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Profile distribution of various micronutrient cations in the teaching and research farm of the centre for dryland agriculture, Bayero University, Kano

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ABSTRACT

Micronutrients are nutrients required by plants in small quantities, and are essential for optimal plant growth and development. They play a crucial role in various physiological processes, contributing to increased crop yield and quality. The research was carried out at the Centre for Dryland Agriculture (CDA) to assess the status of micronutrients across different soil profiles. Five soil mapping units were delineated, and two soil profiles were established in each unit. Soil profile descriptions followed the USDA Soil Survey Manual, and both disturbed and undisturbed samples were collected and subjected to the dilute Hydrochloric acid (HCl) and diethylenetriaminepentaacetic acid (DTPA) analysis. The study found that iron (Fe) levels were generally rated low to moderate, while zinc (Zn), manganese (Mn), and copper (Cu) ranged from moderate to high across all mapping units. Zinc levels extracted with HCl were higher than those extracted with DTPA in all units, except mapping unit downstream (DS), where no consistent trend was observed in both pedons of DS1 and DS2. The distribution of Zn and Mn generally showed inconsistent decreases with depth for both HCL and DTPA extractions. Moderately higher HCl-extractable Cu values were observed in the surface horizons of pedons GH2 and US1 (1.84 and 1.41 mg kg⁻¹, respectively), while slightly elevated DTPA-extractable Cu was recorded in profiles BN1, DS1, and US1. HCl-extractable Fe was mostly low (<2.5 mg kg⁻¹) in surface horizons but reached moderate levels (2.5–5 mg kg⁻¹) in pedons GH2 and US1. Overall, DTPA-extractable micronutrients were rated moderate to high and were generally higher than those extracted by HCl. The findings demonstrated the variability of micronutrient distribution across soil depths and emphasized the need to carefully monitor the application of micronutrient-bearing amendments to prevent potential toxicity.

Keywords: Soil profile, Soil mapping units, Pedons, Dryland agriculture, Micronutrients.

INTRODUCTION

Iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn) are termed as essential micronutrients, required by plants in trace amounts and play very significant roles in plant growth and development. Micronutrients, despite being required in small quantities, are essential for optimal plant growth and development. They play a crucial role in various physiological processes, contributing to increased crop yield and quality. These elements (Fe, Mn, Cu and Zn) are positively charged micronutrients which form complexes with different enzymes and other organic compound functional groups (Shenkin, 2006). Micronutrients are very important for maintaining soil health and also for increasing the productivity of crops. Total levels are rarely

indicative of plant availability, because availability depends on soil pH, organic matter content, adsorptive surfaces, and other physical, chemical, and biological conditions in the rhizosphere (Jiang, 2009). The distribution of micronutrients within a soil profile is influenced by several factors, including parent material, climate, soil texture, organic matter content, biological activity, and human interventions. The knowledge of the profile distribution of micronutrient cations is important as roots of many plants go beyond the surface layer and thus draw a part of the nutrient requirement from the subsurface layers of the subsoils. The information on the distribution of micronutrients across the profile in the Centre for Dryland Agriculture (CDA) research farm has not been

documented despite their importance with respect to crop production. Therefore, this research aimed to study the distribution of micronutrients cations within the soil profiles.

Materials and Methods

The study was carried out at the Centre for Dryland Agriculture (CDA) research farm in Bayero University, Kano, new campus, Tofa Local Government, along Gwarzo road, Kano State. The area of the farm is 35 hectares, with undulating surfaces. It is situated between Latitude $11^{\circ}58'45.09''$ to $11^{\circ}59'6.12''$ N, and Longitude $008^{\circ}24'41.13''$ to $008^{\circ}25'15.88''$ E (Figure 1), with the variation in elevation of 428-440m above the sea level. The mean annual precipitation of the area is about 800 mm around metropolitan Kano.

