COPPER CONCENTRATIONS IN SOILS OF NAROK COUNTY, KENYA

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ABSTRACT

Copper (Cu) deficiency has been identified in soils in major wheat (*Triticum aestivum* L.) growing areas in Kenya. The objective of this study was to determine the concentration levels of copper in soils of wheat growing areas in Narok, County (1.3605° S, 35.7407° E). Fifty soil samples were collected from Narok Town (1.0918° S, 35.8498° E), Olokurto (0.6333° S, 35.8500° E), Nkareta (0.9134° S, 35.7734° E), Olorropil (0° 43' 38" S, 35° 58' 53" E) and Melili (0.9333° S, 36.0833° E). The concentration of Cu ions in the soil samples were determined by use of Atomic Absorption Spectrophotometer. The results showed the concentration levels varied between and within the farms of which 58% of the samples were below the critical value 1.0 mg/kg and was deemed as low concentration whereas 42% of the soil samples were above the critical concentration value of 1.0 mg/kg hence were adequately supplied with Cu for wheat growing. The total average mean was 0.98±0.11mg/kg, which according to Soil Classification was below the critical value of Cu hence, these findings are an indication of copper deficiency in soils in wheat growing areas in Narok North Sub-County. This study recommends that wheat seed should be dressed with Cu compounds before planting and sprayed at tillering stage to alleviate copper deficiency. Moreover farmers should be advised to constantly carry out soil testing in order to correct the deficiency of this micronutrient. It is therefore necessary to formulate fertilizers that contain Cu as a micronutrient.

Key Words: *copper deficiency, concentration levels, Atomic Absorption Spectrophotometer, wheat, critical value*

INTRODUCTION

Globally, most of the arable soils are deficient in micronutrients including Copper (Cu), which affects human nutrition (Cakmak *et al*., 2017). In East Africa soil related abiotic factors hindering wheat (*Triticum aestivum* L.) production in wheat growing regions include poor soil fertility yet, most staple cereals like maize (*Zea mays* L.), rice (*Oryza sativa* L.) and wheat are grown in these soils deficient in micronutrients (Hengl *et al*., 2017). In Kenya, Narok North Sub-County is one of the counties where wheat is grown. However, farmers have experienced decreased wheat yields over the years. This has been mainly attributed to deficiency in micronutrients including Cu, which is very important in wheat growth, development and pollen viability. Cu - deficiency in soils of wheat growing areas identified include Nakuru and Narok (Pinkerton, 1967). Many studies have shown Cu deficiency in remote non-wheat growing areas of the country such as Shimba Hills (Sutton *et al*., 2002) and Solio Wildlife Conservancy (Maskall and Thorton, 1991). This may be indicative of widespread Cu deficiency in Kenyan soil including wheat-growing areas. The general trend in poor production of wheat in East African countries are likely due to poor soil fertility especially nutrient deficiency (Gold *et al*., 1999). This has been worsened by other factors such as pest, diseases, drought and salinity. To solve the micronutrient deficiency and to improve productivity, majority of the farmers in the region have resorted to use of chemical fertilizers. In Kenya, copper oxychloride has been applied as a seed dressing and foliar feed in commercial wheat farms for over two-and-half decades (Owuoche *et al*., 1994 and Pinkerton 1967). Moreover, copper sulphate and copper oxide have been used to correct Cu deficiency in the soil in commercial wheat production in Australia (Graham *et al*., 1981). These inorganic fertilizers provide multiple effects on the plant by increasing vigour, grain yield, and protection of wheat crop from fungal foliar infections (Owuoche *et al*., 1994 and Graham, 1984), however it is harmful to human health, animals and environment if not used properly. The objective of this study was to determine the concentration levels of copper in soils from wheat growing areas of Narok North Sub-County.

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MATERIALS AND METHODS

Experimental site

Narok North Sub-County is located at southern part of Kenya bordering Tanzania and geographically located at latitude 1° 5' 0" S and longitude 35° 52' 0" E, and altitude of 1827 m above sea level (Jaetzold *et al*., 2010). It lies across lower highland (LH) and upper highland (UH) agro ecological zones, which support wheat production in Kenya (Jaetzold *et al*., 2010). The annal rainfall varies between 500 and 1800 mm (Jaetzold *et al*., 2010). The rainfall comes in two seasons. The short rains commence from October to December for both zones and long rains from April to May each year. The lower highland zones experience long rains during early February, with temperatures ranging from 17 to 29 °C (Jaetzold *et al*., 2006). In these areas, the soils are deep and well drained, primarily sandy loam, with a moderate to high inherent fertility (Jaetzold *et al*., 2010).

