low OC, total N and Available P in soils elsewhere in Yola.

The values of exchangeable Ca, Mg, K, and Na in surface soils ranged from 6.0 – 9.6;

0.75 – 4.20; 0.36 – 0.61; and 0.10 – 0.19 cmol kg⁻¹ respectively, while in subsurface soil values of exchangeable Ca, Mg, K, and Na ranged from 5.5 – 8.6; 0.65 – 3.30; 0.32 – 0.56; and 0.11 – 0.18 cmol kg⁻¹ respectively. The values of exchangeable cations Ca²⁺, Mg²⁺, and K⁺ are moderate, while Na⁺ was low in both soil depths. The principal saturating cations in both the soil depths is Ca²⁺, followed by Mg²⁺.

The mean CEC in both surface and subsurface soil is 10.56 and 9.31 cmol kg⁻¹ respectively. In surface soils, 100 % of soils have low CEC, while only 10% of soils in subsurface depth have moderate CEC level. Similarly, the mean ECEC in both surface and subsurface soil is 10.85 and 9.63 cmol kg⁻¹ respectively. Both CEC and ECEC were low. The low CEC values could be due to the inherently low fertility of the soil. Similar low CEC and ECEC were also reported by Wapa *et al.* (2013).

Zinc Status

The available Zn content ranged from 0.18 to 1.71 mg kg⁻¹ with a mean of 1.12 mg kg⁻¹ in surface soil (Table 2), while in subsurface soil available Zn ranged from 0.32 to 2.71 mg kg⁻¹ with a mean of 1.35 mg kg⁻¹, indicating low to medium content of zinc in both soil depths. The low zinc content was also reported by Isa (2017) and Mustapha *et. el.* (2011). In surface soils, 20 % of soils have low level of available Zn, while only 10% of soils in subsurface depth have low level of available zinc. This indicates that some of the soils in the study area were moderate in available zinc as the values were above the critical limit of 0.80 mg kg⁻¹ reported by Esu (1991).

Relationship between Extractable Zinc and other Soil Properties

The relationship between available zinc and some soil properties is presented in Table 4. The primary factors affecting zinc availability in soil are soil pH, clay particles, phosphorus, organic matter content, (Schulte, 2004). In surface soil zinc showed no significant relationship with soil pH, clay, OC, Total N, available P, and CEC, this may be related to the low level of available Zn in the soil. The non-significant correlation between Zn and pH indicated pH did not significantly influence Zn availability in these soils. However, Zn correlated positively with potassium ($r = 0.702^*$) (Table 4) in the surface

soil. Oyinola and Chude (2010) also reported a non-significant correlation between zinc and pH, O.C, and ECEC, but significantly correlated with sand, silt, clay, total N and available P. Earlier, Kparamwang *et al.* (2000) also reported a positive correlation of Zn with organic carbon. Bapetel (2015) also reported a significant and positive correlation between available Zn and organic carbon, thus as organic carbon (organic matter) increased there

would be increase in Zn this could be because of organic matter decomposition which would improve available Zn status. In subsurface soil, zinc showed no significant correlation with soil pH, clay, OC, available P, and CEC, and correlated negatively with Total N ($r = -0.634^*$), this is contrary to the to the result of Oyinola and Chude (2010) and Bapetel (2015) who reported a positive correlation between zinc and total Nitrogen.

Table 1: Physical Properties of the Study Area

Sample	Surface soil (0 – 20 cm)				Subsurface soil (20 – 50 cm)			
	Sand %	Silt %	Clay %	TC	Sand %	Silt %	Clay %	TC
1	80.2	7.5	12.3	SL	72.8	11.4	15.8	SL
2	78.0	9.5	12.5	SL	70.8	10.8	18.4	SL
3	68.1	13.0	18.9	SL	64.4	15.2	20.4	SCL
4	66.5	14.2	19.3	SL	64.1	14.3	21.6	SCL
5	68.0	13.0	19.0	SL	65.2	14.4	20.4	SCL
6	79.8	6.0	14.2	SL	76.1	6.5	17.4	SL
7	68.7	14.0	17.3	SL	64.9	14.5	20.6	SCL
8	55.4	17.4	27.2	SCL	58.3	13.3	28.4	SCL
9	58.2	14.6	27.2	SCL	60.2	13.2	26.6	SCL
10	63.2	8.1	28.7	SCL	61.1	11.3	27.6	SCL
Min	55.4	6.0	12.3		58.3	6.5	15.8	
Max	80.2	17.4	28.7		76.1	15.2	28.4	
Mean	68.5	11.7	19.8		66.0	12.2	21.8	

