Tropical and Subtropical Agroecosystems

STATUS OF AVAILABLE MICRONUTRIENTS OF THE BASEMENT COMPLEX ROCK – DERIVED ALFISOLS IN NORTHERN NIGERIA SAVANNA

[MICRONUTRIENTES DISPONIBLES EN ALFISOLES DERIVADOS DE BASAMENTOS ROCOSOS COMPLEJOS EN LA SABANA NORTE DE NIGERIA]

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SUMMARY

The contents of available boron, zinc, copper, iron and manganese were determined in twenty surface soils (0-30cm depth) and profile pits collected from Northern Guinea and Sudan savanna zones which are the major tomato and horticultural crops growing areas of northern Nigeria savanna. The contents of available B from surface soils, extracted with hot water, varied from 0.04 – 0.28 with a mean of 0.14 mg kg^{-1}, while Zn, Cu, Fe and Mn,extracted with 0.1N HCl, varied from 1.8 –10.5, 1.0 – 9.0, 2.5 –75 and 2.8 – 18 mg kg^{-1}, with means of 4.2, 2.9, 19.6 and 9.2 mg kg^{-1} respectively. The contents of B, Zn, Cu, Fe and Mn in the profile pits ranged from 0.08 – 0.18, 1.5 – 3.5, 0.9 – 3.3, 14 – 26.2 and 11.2 – 20.5 mg kg^{-1} with means of 0.12, 2.4, 1.9, 20.7 and 15.0 mg kg^{-1} respectively. Boron is deficient in all the soils; Zn is deficient in only some of the soils, while the contents of the other micronutrients are adequate. The micronutrients are significantly related to some of the soil properties tested, Soil clay correlated (P=0.01) positively with Cu, Zn, Mn and Fe (r= 0.476**, 0.404**, 0.407** and 0.469** respectively). Similarly, organic C correlated positively with Fe, Cu and Mn. Also, there are significant relationships among the micronutrients; Fe correlated with all the other micronutrients – Cu, Zn, Mn (P=0.01) and B (P=0.05). While Zn correlated with Fe, Cu and Mn. For soils of the pedons, sand and silt correlated with Zn and Cu, pH (H_2O) correlated with Fe, while pH ($CaCl_2$) correlated with B and Fe. Among the micronutrients, B and Cu correlated with Zn. There would be need for B and Zn application to the soils for successful and profitable crop production.

Key words: Soil micronutrients; surface soils; pedons.

RESUMEN

Se determine el contenido de boro, zinc, cobre, hierro y manganeso en 20 suelos (0-30 cm de profundidad) y calicatas de perfil colectadas de las zonas ecológicas de sabana de Sudan y de Guinea, las cuales son las principales zonas horticolas de la sabana Nigeriana. Los contenidos de B disponible en los suelos superficiales, extraido con agua caliente) varió de 0.04 – 0.28 con una media de 0.14 mg kg^{-1}, mientras que los contenidos de Zn, Cu, Fe y Mn, extraidos con 0.1 N HCl, variaron entre 1.8 –10.5, 1.0 – 9.0, 2.5 –75 y 2.8 – 18 mg kg^{-1}, con medias de 4.2, 2.9, 19.6 y 9.2 mg kg^{-1} respectivamente. Los contenidos de B, Zn, Cu, Fe y Mn en las calicatas de perfil varió entre 0.08 – 0.18, 1.5 – 3.5, 0.9 – 3.3, 14 – 26.2 y 11.2 – 20.5mg kg^{-1} con medias de 0.12, 2.4, 1.9, 20.7 y 15.0mg kg^{-1} respectivamente. El B es deficient en todos los suelos, el Zn únicamente en algunos de ellos, mientras que los microminerales restantes se encontraban en niveles adecuados. Se encontró relación entre los micronutrients y algunas de las propiedades de los suelos evaluadas. El nivel de arcilla se correlacionó (P=0.01) positivamente con Cu, Zn, Mn y Fe (r= 0.476**, 0.404**, 0.407** y 0.469** respectivamente). De manera similar, el contenido de C orgánico se correlacionó con Fe, Cu y Mn. Se encontró relación entre Fe y los micronutrientes restantes:Cu, Zn, Mn (P=0.01) y B (P=0.05). Mientras que Zn se correlacionó con Fe, Cu y Mn. Para los suelos de los pedones, la arena y el limo se correlacionaron con Zn y Cu, pH(H_2O) con Fe, y pH($CaCl_2$) con B y Fe. Entre los micronutrients B y Cu se correlacionaron con Zn. Se sugiere la necesidad de aplicar B y Zn para producción de cultivos exitosa.