Soil sampling

Soil samples were obtained from wheat growing farms in Narok North Sub-County in Narok County where wheat is grown under large-scale and small-scale farms. The samples were collected from Narok Town (1.0918° S, 35.8498° E), Olokurto (0.6333° S, 35.8500° E), Nkareta (0.9134° S, 35.7734° E), Olorropil (0° 43' 38" S, 35° 58' 53" E) and Melili (0.9333° S, 36.0833° E) at a depth of 0-20 cm using soil auger as described by Mahler and Tindall (1990). Fifteen sub-samples were randomly collected in a zigzag manner from 0.405 ha farm and placed in a polyethylene bucket in each farm. The soils were then thoroughly mixed and a composite sample was taken and put in a clean polyethylene bag. Fifty (50) soil samples were collected in the 50 randomly selected farms in the Sub-County. Finally, the soil samples were taken to Kenya Agricultural and Livestock Research Organization (KALRO) - Kabete soil laboratory for further analysis.

Determination of copper concentration

To determine Cu content in the soil, soil samples were air-dried at room temperature (about 22±3°C) for three days. According to Okalebo *et al*., 2002, sample of 5 g of each of the dried soil were weighed and placed in a 100 ml bottle and 50 ml of 0.1M hydrochloric acid (extracting solution) added .The extracting solution facilitates freeing of elements to be analysed. It was then mixed well and shaken mechanically with a table universal shaker (Vortex shaker, Jack A. Kraft and Harold D. Kraft, City, U.S.) at a speed of 240 rpm for about one hour. Qualitative Filter Paper, (Whatman Grade 1) was used with V-shaped funnel to filter the suspension. Blank (10 ml of 0.1M hydrochloric acid) and an internal reference sample (10 ml of standard soil) were included in each series (Crop Nutrition Laboratory Services, 2013). Cu concentration was read over an Atomic Absorption Spectrophotometer HCL extraction method (Hinga *et al*., 1980). A wavelength of 324.7 nm was used to quantify the absorption of Cu in the soil samples by use of Atomic Absorption Spectrophotometer (AA-7000 series, Shimadzu Corporation, 1968). The standard was prepared from a stock solution of 1000 mg/L Cu (3.929g from Copper Sulphate Pentahydrate, ammonium ferrous Sulphate, Zinc Sulphate. From the stock solution of Cu, 2 ml was drawn into a 100 ml volumetric flask and fill up with distilled water (20 mg/l Cu). From the 20 μ per kg Cu, 0,2,4,6,8,10, was drawn into each 100 mL volumetric flask and filled up with 0.1 M HCL to make the standard series. These standard series have a concentration of 0-0.4-0.8-1.2-1.6-2.0 mg/kg Cu. The instrument was calibrated using the standard series. The blank extract (10 mL of 0.1M hydrochloric acid) was nebulized into a blue flame and Cu concentration measured (Okalebo *et al*., 2002). After measurement, the Cu concentration in the soil samples was calculated using the following formula by Okalebo *et al*, (2002):

Cu (mg/kg) = (a-b) x 10 x D, where *a* is the concentration of Cu in the soil sample extract (mg/Kg), *b* is concentration of Cu in the blank extract (mg/ kg), *D* is dilution factor, if any.

A table of classifications of available nutrients in soils by HCL extraction method, Hinga *et al*., 1980 was used to establish the concentration of the nutrients, (Table I).

Data Analyses

Descriptive statistical analyses including means, ranges and standard deviations were used to explore the data using Genstat software and graphs plotted in MS Excel. Nutrient sufficiency ranges (low, adequate and excess) were used to group the soil samples depending on respective nutrients levels as by the Soil Classification Table.