TC = Textural class, LS = Loamy Sand, SCL = Sandy clay loam

Table 2: Chemical Properties of surface (0 – 20 cm) soil of the study Area

	pH	EC	O.C	TN	Av P	Ca	Mg	K	Na	CEC	TEA	ECEC	Zn
Sample	1:2.5	dSm ⁻¹	%	%	mg kg ⁻¹		←		cmol (+) kg ⁻¹	→			mg/kg
1	6.6	0.06	0.43	0.09	9.8	9.6	1.20	0.41	0.10	11.31	0.40	11.71	1.35
2	6.5	0.10	0.25	0.12	22.4	7.2	0.75	0.55	0.17	8.67	0.30	8.97	1.33
3	6.1	0.05	0.27	0.08	5.6	8.6	1.00	0.40	0.14	10.14	0.20	10.34	0.78
4	6.3	0.11	0.19	0.11	42.0	6.0	3.00	0.45	0.18	9.63	0.20	9.83	1.32
5	6.0	0.07	0.60	0.10	20.0	9.2	1.00	0.60	0.16	10.96	0.20	11.16	1.18
6	6.9	0.20	0.34	0.09	16.1	8.4	4.20	0.44	0.19	13.23	0.40	13.63	1.07
7	6.2	0.22	0.49	0.13	9.1	8.0	3.25	0.36	0.16	11.77	0.30	12.07	0.18
8	6.6	0.13	0.25	0.14	14.0	6.8	0.80	0.61	0.15	8.36	0.20	8.56	1.68
9	6.9	0.14	0.34	0.09	7.0	9.6	0.85	0.52	0.19	11.16	0.40	11.56	1.71
10	6.3	0.18	0.30	0.11	14.0	8.4	1.00	0.42	0.12	9.94	0.20	10.14	0.96
Min	6.0	0.05	0.19	0.08	5.6	6.0	0.75	0.36	0.10	8.36	0.20	8.56	0.18
Max	6.9	0.22	0.60	0.14	42.0	9.6	4.20	0.61	0.19	13.23	0.40	13.63	1.71
Mean	6.4	0.13	0.35	0.11	17.3	8.1	1.83	0.48	0.15	10.56	0.28	10.85	1.12

EC = electrical conductivity, O.C = organic carbon, TN = Total Nitrogen, Av.P = Available Phosphorus,
CEC = cation exchange capacity, TEA = Total exchangeable acidity, ECEC = Effective cation exchange capacity, Zn = Zinc

Table 3: Chemical Properties of subsurface (20 – 50 cm) soil of the study Area

	pH	EC	O C	TN	Av P	Ca	Mg	K	Na	TEB	TEA	ECEC	Zn
Sample	1:2.5	dSm ⁻¹	%	%	mg kg ⁻¹		←		cmol (+) kg ⁻¹	→			mg kg ⁻¹
1	5.9	0.09	0.34	0.08	8.0	7.0	1.16	0.40	0.12	8.68	0.30	8.98	2.14
2	6.8	0.10	0.27	0.10	18.2	6.7	0.65	0.45	0.15	7.95	0.40	8.35	1.29
3	6.7	0.08	0.20	0.08	6.0	7.3	1.01	0.41	0.15	8.87	0.20	9.07	2.71
4	6.5	0.14	0.17	0.10	19.0	5.5	2.30	0.42	0.17	8.39	0.40	8.79	1.29
5	6.1	0.07	0.35	0.12	15.2	7.1	1.00	0.53	0.16	8.79	0.30	9.09	1.17
6	6.5	0.15	0.30	0.09	13.3	8.1	3.30	0.41	0.18	11.99	0.40	12.39	1.35
7	6.8	0.11	0.34	0.11	8.5	6.8	3.20	0.32	0.18	10.50	0.20	10.70	0.32
8	6.7	0.13	0.24	0.12	11.0	6.1	0.75	0.56	0.17	7.58	0.40	7.98	1.25
9	6.1	0.17	0.30	0.10	8.0	8.6	0.80	0.41	0.18	9.99	0.20	10.19	0.39
10	6.7	0.14	0.25	0.09	11.0	8.0	0.95	0.38	0.11	9.44	0.20	9.64	1.28
Min	5.9	0.07	0.17	0.08	6.0	5.5	0.65	0.32	0.11	7.58	0.20	7.98	0.32
Max	6.8	0.17	0.35	0.12	19.0	8.6	3.30	0.56	0.18	11.99	0.40	12.39	2.71
Mean	6.5	0.12	0.27	0.10	11.9	7.1	1.59	0.43	0.16	9.31	0.30	9.63	1.35

