Status and Distribution of Some Available Micronutrients in Sudan and Sahel Savanna Agro-Ecological Zones of Yobe State, Nigeria

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ABSTRACT

To ensure economic utilization of the soil resources by the resource-poor Nigeria farmers and also help in the government's drive towards food sufficiency, it is important to know the original concentration of micronutrients in the soils and add only as much of the micronutrients as is beneficial to plants and foraging animals. Two study sites (Geidam and Gujba local government areas) were selected to represent the dominant agro-ecological zones in Yobe State. From the results, Copper (Cu) was found to be in the medium category while Zinc (Zn) was generally low in both zones. However, the soil contains Iron (Fe) and Manganese (Mn) above the critical limits for crop production and categorized as "high". It is, therefore, suggested that supplementary application of Zinc (Zn) will be required for sustainable arable crop production and application of organic matter to improve the overall fertility of the soil as well as reduce the possible development of phlinthic/petrophlinthic layers.

Keywords: *Micronutrients, agro-ecological, fertility rating, range*

INTRODUCTION

Fertility or what is also called fruitfulness is not attributable to living beings alone. It is also attributable to such things as the soil or earth. With regard to plant or anything that grows in the soil, the fertility of the soil on which it grows determines to fertility of the plant itself. Hence, soil fertility is an important factor which determines the growth and productivity of plants. It is determined by the presence or absence of macro or micronutrients. Iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn) are essential micronutrients for plant growth (Rangel, 2003; Gao, Yan, Coa, Yang, Wang and Chen (2008). Although required in minute quantities, however, micronutrients have the same agronomic importance as macronutrients and play vital roles in the growth of plants (Mortvedt, Cox, Shuman and Welch, 1991), Nazif, Sajida and Saleem, 2006). Most micronutrients are associated with the enzymatic systems of plants. For instance, Zinc (Zn) is known to promote the formation of growth hormones, starch and seed development, Fe is important in chlorophyll formation, Copper (Cu) in photosynthesis and Manganese (Mn) activates a number of important enzymes

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and is important in photosynthesis and metabolism (FFTC, 2001). Responses of crops to added micronutrients have been reported by Pam (1990); Oyinlola and Chude (2001, 2004), who obtain yield increase of over 100% above the control with optimum rate of micronutrient application. Lombin (1983a, 1983b, 1985a) reveals that there are micronutrient deficiency in some Nigerian savanna soils . Low levels of available Zn and B and adequate levels of Cu and Mn were reported (Enwezor, Udo, Ayotade, Adepetu and Chude, 1990). On a global study, Sillanpää's (1982) report shows 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. Information on soil micronutrient status of northern Nigeria savanna soils is scanty. Thus, several researches advocate the need for assessing the micronutrients status of soils (Ibrahim, Usman, Abubakar and Aminu, 2011; Mustapha, Voncir and Abdullahamid, 2011). Equally, as a pre-requisite to the successful implementation of the scientific agricultural practice, the evaluation of the nutrient status of the soils, including the micronutrients becomes necessary. This will ensure a more economic utilization of the soil resources by the resource-poor Nigeria farmers (Mustapha, 2003) and help in the government's drive towards food sufficiency. Therefore, it is important to know the original concentration of micronutrients in the soils and add as much of the micronutrients as is beneficial to plants and foraging animals. It is against this background that this research is conducted.

MATERIALS AND METHOD

This study was conducted in 2014 in Yobe State. Two study sites Geidam and Gujba local government areas were systematically selected to represent the dominant agro-ecological zones in the State. Geidam in the northern part of the State represents Sahel savanna agro-ecological zone, while Gujba, located in the southern part of the State represents Sudan savanna agro-ecological zone. The climate regime in Yobe State is characterized by single long dry season followed by a shorter wet season. Humidity is low throughout the dry season. Potential evapotranspiration exceeds rainfall except for few months.