RESULTS

Copper ion concentration in the soil

The concentration of Cu was analysed in the 50 soil samples from wheat growing areas in Narok North Sub-County. The results showed the concentration levels varied from sample to sample. The concentration was found to range from 0.1 mg/kg to 2.63 mg/kg in the analysed soil samples in the four wards (Table I). It was classified as low or adequate according to critical value of Cu which is 1.0 mg/kg in the HCL extraction method (Hinga *et al*., 1980). Twenty nine soil samples, which makes up to 58% contained Cu below the critical value of 1.0 mg/kg and was deemed as low whereas 21 soil samples (Figure 1), which makes up to 42% were above the critical value of 1.0 mg/kg hence were adequate in copper. The overall mean of the Cu concentration in the soil samples was 0.98±0.11 (SE) mg/kg (Table II), which according to the soil classification table was below the critical value of 1.0 mg/kg hence; most soil samples analysed were low in Cu ion concentration. The farms in the five wards had different concentration of copper. Most of the soils in Oloropil and Olokurto wards had adequate levels of copper in their soils ranging from 0.1 to 2.63 mg/kg and 0.37 to 2.62 mg/kg respectively (Table I). Farms in the other three wards Melili, Nkareita and Narok North had low levels of Cu in their soils which ranged from 0.33 to 1.99 mg/kg, 0.33 to 1.84 mg/kg and 0.1 to 1.02 mg/kg respectively (Table I).

TABLE I- COPPER (CU) CONCENTRATIONS IN THE SOIL SAMPLED FROM NAROK KENYA

	Soil Depth 0-30 cm		
Lab No (Soil samples)	Copper value (mg/kg)	Class	
Farm 1 (Oloropil)	2.32	Adequate	-
Farm 2 (Oloropil)	2.35	Adequate	-
Farm 3 (Oloropil)	0.10	-	Low
Farm 4 (Oloropil)	1.0.0	Adequate	-
Farm 5 (Oloropil)	0.24	-	Low
Farm 6 (Oloropil)	2.63	Adequate	-
Farm 7 (Oloropil)	1.06	Adequate	-
Farm 8 (Oloropil)	1.00	Adequate	-
Farm 9 (Oloropil)	2.22	Adequate	-
Farm 10 (Oloropil)	0.67	-	Low
Farm 11 (Olokurto)	0.90	-	Low
Farm 12 (Olokurto)	2.10	Adequate	-
Farm 13 (Olokurto)	2.62	Adequate	-
Farm 14 (Olokurto)	1.11	Adequate	-
Farm 15 (Olokurto)	0.37	-	Low
Farm 16 (Olokurto)	1.00	Adequate	-
Farm 17 (Olokurto)	1.60	Adequate	-
Farm 18 (Olokurto)	1.00	Adequate	-
Farm 19 (Olokurto)	1.60	Adequate	-
Farm 20 (Olokurto)	0.72	-	Low
Farm 21 (Melili)	0.33	-	Low
Farm 22 (Melili)	0.45	-	Low
Farm 23 (Melili)	0.84	-	Low
Farm 24 (Melili)	0.97	-	Low

Farm 25 (Melili)	0.79		Low
Farm 26 (Melili)	1.89	Adequate	-
Farm 27 (Melili)	0.77	-	Low
Farm 28 (Melili)	1.28	Adequate	-
Farm 29 (Melili)	0.62	-	Low
Farm 30 (Melili)	1.99	Adequate	-
Farm 31 (Narok North)	1.84	Adequate	-
Farm 32 (Narok North)	0.67	-	Low
Farm 33 (Narok North)	0.33	-	Low
Farm 34 (Narok North)	0.48	-	Low
Farm 35 (Narok North)	0.68	-	Low
Farm 36 (Narok North)	0.59	-	Low
Farm 37 (Narok North)	0.97	-	Low
Farm 38 (Narok North)	0.72	-	Low
Farm 39 (Narok North)	1.00	Adequate	-
Farm 40 (Narok North)	1.21	Adequate	-
Farm 41 (Nkareita)	0.36	-	Low
Farm 42 (Nkareita)	0.12	-	Low
Farm 43 (Nkareita)	0.10	-	Low
Farm 44 (Nkareita)	0.30	-	Low
Farm 45 (Nkareita)	0.42	-	Low
Farm 46 (Nkareita)	0.65	-	Low
Farm 47 (Nkareita)	1.00	Adequate	-
Farm 48 (Nkareita)	1.02	Adequate	-
Farm 49 (Nkareita)	0.12	-	Low
Farm 50 (Nkareita)	0.15	-	Low
Total n =50		21	29

Copper (Cu) concentrations in different soils samples tested from different farms in the five wards of Narok North Sub-County. From the results 21, soil samples had adequate levels of copper and 29 soil samples had low concentration.