Four soil mapping units were delineated based on auger observations at 154 grids, and named as;

Greenhouse (GH), Bananah (BN), Downstream (DS) and Upstream (US). Two standard profiles ($2 \times 1 \times 2$ m) were cited and dug in each of the soil units to a 2 m depth, unless an impenetrable layer or water table was encountered. The profiles were described according to the USDA Soil Survey Manual (Soil Science Division Staff, 2017) and soil samples were collected evenly within each of the horizons. Soil micronutrients (Cu, Fe, Mn, and Zn) were determined using the dilute Hydrochloric acid (HCl) and diethylenetriaminepentaacetic acid (DTPA) method described by Lindsay and Norvell (1978). Ten grams soil sample were saturated with diethylenetriaminepentaacetic acid (DTPA) solution, shaken for two hours and centrifuged. The Zn, Cu, Fe, and Mn in the extracts were determined using an atomic absorption spectrophotometer (AAS). The data were subjected to analysis of variance (ANOVA) and means were separated using Turkey Honestly significance differences (HSD).

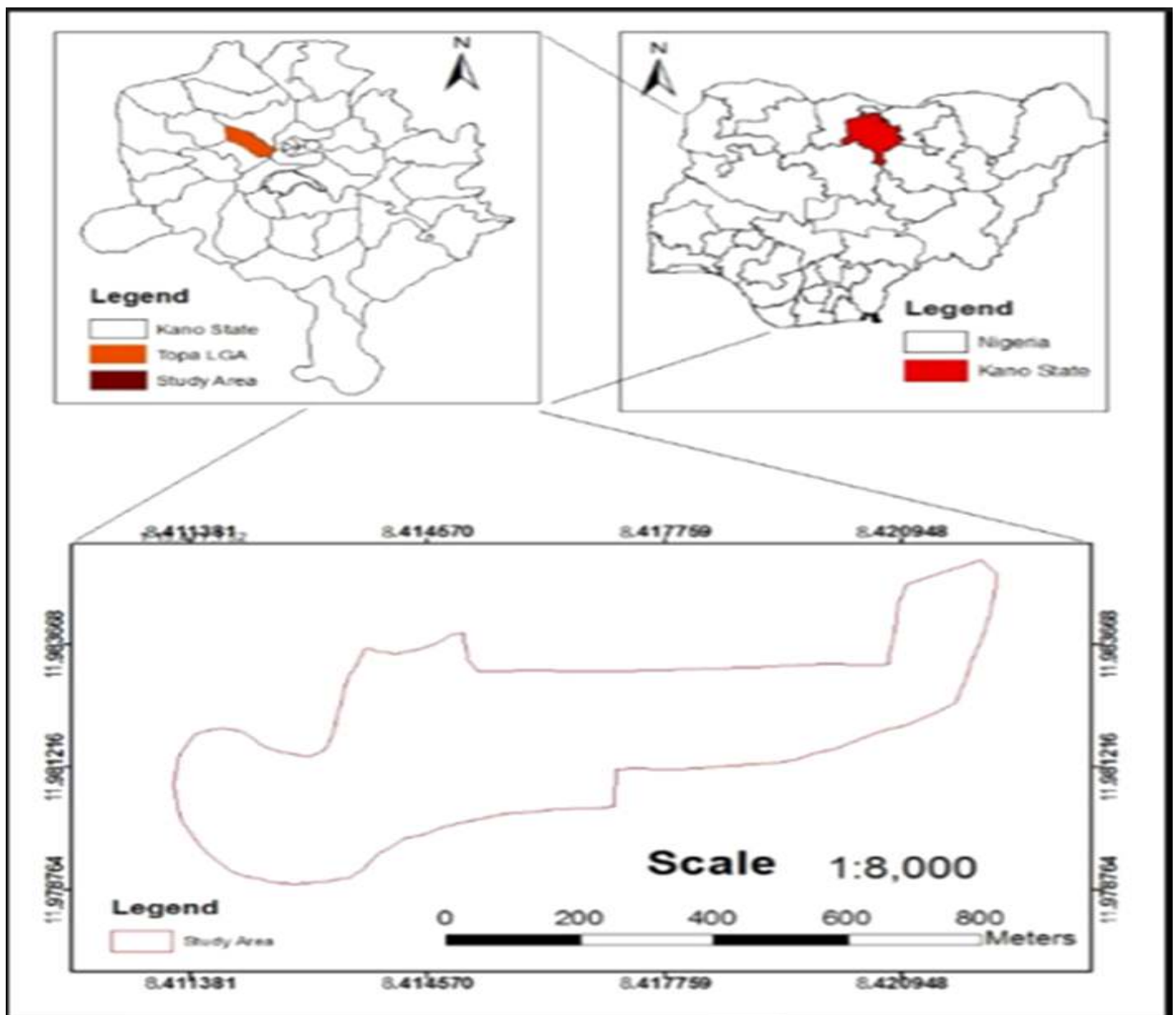


Figure 1: Map of the location of the study area

Results and Discussion

The status of available micronutrients extracted with both 0.1M HCl and DTPA is presented in Table 1. The values of Fe extracted with hydrochloric acid (HCL) in the surface horizon varied from 0.04 - 3.62 mg kg⁻¹, and from 0.14 - 5.04 mg kg⁻¹ in the subsurface layers. The iron (Fe) content extracted with HCL was generally rated low (<2.5 mg kg⁻¹) in all the surface horizons, while moderate values (2.5 -5 mg kg⁻¹) were observed in the surface horizons of pedon GH2 and US1. The higher values of HCL-extractable Fe in the surface horizons of pedon GH2 and US1 might be attributed to regular addition of Fe through plant residues in the surface layers in soil units, and the finding conforms with the results reported by Odunze and Kureh (2007) and Aliyu (2023) of soil in Northern Guinea Savannah Iron (Fe) content (HCL) was inconsistently decreased with an increase in soil depths in pedon GH2, BN2 and DS1, whereas an irregular increasing trend was observed in pedon BN1, DS2, US1 and