Palabras clave: Micronutrientes del suelo; suelos superficiales; pedones.

INTRODUCTION

Information on soil micronutrient status of northern Nigeria savanna soils is scanty. Investigations carried out so far have revealed micronutrient deficiency in some Nigerian savanna soils (Lombin (1983a, 1983b, 1985a). Low levels of available Zn and B and adequate levels of Cu and Mn were reported (Enwezor, 1991). On a global study Sillanpää (1982) reported generally low to deficient levels of B, Cu, Mo and Zn and normal to excessive levels of Mn in a number of soils from Nigeria. Responses of crops to added micronutrients have been reported by Pam (1990) and Oyinlola and Chude (2001, 2004), who obtained yield increase of over 100% above the control with optimum rate of micronutrient application.

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 large percentage of tomato (*Lycopersicon esculentum* Mill.), carrot (*Daucus carota* L), lettuce (*Lactuca sativa L.*), cabbage (*Brassica oleracea* L.), pea (*Pisum sativum* L.) and other vegetable crops consumed in Nigeria are produced in Northern Guinea (NG) and Sudan (S) savanna zones of Nigeria. For sustainability purpose there is need to know the micronutrient status of these soils, which are cropped to tomato and other vegetable crops twice or thrice a year. The objectives of this study were: i) To determine the contents of available Zn, Cu, B, Mn and Fe in the soils, ii) To investigate the relationship between micronutrients and soil properties.iii) To identify micronutrient limiting areas where application of micronutrient fertilizers will be needed for higher crop yield.

MATERIAL AND METHODS

Soil samples used for the study were taken from twenty sites at 0 – 30 cm depth from major vegetable cultivated fields in Northern Guinea and Sudan savanna areas of Nigeria. Soil samples from profile pits of pedons sank in Samaru (Latitude 11^{o}, 11'N, Longitude 07^{o} 38'E) and Kadawa (11^{o} 39'N, 08^{o} 02'E) which are target areas for tomato and other horticultural crops production areas were also used for the study. Samaru is located in the Northern Guinea savanna, while Kadawa is located in the Sudan savanna ecological zone. The irrigation Research Stations of Institute for Agricultural Research of Ahmadu Bello University, Zaria. Nigeria, are sited in these two towns. Parent materials for both Northern Guinea and Sudan savanna zones is Pre-Cambrian older granite. The sampled soils, which are Alfisols, were air-dried, ground and sieved through a 2mm sieve and used for laboratory analysis. Particle size distribution was determined by the hydrometer method (Day, 1965). Soil pH was measured in water and 0.01M $CaCl_2$ (1:2.5 w/v) using glass electrode pH meter. Organic carbon was determined by the dichromate wet oxidation method of Walkley and Black (Nelson and Sommers, 1982). Available P was determined by Bray 1 method (Bray and Kurtz, 1945). A mixture of 1N NH_4F+0.5N HCl was used to extract P from soil (1:7 w/v) and the concentration of the P were determined colorimetrically in a spectrophotometer (spectronic 70) Total N was determined by the kjeldahl procedure of Bremner and Malvaney (1982). Effective cation exchange capacity and exchangeable cations were determined by the method described by Juo (1979). Micronutrients - Cu, Fe, Zn and Mn were extracted with 0.1N HCl as described by Osiname *et al.* (1973) and the concentration of nutrients determined with atomic absorption spectrophotometer (Unicam 969). Available-B was extracted with hot water and determined colorimetrically by improved Azomethine-H method (Wolf, 1974).