TABLE II-STATISTICS AND PERCENT CU CONCENTRATION IN SOILS SAMPLES

Descriptive Statistics	Value (mg/kg)	
Mean	0.98	
Range	0.1-2.63	
Standard deviation	0.72	
Standard error	0.11	
Number of sample	< 1.0	58%
Number of sample	>1.0	42%

Summary statistics (Mean, Standard Deviation Standard error and Range) and percent of soils samples with copper concentration levels below and above critical value for copper 1.0 mg/kg. (21 soil samples were above the critical value hence adequate in copper and 29 soil samples below the critical value hence low in copper).Figure 1

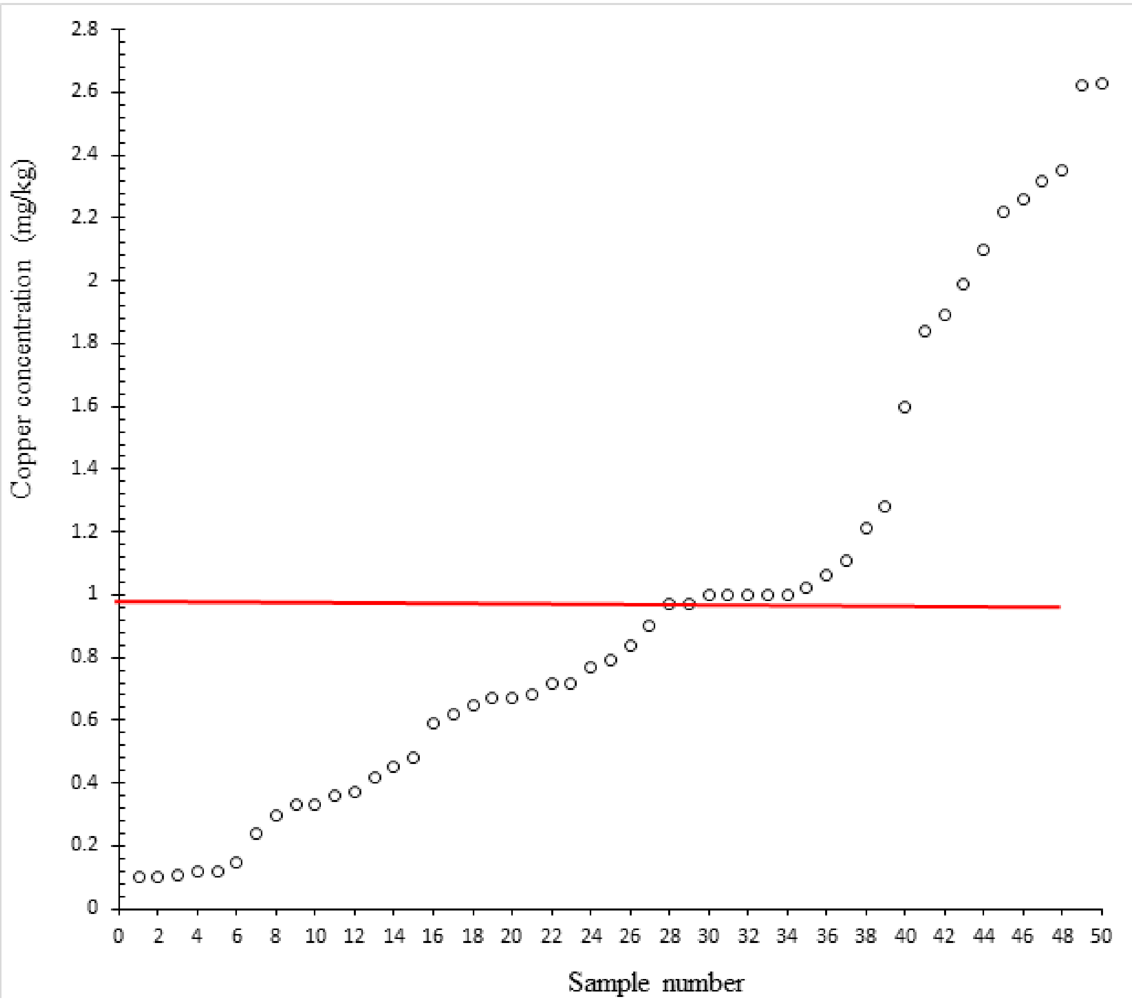

Figure 1: Copper (Cu) concentrations in different soils samples

The continuous red line separates values that lie below and above the critical value for copper 1.0 mg/kg.

DISCUSSION

The total mean of the copper concentration in the soil samples of all the farms in the five wards was 0.98±0.11 mg/kg, which according to the soil classification was below the critical value of 1.0 mg/kg which indicates copper deficiency. This copper deficiency can be attributed to the genesis of the soil from volcanic activity that lack micronutrients and extended periods of soil erosion. It can also be due to continuous intensive cropping without applying fertilizer or manure containing these nutrients and low and unbalanced use of fertilizers containing mainly Nitrogen (N), Phosphorus (P) and Potassium (K). The farms in the different wards had different Cu concentration in the soil. Most of the farms in Oloropil and Olokurto wards had adequate levels of Cu concentration levels in their soils whereas farms in Melili, Nkareita and Narok North had low levels of Cu concentrations in their soils. However, determination of the efficiency of the wheat plant concerning uptake and utilization of Cu was beyond the scope of this study. The adequate levels of Cu could have resulted from the relatively high organic matter status of the soils in Oloropil and Olokurto wards compared to the other three wards; Melili, Nkareita and Narok North. Landon (1991), Katyal and Randhawa (1983) showed that iron, zinc and copper content increases with rise in organic matter levels in the soils. Relatively high copper content in Oloropil and Olokurto wards soils compared to other three wards; Melili, Nkareita and Narok North soils might also be due to differences in parent rock from which the soil is formed, difference in modes deposition, transport and weathering regimes (White and Zasoski, 1999).