Geologically, the Sahel zone consists of quaternary deposits of the chad formation made up of consolidated sand and clays while in the Sudan, it is mainly basement complex. The soils are grouped on the basis of parent materials into Aeolian deposits, lacustrine, alluvial deposits and 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 adonsoniadigitata, while the Sudan is dominated by scrubby vegetation interspaced with tall trees. In each location, a total of 26 composite samples were collected using augers at two depth intervals of 0-15cm and 15-30cm. At each depth, 5 samples were collected for composit. The samples were air dried, ground using porcelain pestle and mortar and passed through 2mm mesh sieve. Particle size distribution was determined using hydrometer method as outlined by Anderson and Ingram (1993). Soil pH was determined by Potentiometric as described by Wendt (1996). Organic carbon was determined by Walkely-Black method as outlined by Anderson and Ingram, (1993). Exchangeable bases

(Cadmium (Ca), Magnesium (Mg), Potassium (K) and Sodium (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, Schulte and Corey, 1973) and determined on an atomic absorption spectrophotometer (Model 210) at appropriate wave length. Data obtained were subjected to analysis of variance (ANOVA) and means that were statistically significant 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 on table 1. The results indicate that the soils have relatively high sand with a mean value of 662 g kg^{-1} and a mean clay content of 147 g kg^{-1} giving the soils, a generally loamy sand to sand texture. The results also indicate that all fractions varied significantly ($P < 0.05$) between the zones with Sudan having higher fraction in silt and clay, while Sahel having high proportion of sand. This is expected and further ascertained by Jones and Wild (1975), who report that most savanna soils are sandy in nature which is associated with low water holding capacity (WHC). Clay content increases with soil depth (Table 1). This might be attributed to removal of the fraction by surface run-off and also by alluviation. This is a common phenomenon in soil in this agro-ecology as was also reported by Voncir, Mustapha, Tenebe, Kumo and Kushwaha (2008).

The soil reaction (in H_2O) ranged from pH 6.34 to 6.54 (mean=6.44) indicating slightly acidic reaction (Table 2). Though generally acidic, the pH value varies significantly ($P < 0.05$) between zones and depth considered. The Sahel zone is more acidic than the Sudan zone likewise, the surface (0-15 cm) pH was found to be more acidic than the subsurface(15-30 cm). 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, Mustapha, Tenebe, Kumo and Kushwaha, 2008; Kolo, Mustapha and Voncir, 2009) and or the use of acid–forming fertilizer such as urea for agricultural purposes.

Table 2 further shows that the organic carbon content fell within the “low” category (Esu,1991) of fertility classes for Northern Nigeria Savanna soils, across the zone; the values significantly ($P < 0.05$) ranged from 3.45 to 6.18 (mean = 4.82) g kg^{-1}. Significant ($P <0.05$) differences were also observed across surface (0-15cm) and subsurface (15-30 cm) in both zones;with mean value of 4.82 g kg^{-1} organic carbon content. This would suggest that the soils would be prone to leaching of nutrients. Similar low organic carbon values have been reported by Yaro, Kparmwang, Raji and Chude (2006) for the Nigeria savanna soils. Other reports indicate low organic carbon content for soils in the northern guinea savanna zone of Nigeria (Mustapha and Nnalee, 2007; Mustapha, Yerima, Voncir and Ahmed, 2007). The low organic carbon contents of the soils are characteristics of the savanna due partly to rapid decomposition and mineralization of organic matter and to poor management sometimes by burning of crop residues by farmers (Lawal, Odofin, Adeboye and Ezenwa, 2012). Greenland (1995) attributes 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 into these soils in order to beef up the soil organic carbon level (Lawal, Odofin, Adeboye and Ezenwa, 2012). The exchangeable bases (Ca, Ma, K and Na) except Na, significantly ($P < 0.05$) vary across zones and depths (Table 3). The exchangeable bases in this study are mostly rated low and medium across Sahel and Sudan agro-ecological zone respectively regardless of depth based on Esu's (1991), critical limits and micro nutrients fertility ratings (Table 5). This reflects the low and medium CEC of the soils across Sahel and Sudan zone respectively and the depth considered. This conforms with the findings of Oyinyola and Chude (2010) in Northern Nigeria Savanna.