The mean values and standard deviation of mean of the soil properties were computed. Simple linear correlation analysis was done to show the relationship between micronutrients and other soil properties.

RESULTS AND DISCUSSION

Soil Properties

The data on physico-chemical properties of the soils are given in Table 1. Silt content ranged from 200 – 460g kg^{-1} with a mean of 357g kg^{-1}, while clay content ranged from 90 – 270 g kg^{-1} with a mean of 138gkg^{-1}. The texture of the soils ranged from sandy loam to loam. The soils were moderately acidic, the pH in water ranged from 4.6 to 6.8 with a mean of 5.5. The organic carbon (OC) contents which ranged from 2.6-13.4g kg^{-1} fell within the low to medium fertility classes for Northern Nigerian savanna soils. This would suggest that the soils would be prone to leaching of nutrients. Available P contents in the soils ranged from 3.9-19 m kg^{-1} fell within the low to medium fertility classes (Enwezor *et al.*, 1990). The total N contents of the soils (0.4-1.4 g kg^{-1}) are low and values fall short of the medium class. Jones and Wild (1975) had earlier reported low values of organic carbon, available P and total N in Nigerian savanna soils. The exchangeable cations Ca^{2+}, Mg^{2+}, K^+ and Na^+ are low, reflecting the low CEC of the soils. The principal saturating cations in all the soils is Ca^{2+}, followed by Mg^{2+}.

Twelve soil samples have ECEC higher (0.74 – 7.6cmol kg^{-1}) than the critical value of 4.0 cmol kg^{-1} needed to retain most cations against leaching in the highly weathered sandy soils as suggested by Sanchez (1976).

The results obtained for the pedon soils showed that silt content ranged from220-440gkg^{-1} (Table 1), while clay content ranged from 150-470gkg^{-1}, pH (H_2O) ranged from 6.3-6.9. Total N, available P, OC and exchangeable cations contents of the pedon soils were low, similar findings had been reported by Esu and Ojanuga, 1985.

Available micronutrients in surface soil samples.

Boron

The values of available B in the soils varied from 0.04 - 0.28 mg kg^{-1} with a mean of 0.14 mg kg^{-1} (Table 2). These values are slightly lower than 0.18 – 0.36 mg kg^{-1} B reported by Lombin (1985b) and slightly higher than 0.08 – 0.17 mg kg^{-1} obtained by Daudu (1989), for soils of Northern Nigeria savanna.

Table1: Physico-chemical properties of surface and Pedon soils.

	Surface soils			Pedon Soils		
Parameters	Range	Mean	SD	Range	Mean	SD
Sand (g kg^{-1})	270-710	510	9.5	250-570	437	12.3
Silt (g kg^{-1})	200-460	357	6.7	220-440	304	7.9
Clay (g $kg^{-1)}$	90-270	138	5.5	150-470	260	11.5
Textural class*	SL-L			L-C		
pH(H_2O)	4.6-6.8	5.5	0.58	6.3-7	6.7	0.17
pH($CaCl_2$)	4.2-5.6	5.0	0.4.	5.3-5.8	5.7	.15
O.C (g kg^{-1})	2.6-13.4	6.3	3.6	0.8-9.2	3.4	3.4
Avail. P (mg Kg^{-1})	3.9-19	9.8	3.9	3.2-5.9	4.2	0.98
Total N (g kg^{-1})	0.4-1.4	0.6	0.3	0.21-0.7	0.4	0.14
ECEC (cmol kg^{-1})	1.3-11.6	5.8	5.3	2.9-18.7	6.5	2.9
Exch. Acidity(cmol Kg^{-1}	0.1-0.3	0.22	0.1	0.12-0.4	0.3	0.12
Exch. Ca (cmol Kg^{-1})	0.8-12.5	4.2	3.3	1.02-7.0	4.2	1.94
Exch. Mg(cmol Kg^{-1})	0.08-3.1	1.1	0.8	0.18-3.0	1.5	1.0
Exch. K (cmol Kg^{-1})	0.05-1.04	0.4	0.3	0.12-1.1	0.3	0.30
Exch. Na(cmol Kg^{-1})	0.11-0.70	0.3	0.2	0.15-0.34	0.3	0.06