EC = electrical conductivity, O.C = organic carbon, TN = Total Nitrogen, Av.P = Available Phosphorus,
CEC = cation exchange capacity, TEA = Total exchangeable acidity, ECEC = Effective cation exchange capacity, Zn = Zinc

Table 4: Correlation analysis (r) between Zinc and soil properties

Surface (0 – 20 cm) soil		Subsurface (20 – 50 cm) soil	
Soil property	'r' value	Soil property	'r' value
Sand (%)	0.258	Sand (%)	0.299
Silt (%)	0.153	Silt (%)	0.017
Clay (%)	0.260	Clay (%)	0.382
pH	0.550	pH	0.054
EC (dS m ⁻¹)	0.382	EC (dS m ⁻¹)	0.524
O.C (%)	0.345	OC (%)	-0.366
TN (%)	0.054	TN (%)	-0.634*
Av P (mg kg ⁻¹)	0.216	Av P (mg kg ⁻¹)	-0.180
Ca (cmol (+) kg ⁻¹)	0.043	Ca (cmol (+) kg ⁻¹)	-0.130
Mg (cmol (+) kg ⁻¹)	0.455	Mg (cmol (+) kg ⁻¹)	-0.277
K (cmol (+) kg ⁻¹)	0.702*	K (cmol (+) kg ⁻¹)	0.194
Na (cmol (+) kg ⁻¹)	0.147	Na (cmol (+) kg ⁻¹)	0.525
CEC (cmol (+) kg ⁻¹)	0.383	TEB (cmol (+) kg ⁻¹)	-0.312
TEA (cmol (+) kg ⁻¹)	0.141	TEA (cmol (+) kg ⁻¹)	0.080

EC = electrical conductivity, O.C = organic carbon, Av.P = Available Phosphorus,

TN = Total Nitrogen, CEC = cation exchange capacity, TEA = Total exchangeable acidity, Zn = Zinc. * = significant at 5%

CONCLUSION

Results from present study indicate that the soils were generally sandy clay to sandy clay loam in texture, slightly acidic and low in organic carbon, Total N and low to medium in exchangeable bases and available zinc content. It could be recommended that application of inorganic fertilizers plus zinc and organic material should be encourage improving the fertility status of the soil.

ACKNOWLEDGEMENTS

We wish to thank the technical and laboratory staff of Soil Science Department, Modibbo Adama University Yola, for Laboratory work

REFERENCES

- Adebayo, A. A., and A. L. Tukur (1999). Adamawa start in Maps. Paraclete Pub Yola, Nigeria
- Alam, S.M., and S. Raza. 2001. Micronutrient Fertilizers. *Pakistan Journal of Biological Sciences*. 4(11): 1446 – 1450.
- Bapetel, U (2015). Influence of Phosphorus, Zinc and Copper Application on Their Uptake By Maize (*Zea Mays* L.) In Maiduguri, Nigeria. Unpublished Ph.D Thesis, Faculty of Agriculture University of Maiduguri, Borno State, Nigeria
- Bapetel, U., Isa, S. S., Tahir A. M., and Abdulkadir, N. A. (2021). Assessment of Fertility Status of Soil of Geriyo Irrigation Project, Adamawa State, Nigeria. *Nigerian Journal of Tropical Agriculture*. 21: 102 – 111
- Bray, R. H., and A. Kurtz (1945). Determination of Total, Organic, and Available forms of Phosphorus in soil. *Soil Science*. 59: 39 – 45
- Bremner, J.M. (1996). Total Nitrogen. Sparks, D.L. (ed) Methods of Soil analysis: Parts, Chemical Methods. 2nd ed, SSSA book series No. 5, SSSA, Madison, WI, 1085 – 1125
- Enwezor, W.O., Udo, E.J. Ayotade, K.A. Adepetu, J.A., Chude, V.O. (eds.) (1990). A review of soil and fertilizer use in Nigeria. In FPDD. Literature review on soil fertility investigations in Nigeria (Five Volumes). Federal Ministry of Agriculture and Natural Resources, Lagos. 281 pp.
- Esu, I.E., (1991). Detailed soil survey of NIHORT farm at Bunkure, Kano State, Nigeria. Institute of Agricultural Research, Zaria. 72pp
- E.Y. Oyinlola, and V.O. Chude. (2010). Status of Available Micronutrients of the Basement Complex Rock – Derived Alfisols in Northern Nigeria Savannah. *Tropical and Subtropical Agroecosystems*. 12: 229 – 237
- FFD (Federal Fertilizer Department). (2012). Fertilizer Use and Management Practices for Crops in Nigeria. 4rd Ed. Pp 57 – 63. FFD/FMARD, Abuja, Nigeria.
- Gee, G.W., and J.W. Bauder. (1986). Particle Size Analysis. In: A. Klute (ed). Methods of Soil Analysis. Part 1. 2nd Ed. Pp 383-411. Agronomy Monograph 9. American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin.