Copper (Cu) status: The contents of available Cu ranged from 0.31 – 1.09 mg kg^{-1}, with mean value of 0.70 mg kg^{-1} in the studied zones (Table 5). Based on Esu's (1991) micro nutrients fertility ratings (Table 4), the values fall in the medium" categories. However these values are above the values reported by Mustapha and Singh (2003) for soils elsewhere in Galambi, Bauchi State, Nigeria in similar agro-ecology but similar to values (means= 0.36 mg kg^{-1}) obtained by Biwe (2012) in a study conducted in Gubi, Bauchi State, Nigeria. Between the depths considered, Cu varied significantly ($p < 0.05$). The upper surface (0-15 cm) in both zones contained more Cu than the lower (15-30 cm) surface and both fall within the "medium" fertility rating (Esu, 1991) categories. Thus, it could be predicted that the deficiency of Cu will not occur in these soils in the nearest future. Lombin (1983a) reports 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 zones significantly ($p < 0.05$) ranged from 0.48 to 0.85 mg kg^{-1} with a mean value of 0.67 mg kg^{-1}. Based on the critical limits of Esu (1991), all the soils fall in the category of "low" Zn status and would require Zn fertilization for a better crop production except few locations in the Sudan zone (table 5). The values obtained in this study are indeed similar to 0.58 mg kg^{-1} (mean) obtained by Mustapha, Mamman and Abdulhamid (2010) in a study carried out in Gombe, Nigeria. Zinc (Zn) distribution in surface (0-15cm) was significantly ($P < 0.05$) more than the Zn content in subsurface (15-30 cm) especially in the Sahel zone, falling into "low" or "medium" fertility rating (Esu, 1991) category. As Zn decreases with depths, its implication here is that plants may not have a Zn "store" in the lower surface (15-30 cm). Similar decrease with depth was also observed by Singh and Shukla (1985) and Bassirani, Abolhassani and Galavi (2011). This also conforms to the findings of Mustapha, Voncir and Abdullahamid (2011) in soils of Gombe, Nigeria.

Iron (Fe) status*:* This study reveals that Sudan agro-ecological zone had significantly ($P < 0.05$) more Fe than Sahel zone. The available Fe ranged from 5.78 to 16.52 mg kg^{-1} with a mean of 11.15 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, Mamman and Abdullahamid (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, Voncir and Abdullahamid (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 7.47 to 4.05 mg kg^{-1} in Sahel zone to 19.99 to 13.18 mg kg^{-1} in Sudan zone. 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 acidic 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, Mamman and Abdullahamid (2010).

Manganese (Mn) status: Mn in the studied soils ranged from 14.09 to 25.23 mg kg^{-1} (mean = 19.66 mg kg^{-1}) and significantly ($P < 0.05$) different, with Sudan agro-ecological zone having more Mn content than Sahel. 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 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 results in Bauchi State, Nigeria. The surface (0-15 cm) soils have more Mn content than the sub surface (15-30 cm). 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 Fe and Mn in the soils studied could lead to the formation of complexes which could lead to serious drainage and infiltration problems (Mustapha, Voncir and Abdullahamid, 2011).

CONCLUDING REMARKS

Results obtained from this study indicate that the soils were generally sandy to loamy sand in texture, slightly acidic and low in organic carbon with low to medium contents of exchangeable bases and Cation Exchange Capacity (CEC). 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.