*Textural class; - SL – Sandy loam, L – Loam. C – Clay

Wolf (1971) considered any soil with 0.4 mg kg^{-1} B or less as low in available B, whereas Sims and Johnson (1991) reported a critical range of 0.1-2.0 mg $kg^{-1}$for hot water soluble B. The content of available B in the Nigerian savanna soils ranges from low to very low (Lombin, 1985b; Oyinlola *et al*., 2000). The result obtained in this study is justified by the report of Oyinlola and Chude (1997) who studied the boron adsorption capacity of the soils of northern Nigeria savanna and reported that the soils have low capacity to absorb B which makes B susceptible to leaching loses.

The major soil factors which may cause B content to be low in soils are low B content in the parent material and in primary B containing minerals which decompose easily, soil type, pH and leaching (Sims and Johnson, 1991, Tisdale *et al* 2003).

Table 2: Available micronutrients in the surface soils (mg kg^{-1}).

Micronutrients	Range	Mean	SD
Boron	0.04-0.28	0.14	0.06
Zinc	1.8-10.5	4.2	2.4
Copper	1.0-9.0	2.9	1.7
Iron	2.5-75	19.6	8.4
Manganese	2.8-18	9.2	4.7

Zinc

The available Zn varied from 1.80 - 10.5 mg kg^{-1} with a mean of 4.2 mg kg^{-1}. (Table2). Eight soil samples have their values above the critical soil Zn of 3.3 mg kg^{-1} reported by Pam (1990) who worked on Nigerian savanna soils. Critical range of 1.0 to 5.0 mg kg^{-1} (Sims and Johnson, 1991, Deb and Sakal, 2002) had been reported elsewhere. However, the values obtained from this study are within the range obtained from the report of Lombin (1983b), who worked on the Zn content of Nigeria savanna soils.

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). From the result obtained in this study, it could be inferred that some Northern Nigerian savanna soils are deficient in Zn.

Copper (Cu)

The contents of available copper ranged from 1.0 – 9.0 mg kg^{-1}, with 2.9 mg kg^{-1} as mean (Table 2). These values are above the values reported by Fagbami *et al*. (1985) and are slightly above the range of values reported by Kparmwang *et al*. (1998) and Yaro *et al.* (2002). Critical levels for 0.1N HCl extractable Cu in soils is 1.00 to 2.00 mg Cu kg^{-1} soil (Sims and Johnson, 1991) and 1.0 - 3.0 mg kg^{-1} (Deb and Sakal, 2002, Tisdale *et al*, 2003). If this is applied to the values obtained in this study, 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). The results obtained in this study confirmed the findings of Sillanpää (1982) as part of a global study on soil micronutrient status had reported generally low to deficient levels of Cu, in some Nigerian soils, Lombin (1983a) had earlier reported that the contents of available Cu in soils of Northern Nigeria savanna are adequate and poses no fertility problem.

Iron (Fe)

Available Fe ranged from 2.5 – 75 mg kg^{-1} with a mean of 19.6 mg kg^{-1}. These values are within the reported values by Kparmwang *et al*. (2000) and below the values reported by Kparmwang *et al.* (1995). Although available Fe is generally high in the tropical soils, localized deficiencies of Fe are known to occur (Enwezor *et al*., 1990). About 16 soils have available Fe value above the critical range of 3.0 – 4.5 mg kg^{-1} Fe (Sillanpää, 1982). Deb and Sakal (2002) had reported critical range of 0.1N extractable Fe as 2.5 – 5.8mg kg^{-1} Fe. High levels of available Fe in these soils could be due to the acid conditions of the soils. Available Fe poses no fertility problem in the soils studied.