US2. Low content HCL-extractable Fe was observed in the surface soil compared to the subsurface soil, which might be attributed to high organic matter and clay content in the soil which bound them strongly to the surface exchange complex making them unavailable in the soil. The higher value in subsurface could be linked to nature of parent materials or geological formation. Maniyunda *et al.*, (2015) stated that the high content of Fe in savannah soils might be linked to the nature of soils formed from the basement complex, which were characterized by higher available Fe content in their mineral compound (hematite and goethite). Inversely, higher values of Fe (DTPA) were recorded in most overlying horizons and ranged from 0.93 – 87.62 mg kg⁻¹ and decreased irregularly with increase in soil depth in all the soil units. The values of Fe extracted by DTPA were generally higher than those extracted by HCl in most of the profiles except in pedon BN2 and DS2 where a different pattern was observed.

The values of Zinc (Zn) extracted by HCl were higher than those extracted by DTPA in all soil units, except map unit DS where an undefined pattern was observed in pedon DS1 and DS2. The values of Zn were inconsistently decreased with soil depth

increase for both HCl and DTPA in all the pedons, except profile DS1 and DS2 where an uneven pattern was observed (Table 1). Furthermore, soil mapping unit BN has higher values of Zn for both HCl and DTPA extractions than any other unit. This finding was unusual and could have been influenced by stronger selectivity for zinc and manganese in specific soil conditions, such as soil pH. The values of Zn and Mn were inconsistently decreased with soil depth for both HCl and DTPA in all the mapping units, because Zn and Mn tend to be less mobile in the soil compared to some other nutrients and they can be readily adsorbed onto soil particles, particularly clay minerals and organic matter, which are often more abundant in the surface soil. Sharma *et al.*, (2000) stated that organic matter decomposition promoted the available Zn in the surface soils as a result of stable complexes that Zn forms with organic compounds.