Most soil samples analysed in the wards were low in Cu ion concentration, since for normal arable soils, total Cu range from 1 to about 50 ppm (Gilbert, 1952). This finding is in agreement with the study done by Pinkerton 1967. He established Cu deficiency which contain less than 3 mg/kg Cu by analysis with Aspergillus niger (M), in soils in some of wheat growing areas including Nakuru and Narok. According to Sutton *et al*., 2002 their studies have showed Cu deficiency in remote non-wheat growing areas of the country such as Shimba Hills and Solio Wildlife Conservancy (Maskall and Thorton, 1991). This may be indicative of widespread Cu deficiency in Kenyan soils including wheat-growing areas. However, this study does not agree with the findings of Nafuma *et al*., (2001) who found the concentration of copper in soils of Uasin Gishu to range from 2-7 mg/kg which is adequate based on a critical value of Cu, 1.0 mg/kg. Moreover, according to the studies done by Farshid, 2011 in the soils of Tashk, he found the concentration of Cu in the soils to be 1.4 mg/kg, which was sufficient based on a critical value of Cu 1.0 mg/kg. This was much higher compared to concentrations of Cu found in this study.

CONCLUSION AND RECOMMENDATIONS

The Cu concentration levels of the analysed samples varied between samples. The concentration was found to range from 0.1 to 2.63 mg/kg the in the 5 wards. The overall mean of Cu concentration for the analysed soil samples was 0.98±0.11 (SE) mg/kg, which is below the critical value 1.0 mg/kg. The farms in the different wards had different Cu concentration in the soil. Most of the farms in Oloropil and Olokurto wards had adequate levels of Cu in their soils whereas most farms in the other three wards Melili, Nkareita and Narok North had low levels of Cu in their soils. The finding of this study indicate Cu deficiency in soils of wheat growing areas in Narok which might have originated from volcanic activities. Thus, wheat seed should be dressed with Cu compounds before planting and sprayed at tillering stage to alleviate copper deficiency. Moreover farmers should be advised to constantly carry out soil testing in order to correct the deficiency of this micronutrient. It is therefore necessary to formulate fertilizers that contain Cu as a micronutrient.

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