Manganese (Mn)

The values of available Mn vary from 2.80 - 19.0 mg kg^{-1} with a mean of 9.2 mg kg^{-1} as shown in Table2. The values are lower than those reported by Kparmwang *et al*. (1995, 2000) and higher than those obtained by Lombin (1983a). Most of the soils have available Mn above the critical soil Mn of 1 – 4 mg kg^{-1} (Sims and Johnson, 1991). However, Lombin (1983a) had reported that the northern Nigerian savanna soils which are predominantly mildly to medium acid seem well supplied with Mn at present and the prospect of deficiency problems in the foreseeable future seems remote. The high values could be due to acid conditions of the soils.

Available micronutrients in pedons soil samples.

The content of available micronutrients in the soil profile is shown in Table 3.

Boron (B)

In profile SA, the contents of available B varied from 0.08 – 0.13 mgkg^{-1} with a mean of 0.11mg kg^{-1}. These results are within the range of values obtained by Daudu (1989) and Kparmwang *et al.* (2000). There was a gradual increase in the contents of available B from AB to Bt3 horizon; which could be related to higher clay contents in Bt2 and Bt3 horizons. The situation was the same with profile KA where B contents varied from 0.10 – 0.18mg kg^{-1} Considering 1.0 – 2.4 mgkg^{-1} available B as critical limit (Wolf, 1971), B contents of all the soils are in deficient range and might be limiting factor for crop growth. Brady and Weil (2002) related the low B contents in soils to initial low B content in the soil parent material, loss through leaching and extremes of pH.

Zinc

The contents of available Zn in profile SA varied from 1.5 - 2.1 mg kg^{-1} and mean was 1.9mg kg^{-1}, while it varied from 2.7 - 3.5 mg kg^{-1} and mean was 3.0mg kg^{-1} in profile KA (Table3). Apart from the result obtained in the Ap horizon for the two profiles, there seems to be no difference in the result obtained for the remaining horizons (Table3). Chesworth (1991) had reported that Zn is of low mobility in soils, which seems to explain similar results within the profiles. Generally with the exception of Ap horizon the contents of available Zn obtained from this study fell below the critical available level of 3.3

mg kg^{-1} for HCl extractable Zn as reported by Pam (1990) who worked on soils from the same area.

Copper (Cu)

Available Cu varied from 0.9 - 1.3 mg kg^{-1} with a mean of 1.1mg kg^{-1} in profile SA and 2.6-3.3 mg kg^{-1} with mean of 3.0mg kg^{-1} in profile KA. These values are within the range reported by Kparmwang *et al.* (1998) and Yaro *et al.* (2002). Sims and Johnson (1991) had placed the critical values for HCl extractable Cu as 1.0 – 2.0 mg Cu kg^{-1}. If this is applied to the result obtained from this study, it can be said that the contents of available Cu in these profiles are adequate and poses no fertility problem.

Iron (Fe)

The soils are rich in available Fe content which varied from 19 – 21mg kg^{-1} with a mean of 20.4mg kg^{-1} in the SA profile, while it varied from 14 – 26.2mg kg^{-1} in the KA profile with a range of 21.03mg kg^{-1} (Table3). The values are similar to those obtained by Kparmwang and Malgwi (1997). Available Fe increased with increase in depth in the two profiles. Profile KA (B horizon) recorded the highest content of available Fe (26.2mg kg^{-1}). This is expected as Fe/Mn concretions were observed in the horizon during sampling.

The contents of available Fe in the soils are sufficient and well above the critical range of 3.0-4.5mg kg^{-1} (Sillanpää, 1982) and 2.5-5.8mg kg^{-1} (Deb and Sakal, 2002) extractable Fe. The results obtained from this study are similar to the one reported by Kang and Osiname (1972) who reported that Fe deficiency is unlikely in acid soils.