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The decrease in Mn with soil depth followed a similar pattern with that of organic carbon and the finding conformed with the research reports of Raji (2016) and Aliyu (2023). Additionally, Jimoh (2021) reported that an increase in OC content in the soil might increase the availability of Mn content in the soil. Furthermore, the content of Mn was also reported to be higher in the surface horizon and decreased irregularly with increasing soil depth (Gupta *et al.* 2003 and Oti *et al.* 2017)

Moderately higher values of Cu extracted by HCl were observed in the surface soil of pedon GH2 and US1 with the values of 1.84 and 1.41 mg kg⁻¹ respectively, whereas profile BN1, DS1, and US1 had slightly higher values of Cu extracted by DTPA in the horizons. Copper (Cu) also showed a similar trend to that observed in Fe with inconsistent distribution within the soil depth. The values of copper were rated moderate based on the critical limit (0.21 – 2 mg kg⁻¹) reported by Esu (1991), and the upper horizons of soil unit GH and US had slightly higher values of Cu than their corresponding underlying horizons (Table 1). The higher values of Cu in these surface soils might be attributed to complexation of Cu with organic matter content in the soil, and similar finding was reported by Dhaliwal *et al.* (2019) who stated that organic carbon enhanced the availability of Cu through the formation of complexes with organic matter,

preventing Cu from losses through fixation, leaching oxidation and precipitation. The increase in copper content with depth, might probably due to the bund effect of extractable Cu to clay fraction (Raji, 1995), to parent materials or specific properties of the soil, hence the presence of specific clay minerals with a high affinity for Cu can promote its accumulation in deeper horizons. Aliyu (2023) attributed higher concentration in the B horizon to vertical eluviations of Cu and leaching and low organic matter content, while Maniyunda (2012) linked an increase in Cu at the subsurface soil to the weathering of calcium-bearing parent materials.

Comparing the profiles, there were no significant difference between all the surface soil variables for the two methods, except iron extracted with HCl, which had a significant difference ($p < 0.05$) (Table 2). Similarly, significant differences were observed in the entire underlying horizon, except Zn (HCl) (Table 3). The soil mapping units did not significantly differ in the distribution of the micronutrients between the two methods in the surface soil, except for Cu where significant higher value was recorded in the GH mapping unit (Tables 4 and 5). The soil unit DS and BN recorded the highest significant values of Zn, Mn and Cu extracted by DTPA, while US and BN mapping exhibited high significant values of Fe and Cu extracted with HCl with values of 3.04 mg kg⁻¹ and 1.001 mg kg⁻¹ respectively.

Table 2: Analysis of variance of micronutrients in the Surface Soils in different Soil Profiles

Profile	Iron (Fe)		Zinc (Zn)		Manganese (Mn)		Copper (Cu)	
	HCl	DTPA	HCl	DTPA	HCl	DTPA	HCl	DTPA
	mg kg ⁻¹							
GH1	0.52b	19.25	0.23	0.11	17.98	4.63	1.51	0.78
GH2	2.82ab	9.35	0.56	0.44	13.07	9.46	1.84	2.37
BN1	1.00b	16.8	1.01	1.15	11.8	9.53	0.76	5.04
BN2	0.28ab	0.93	0.26	0.04	1.37	0.96	0.54	1.24
DS1	1.33ab	66.5	0.59	0.18	24.24	42.06	0.86	2.85
DS2	0.04ab	21.1	0.13	0.63	5.06	7.11	0.74	1.15
US1	3.02a	27.08	0.28	0.07	7.73	6.84	1.03	0.47
US2	0.95ab	49.37	0.2	0.34	21.22	22.7	0.91	0.88
P-Value	0.031	0.111	0.8	0.822	0.286	0.09	0.085	0.056

Table 3: Analysis of variance of micronutrients in Subsurface Soils in different Soil Profiles