- Grant, W.T. (1982). Exchangeable Cations and Exchangeable Acidity. In: Page, A.L. (eds). Methods of Soils Analysis Part 2. Chemical and Microbiological Properties. 2nd Ed. Agronomy Monograph 9. American Society of Agronomy and Soil Science Society of America, Madison, Wisconsin, USA
- Isa, S. S. (2017). The Fertility Assessment of Geriyo Floodplain Soils of Yola North Local Government Area, Adamawa State Nigeria. Unpublished B.Tech Project, Faculty of Agriculture, Modibbo Adama University, Yola. 31p.
- Kparmwang, V. O. Chude, B. A. Raji, and A. C. Odunze. (2000). Extractable micronutrients in some soils developed on sandstone and shale in the Benue valley, Nigeria. *Nigerian Journal of Soil Research*. 1: 42 – 48
- Kparmwang T., B. A. Raji., A. C. Odunze, and V. O. Chude. (2001). Properties, classification and agricultural potentials of Ustults and Tropepts on a sedimentary toposequence in the Benue. *Nigerian Journal of Soil Research*. 2: 58 – 65
- Lombin, G. (1983). Evaluating the micronutrients fertility of Nigeria's semi-arid savanna soils. II Zinc. *Soil Science* 136: 42 – 47
- Malgwi, W. D., A. G. Ojanuga, V. O. Chude, T. Kparmwang and B. A. Raji. (2000). Morphological and physical properties of some soils at Samaru, Zaria, Nigeria. *Nigerian Journal of Soil Research*. 1: 58 – 64
- Musa, H. (2006). Characterisation and Classification of the Soil of School of Agriculture and Agricultural Technology, Yola. Unpublished M. Tech Thesis, School of Agriculture and Agricultural Technology, Federal University of Technology, Yola.
- Mustapha, N. Vancir, S. Umar. And N. A. Abdulhamid (2011). Status and Distribution of some Available Micronutrients in thr Haplic usterts of Akko Lcal Government Area, Gombe State, Nigeria. *International Journal of Soil Science*. 6 (4): 267 – 274.
- Nazif, W., S. Perveen and I. Saleem, (2006). Status of micronutrients in soils of District Bhimber (Azad Jammu and Kashmir). *J. Agric. Biol. Sci.*, 1: 35 – 40.
- Nelson, D.W. and Sommers, L.E (1982). Total Organic carbon, organic matter. In: Pages, A.L., Miller R.H and Kenney, D.R. (Eds). *Methods of Soil Analysis: part 2 Ameri. Soc. Agron.,Madison, Wisconsin.,* pp.539 – 579
- Schulte, E.E. (2004). Soil and Applied Zinc. Understanding Plant Nutrients. University of Wisconsin Extension Publication No. A 2527. <http://learningstore.uwex.edu/pdf/A2527.pdf>
- Sillanpää, M. (1982). Micronutrients and the nutrient status of soils. A Global Study, FAO Soils Bulletin. No. 48. FAO, Rome, Italy.
- Osiname, O. A., E. E. Schulte, and R. B. Corey (1973). Soil test for available copper and zinc in soils of western Nigeria. *Journal of Science Food Agric*. 24: 1341 – 1349
- Oyinlola E. Y. and V. O. Chude. (2010). Status of available micronutrients of the basement complex – derived Alfisols in Northern Nigeria Savanna. *Tropical and Subtropical Agroecosystems*. 12: 229- 237
- Vancir, N., S. Mustapha, V.A. Tenebe, A.L. Kumo and S. Kushwaha, (2008). Content and profile distribution of extractable zinc (Zn) and some physicochemical properties of soil along a toposequence at Bauchi, Northern Guinea Savanna of Nigeria. *Int. J. Soil Sci.*, 3: 62-68.
- Wapa, J.M., S. O. Ajeniyi, and J.D. Kwari. 2013. Response of Extra Early Maize (*Zea mays* L.) variety to Different Organic Manures in the Drier Sub-region of Northern Nigeria. *Nigerian Journal of Soil Science*. 23 (2): 52 – 59.
- Zata, A. I. Vahyala, I. E. and Bapetel, U. (2005). The Fertility Status of some soils in Girei Local Government Area, Adamawa State, Nigeria. *Nigeria Journal of Tropical Agriculture*. 7(2): 262 – 268