Manganese (Mn)

Available Mn which increased with increase in soil depth ranged from 14 – 17 and 11.2 – 20.5 mg kg^{-1} in profiles SA and KA respectively. The highest value of 20.5mg kg^{-1} was obtained from B horizon of profile KA. This as earlier mentioned was due to Fe / Mn concretions. Harmsen and Vlek (1985) had reported that trees and deep-rooted crops may extract micronutrients from deeper layers and deposit them on the soil surface in organic form, which subsequently decompose and release the micronutrients, organic acids and chelating agents. These form soluble complexes with elements such as Fe, Mn, Cu and Zn, which may leach down and accumulate in B-horizon or leach down to the deeper layers and be carried away with Drainage waters. The values of available Mn obtained from this study were lower than those reported by Kparmwang *et al.* (1995). However, available Mn in these soils is high and above the critical range of 1 – 4 mg kg^{-1} (Sims and Johnson, 1991).

Table 3: The contents of available micronutrients in the soil profiles (mg kg^{-1}).

Horizon	Depth (cm)	Boron	Zinc	Copper	Iron	Manganese
			Profile SA (Ultic Haplustalf)			
Ap	0 – 15	0.08	1.5	0.9	19	14
AB	15-28	0.10	1.9	1.3	21	15
Bt1	28 -40	0.11	1.9	1.2	20	17
Bt2	40-128	0.13	2.0	1.0	21	16
Bt3	128-175	0.13	2.1	1.0.	21	17
			Profile KA (Typic Halustepts)			
Ap	0-30	0.18	3.5	3.3	14	11.6
AB	30-45	0.14	2.9	2.8	19.8	11.2
BA	45-65	0.12	2.7	2.9	24.1	12.7
B	65-130	0.10	2.7	3.0	26.2	20.5

Relationship between micronutrients and soil properties

Sand correlated negatively with all the micronutrients determined except B as shown in Table 4. Silt also significantly correlated positively with Zn and Mn. Clay correlated with Fe, Cu, Zn and Mn (r = 0.470**, 0.476**, 0.404** and 0.407** respectively). The significant relationships between clay and the micronutrients signify the importance of clay in the availability of these micronutrients. Lombin (1983b) and Sadiqq *et al.* (2008) had reported similar significant relationships in their studies.

Soil pH (water) also correlated with available Cu (r = 0.436**) and Mn (r = 0.376**) (Table 4).

Kparmwang *et al.* (1998) had reported significant correlation between HCl extractable Cu and pH in Northern Nigeria savanna soils. This signifies that pH is important for the availability of the micronutrients. Sims and Johnson (1991) had reported that the availability of Mn in the soils is affected by pH and texture.

Significant correlations exist between organic carbon (OC) and available Fe, (r = 0.344**), Cu (r = 0.510**) and Mn (r = 0.522**) as shown in Table 4. This shows that a large amount of organic bound Fe and Cu are available in the soils. Similar relationships had been reported by Katyal and Sharma (1991) Kparmwang and Malgwi (1997). Tisdale *et al.* (2003) had reported that micronutrients form stable complexes with soil organic matter – components and that organically bound forms of the micronutrient cations are more available to plants than the inorganic forms of pools, insoluble inorganic precipitates and those held in primary minerals.

Available P and total N also correlated with Fe, Zn and Mn. These emphasize the important influence of available P and Total N to the micronutrients in savanna soils. The ECEC which determines most exchange reaction in soils was observed to significantly correlate with Fe and Mn.

The fact that clay and OC correlated significantly with the micronutrients is in line with the findings of Lombin (1983b) who reported that OC and clay are generally considered the mainstay of extractable micronutrients in the soil. Similarly, Balasubramanian *et al.* (1984) reported that the levels of many nutrients in savanna soils are intrinsically tied to the level of OC in these soils. The result obtained from this study confirms the report of Deb and Sakal (2002), Brady and Weil (2002) and Tisdale *et al.* (2003) that the availability of most the micronutrients in soils depend on soil pH, OC content, adsorptive surfaces and other physical, chemical and biological conditions in the rhizosphere.

Pedon Soils

The relationships between soil properties and micronutrients in the profile soils are shown in Table 4. Sand significantly correlated with Zn (r = 0.749*) and Cu(r = 0.920**), while silt correlated negatively with Zn (r = - 0.771*) and Cu (r = -0.705*.) This signified that availability of Zn and Cu in the pedons are affected by texture (Kparmwang *et al.*, 1998). There were negative correlations between pH (H_2O) and Fe (r = - 0.718*), pH ($CaCl_2$) and B (r = - 0.687*) whereas pH ($CaCl_2$) significantly correlated positively with Fe (r = 0.808*). The negative relationships indicate that the availability of Fe decreased with increase in pH (H_2O). Similar relationships had been reported by Sims and Johnson, (1991) and Kparmwang and Malgwi (1997).