Profile	Iron (Fe)		Zinc (Zn)		Manganese (Mn)		Copper (Cu)	
	HCl	DTPA	HCl	DTPA	HCl	DTPA	HCl	DTPA
	mg kg ⁻¹							
GH1	1.66ab	7.82b	0.144	0.085ab	8.78ab	6.47b	0.73abc	0.49bc
GH2	2.04ab	3.39b	0.213	0.020b	2.17bc	2.77b	1.07a	3.14a
BN1	0.87ab	6.27b	0.275	0.020b	2.46bc	1.63b	1.04a	3.00a
BN2	0.32b	0.28b	0.159	0.038b	1.08c	0.67b	0.98abc	1.26b
DS1	2.35ab	46.91a	0.193	0.380ab	15.05a	38.0a	1.04a	1.47b
DS2	0.33b	0.52b	0.136	0.412a	2.05bc	3.17b	0.65bc	1.21b
US1	3.17a	15.34b	0.307	0.045ab	2.34bc	1.46b	0.72abc	0.15c
US2	2.86a	16.59b	0.149	0.173ab	5.20bc	5.87b	0.59c	1.38b
P-Value	0.001	<0.001	0.232	0.008	<0.001	<0.001	0.001	<0.001

Table 4: Analysis of variance of micronutrients in Surface Soils in different Soil Units

Unit	Iron (Fe)		Zinc (Zn)		Manganese (Mn)		Copper (Cu)	
	HCl	DTPA	HCl	DTPA	HCl	DTPA	HCl	DTPA
	mg kg ⁻¹							
GH	1.29	15.96	0.343	0.217	16.34	6.240	1.619a	1.307
BN	0.76	11.51	0.755	0.777	8.320	6.670	0.686b	3.770
DS	0.90	51.33	0.435	0.330	17.85	14.65	0.821b	2.280
US	1.98	38.22	0.239	0.205	14.47	30.41	0.968b	0.673
P-Value	0.479	0.091	0.580	0.667	0.635	0.160	0.003	0.090

Table 5: Analysis of variance of micronutrients in Surface Soils in different Soil Units

Unit	Iron (Fe)		Zinc (Zn)		Manganese (Mn)		Copper (Cu)	
	HCl	DTPA	HCl	DTPA	HCl	DTPA	HCl	DTPA
	mg kg ⁻¹							
GH	1.82ab	5.92	0.173	0.057b	5.948	4.880ab	0.872ab	1.623ab
BN	0.56b	2.94	0.211	0.030b	1.694	1.098b	1.006a	2.032a
DS	1.23b	21.1	0.161	0.397a	7.827	18.67a	0.827ab	1.323ab
US	3.04a	15.87	0.239	0.100b	3.567	3.346ab	0.662b	0.677b
P-Value	0.001	0.065	0.532	<0.001	0.092	0.041	0.032	0.044

CONCLUSION

This study elucidated the profile distribution of essential micronutrient cations (Fe, Zn, Mn, Cu) within the soils of the Teaching and Research Farm, Centre for Dryland Agriculture, Bayero University Kano. Findings indicated a heterogeneous distribution, with Fe levels predominantly low to moderate, while Zn, Mn, and Cu concentrations ranged from moderate to high across the delineated soil profiles. The observed inconsistent vertical distribution of these micronutrients is attributable to complex interactions involving organic matter content, clay mineralogy, and parent material characteristics. Furthermore, DTPA-extractable micronutrient concentrations generally surpassed

those obtained via HCl extraction, demonstrating method-dependent availability assessments. These results underscored the intrinsic variability in micronutrient dynamics within these agricultural soils and emphasized the critical necessity for precise, site-specific micronutrient management strategies. Such targeted interventions are crucial for optimizing plant nutrition, mitigating potential toxicities, and ultimately fostering sustainable agricultural productivity in similar dryland environments.

RECOMMENDATION

Application of any materials bearing micronutrient should be monitored so as to reduce the toxicity of micronutrients

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