Table 1: Particle Size distribution of Sudan and Sahel soils

	Sand	Silt g kg-1	Clay	Texture
Agro ecological zone				
Sudan	513.36b	240.47a	168.21a	Loamy sand
Sahel	811.17a	50.75b	126.58b	Sand
Mean	662.27	145.61	147.40	
SE+	210.59	483.69	106.14	
Location				
BuniGari	540.24	230.28	220.48	Sandy loam
College of Agric N/site	570.24	270.28	150.48	‘’ ‘’
Kasatchiya	515.24	300.28	175.48	‘’ ‘’
Gujba Village	505.24	285.28	195.48	‘’ ‘’
KasatchiyaWango	620.24	170.28	200.48	‘’ ‘’
College of Agric. Old site	550.24	270.28	170.48	‘’ ‘’
Horeyunwa	540.24	315.28	135.48	‘’ ‘’
Katarko	530.24	340.28	120.48	‘’ ‘’
GarinShuwa	610.24	280.28	100.48	‘’ ‘’
BuniYadi	615.24	185.28	190.48	‘’ ‘’
GarinKarekare	535.24	210.28	245.48	‘’ ‘’
Cattle Ranch	622.24	228.28	149.48	‘’ ‘’
GarinItace	629.24	239.28	131.48	‘’ ‘’
Guwalturam	870.40	24.28	105.04	Sandy
LawalBukarti	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	‘’ ‘’
KoriFadama	825.40	55.56	115.04	‘’ ‘’
KiriKasama	770.40	80.56	145.04	‘’ ‘’
Kalgeri	790.40	65.56	140.04	‘’ ‘’
GonariKukawa	820.40	70.56	105.04	‘’ ‘’
KirjinTilo	845.40	50.56	100.04	‘’ ‘’
Yalemari	870.40	10.56	115.04	‘’ ‘’
Mean	691.49	153.50	147.49	
SE±	23.95	14.06	9.69	
Depth (cm)				
Sudan				
0-15	533.47	231.51	156.48	Loamy sand
15-30	493.24	249.43	179.94	‘’ ‘’
Sahel				
0-15	832.71	38.87	113.12	Sandy
15-30	789.63	62.43	140.04	‘’ ‘’
Mean	737.26	145.61	147.40	
SE±	53.31	26.83	32.19	

Source: Laboratory analysis, 2014

Table 2: pH and Organic Carbon Distribution of the Sudan and Sahel Agro-Ecological zones

	pH (H2O) (1:1)	pHc (1:2.5)	Org. C. g kg-1
Agro-ecological zone			
Sudan	6.34a	5.53b	6.18a
Sahel	6.54a	5.78a	3.45b
Mean	6.44	5.66	4.82
SE+	6.44	0.63	6.95
Location			
BunuGari	5.86	5.51	5.09
College of Agric N/site	6.16	5.53	5.54
Kasatchiya	6.41	5.70	6.62
Gujba Village	6.37	5.13	4.87
KasatchiyaWango	7.00	5.47	3.76
College of Agric.Old Site	6.54	5.80	5.33
HoreYunwa	6.14	5.44	5.53
Katarko	6.79	6.05	6.08
GarinShuwa	6.12	5.34	7.57
BuniYadi	5.99	5.24	7.07
GarinKarekare	5.97	5.32	6.52
Cattle Ranch	6.15	5.30	9.89
GarinItache	7.02	6.00	6.59
Guwalturam	6.45	5.68	3.79
LawalBukarti	6.65	5.88	3.19
Tororo	6.70	6.02	3.24
Mobanti	6.73	6.03	2.99
Kukawa India	6.55	5.66	3.22
Shaneneri	6.60	5.71	3.95
Abbati	6.53	5.60	3.25
KoriFadama	6.90	6.15	2.95
KiriKasamma	6.38	5.66	2.55
Kalgeri	6.59	5.69	3.50
GonariKukawa	6.45	6.02	4.20
KirjinTilo	6.22	5.40	4.11
Yalemari	6.40	5.61	4.02
Mean	6.45	5.65	4.82
SE±	0.08	0.01	0.01
Depth (cm)			
Sudan			
0-15	6.54ab	5.70ab	7.26a
15-30	6.15c	5.35b	5.11b
Sahel			
0-15	6.67a	5.91a	3.69c
15-30	6.40b	5.56b	3.21c
Mean	6.44	5.63	4.82
SE±	0.43	0.40	1.98