Table 4: Simple correlation (r) between soil properties and micronutrients [1].

Soil Properties	Boron	Zinc	Copper	Iron	Manganese
Surface soils					
Sand	0.0314	-0.445**	-0.399**	-0.296*	-0.452**
Silt	-0.058	0.338*	0.200	0.186	0.354**
Clay	-0.010	0.404**	0.476**	0.469**	0.407**
pH(H_2O)	0.269	0.211	0.436**	0.242	0.376**
pH($CaCl_2$)	0.119	0.177	-0.134	0.004	-0.377**
O.C	0.262	0.198	0.510**	0.344*	0.522**
Available P	0.273*	0.383**	0.231	0.476**	0.278*
Total N	0.117	0.284*	0.459**	0.417**	0.545**
ECEC	0.215	0.068	0.178	0.307*	0.299*
Pedon soils					
Sand	0.237	0.749*	0.920**	0.048	-0.348
Silt	-0.613	-0.771*	-0.705*	-0.217	-0.075
Clay	-0.162	-0.264	-0.486	0.116	0.444
pH(H_2O)	0.221	0.065	-0.184	-0.718*	-0.021
pH($CaCl_2$)	-0.687*	-0.532	-0.351	0.808**	0.400
O.C	-0.477	-0.056	0.190	0.170	0.335
Available P	-0.017	0.303	0.391	-0.107	0.268
Total N	-0.360	0.381	-0.318	-0.445	-0.344
ECEC	0.569	0.639*	0.537	0.237	-0.029

** Significant at 1%, * Significant at 5%. [1] = 50degrees of freedom for surface soils and 9 for Pedon soils.

Relationship among the Micronutrients

There are relationships among the micronutrients as shown in Table 5. Available Fe correlated with the other micronutrients, Cu (r = 0.540**), Zn (r = 578**), Mn (r = 532**) and B (r = 0.290*). Available Cu also correlated with available Zn (r = 0.351*) and Mn (r = 0.689**). Buckley, (1989) had reported that the surfaces of secondary oxides of Mn control the behavior of certain trace elements by adsorption and specifically that Mn coatings on elastic particles attract Cu and Zn among others.

For the pedon soils, Zn correlated with B (r = 0.784*) and Cu (r = 0.925**). The significant relationships among the micronutrients signify that their availability is controlled by similar pedogenic processes or factors (Kparmwang and Malgwi, 1997).

CONCLUSION

Results obtained from this study has shown that, out of five micronutrients studied namely, B ,Zn, Cu, Fe, Mn, only B was found to be clearly deficient in both surface and pedon soils. This infers that there is low content of B in the parent materials of the soils. Similarly the concentration of Zn was found to be inadequate in some soils. For successful and profitable crop production, there would be need to supply B and Zn from fertilizers especially for high B and Zn requiring crops. The significant relationship among the micronutrients points to the fact that, their availability is controlled by similar factors. Also the significant relationship between micronutrients and soil properties shows the importance of these soil properties (clay, pH OC) in the availability of micronutrients. The importance of organic matter in the supply of micronutrients was also observed in this study. Farmers in the study area are advised to apply organic matter to their farm to supply nutrients.

Table 5: Simple Correlation between Micronutrients in surface soils (lower diagonal) and pedon soils (upper diagonal).

	Boron	Zinc	Copper	Iron	Manganese
Boron	-	0.784*	0.501	0.582	0.492
Zinc	0.137	-	0.925*	-0.214	-0.383
Copper	0.020	0.351*	-	0.034	-0.281
Iron	0.290*	0.578**	0.540**	-	0.617
Manganese	-0.018	0.389*	0.689**	0.532**	-

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