Source: Laboratory analysis, 2014

Table 3: Amount of Exchangeable Bases and CEC of the two Agro –ecological Zones

	Ca	Mg	K	Na	CEC
			Cmol (+) kg-1		
Agro-ecological zone					
Sudan	3.74a	0.69b	0.20a	0.21	7.68a
Sahel	1.20b	1.00a	0.12b	0.22	3.40b
Mean	2.47	0.87	0.16	0.22	5.59
SE±	6.49	0.79	0.22	0.04	5.54
Location					
Buni Gari	3.17	0.70	0.14	0.19	5.89
College of Agric N/site	3.39	0.47	0.25	0.29	6.62
Kasatchiya	3.53	0.73	0.19	0.18	6.18
Gujba Village	3.34	0.73	0.20	0.16	5.70
Kachiya Wango	4.62	0.51	0.22	0.16	8.52
College of Agric. Old site	4.23	0.51	0.20	0.25	8.00
Hore Yunwa	2.59	0.52	0.15	0.15	6.75
Katarko	5.42	0.94	0.25	0.27	12.30
Garin Shuwa	3.47	0.68	0.17	0.15	7.46
Buni Yadi	2.73	0.66	0.18	0.19	6.10
Garin Karekare	3.12	0.49	0.14	0.21	6.72
Cattle Ranch	3.65	0.96	0.22	0.22	8.77
GarinItace	5.35	1.09	0.35	0.27	10.62
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	8.70
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	2.47	0.85	0.16	0.22	5.72
SE±	0.09	0.04	0.02	0.02	1.05
Depth (cm)					
Sudan Zone					
0-15	4.23	0.72	0.24	0.22	8.75
15-30	3.25	0.66	0.17	0.19	6.59
Sahel zone					
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	2.47	0.85	0.16	0.22	2.60
SE±	0.18	0.04	0.01	0.01	0.40

Source: Laboratory analysis, 2014

Table 4: Distribution of Micronutrients in Location of the two Agro - ecological zones

	Cu	Zn	Fe	Mn
		mg kg-1		
Agro-ecological zones				
Sudan	1.09	0.48b	16.52a	25.23a
Sahel	0.31	0.85a	5.78b	14.09b
Mean	0.70	0.67	11.15	19.66
SE±	1.99	0.92	22.55	28.30
Location				
BuniGari	1.19	0.52	15.24	23.62
College of Agric. /Nsite	1.22	0.41	13.56	16.98
Kasatchiya	1.14	0.33	17.15	29.1
Gujba Village	1.33	0.33	15.09	30.97
KasatchiyaWango	1.31	0.33	13.66	17.34
College of Agric./Osite	0.95	0.53	17.38	21.34
HoreYunwa	0.77	0.63	13.74	29.09
Katarko	1.12	0.67	11.69	21.05
GarinShuwa	1.01	0.49	19.45	23.97
BuniYadi	0.96	0.59	23.13	24.13
Garinkarekare	1.06	0.53	15.53	29.94
Cattle Ranch	1.12	0.49	20.49	33.13
GarinItache	0.97	0.50	19.49	30.28
Guwalturam	0.20	0.75	4.29	12.14
LawalBukarti	0.19	1.05	4.74	8.70
Tororo	0.26	0.97	5.39	7.76
Mobanti	0.31	0.90	5.77	55.96
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
KoriFadama	0.28	0.55	6.26	11.03
KiriKasamma	0.40	0.79	6.63	12.03
Kalgeri	0.42	1.02	7.60	7.67
GonariKukawa	0.45	0.90	8.00	13.74
KirjinTilo	0.41	0.82	5.20	10.50
Yalemari	0.21	0.93	9.00	11.83
Mean	0.70	0.67	11.18	14.77
SE±	0.04	0.03	0.73	2.69
Depth (cm)				
Sudan				
0-15	0.96a	0.58b	19.99a	31.19
15-30	1.22a	0.06b	13.18b	19.27
Sahel				
0-15	0.34c	1.03a	7.47c	12.30
15-30	0.28c	0.06b	4.08	15.86
Mean	0.70	0.66	11.73	19.66
SE±	0.24	0.38	6.80	1.21

Source: Laboratory analysis, 2014

Table 5: Critical limits for interpreting levels of analytical parameters/Fertility rating

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
Org. C (g kg^{-1})	< 10	10-15	> 15
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)

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