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Assessment of Available Macro and Micronutrient Status in Soils of Mansala-Kayikoro, Kita Mali

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ABSTRACT

Background: The soil fertility assessment is crucial for sustainable agriculture and plant yields. The knowledge of the trophic level of agricultural soil fertility is mandatory in order to define the development of food crops due to the lack of soil fertility assessment in this region and the decrease in crop yields.

Methods: In this context, an investigation was carried out to study the fertility status of the Mansala-Kayikoro soils and some essential soil properties, such as pH, CEC, OM, EC *etc*. Ten soil samples were collected from farming areas and analyzed for macronutrients, micronutrients and essential soil physicochemical properties.

Result: Soils of the Kayikoro area were highly acidic to slightly acidic in reaction with a low to high organic carbon (OC) content. According to the data, the cation exchange capacity (CEC) was deficient. The available macronutrients such as N, P and K content in the soils were found below the requirement of plant. The concentration of micronutrients such as iron, copper, manganese and zinc was slightly low in the analyzed samples.

Key words: Available NPK, Fertility, Mali, Mansala-Kayikoro, Nutrients.

INTRODUCTION

The soils of Sub-Saharan African countries have a low level of inherent fertility associated with specific natural constraints for each Agroecological zone. The Agricultural area of Mansala-Kayikoro (Mali) has lacked investigations and the crops have growing and yield problems. These deficiencies are critical factors in crop production. It is necessary to use agrochemical fertilizers inputs under different crops to compensate for the lack of nutrients (Romera *et al*., 2021). Soil fertility is a vital factor that influences the productivity of various crops. It is also seen as part of the sustainable agriculture production process. The productivity of soil depends on its ability to provide nutrients to its plants. The lack of these essential nutrients can severely affect soil stability and productivity (Naidu *et al*., 2019). The arable soils of Mansala-Kayikoro are deficient in micronutrients, especially in Zinc (Zn), Boron (B) and Copper (Cu), which subsequently affect plant production capacities (Gårdestedt *et al*., 2009).

The trophic level of soil depends on many factors that the land users must know, such as soil types, climate, fauna and flora. Fertile soil is rich in organic matter that retains water and provides the nutrients crops need. It also has an equilibrated texture for easy water drainage (Matthews, 2014). Understanding the dynamics of nutrient uptake and their biological interactions can help improve the efficiency of croplands. However, excess concentrations of any nutrient may cause the uptake of certain plants, which afterwards can also affect the overall productivity of the soil. Aside from the micronutrients present in the soil, the availability of macronutrients also promotes crops' most critical growth and production factor (Dhotare *et al*., 2019).

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The physicochemical properties such as soil texture, OM, calcium carbonate, CEC, pH and EC of soil play a significant role in determining nutrient availability (Kakar *et al*., 2018). The present investigation was carried out to assess the status of available macro and micronutrients to help farmers with the exact quantity of fertilizers they need to supply for the adequate production of their crops.

MATERIALS AND METHODS

Study area

Mansala-Kayikoro is the study area. It is located in western Mali, near the rural commune of Kofeba, in the Region of Kita. It is situated between latitude 13°00′50.39″N and longitude 09°39′28.90″W with an altitude of 312 m

(1023,62 feet) from mean sea level, as indicated in the study area map (Fig 1). The study area has a relatively dry tropical semi-arid and it is characterized by two main seasons: rainfall and temperature. The rain is seasonal and it varies between 300 to 1000 mm annually and is mainly received from June to October. In summer maximum temperature ranges from 29°C to 40°C. The area is vital for food crop cultivation and the economic source of the farmers in this region mainly depends upon the crops of millet, sorghum, groundnut and cotton.

Sampling and preparation of soil samples

In this study, a non-probability sampling technique was used. Several sampling points were selected and 10 soil samples were taken and mixed according to the Fisher device to obtain 4 composite samples (D_1, D_2, D_3 and D_4). Samples were collected from 0 to 30 cm depth according to the rooting depth of food crops. Soil samples were collected and labelled in a rigid paper bag for the laboratory for macro and micronutrients as well as physicochemical analysis. After removing plant debris and pebbles, the samples were air-dried for one week and then sieved to ensure homogeneity using a 2 mm sieve. This study's experimental works were carried out in the Laboratory of the School of Engineering and Technology/National Forensic Sciences University, Gandhinagar, Gujarat, India. This investigation was performed between February to June 2022.

Physicochemical properties analysis

The collected soil samples were analyzed using standard techniques for soil physicochemical properties. Soil pH was determined in 1/2.5 (soil/water ratio w/v) suspension with a pH meter model (OAKLON pH 550) according to the method of Grewelling and Peech (1960). Organic matter (OM) content was measured according to the ignition method after burning at 500-600°C overnight (Schollenberger, 1945). Electrical conductivity (EC) was measured using a portable probe conductivity meter (Systronics conductivity meter 304). The cation exchange capacity (CEC) was assessed with the Agronomic Soil Tests method. Calcium Carbonate ($CaCO_3$) was measured using titration. The studied soil samples' texture was measured using the hydrometer method based on Stoke's law and the physicochemical values are shown in Table 2.

Macronutrient analysis process

The concentration of exchangeable Potassium, Sodium and Calcium extraction in the soil was carried out according to the method developed by Ghosh *et al*. (1983). Ten grams of dried soil were shaken with 50 ml of neutral standard ammonium acetate solution for 30 minutes and filtered immediately through a dry filter paper (Whatman No.1). The flame photometer determined the content of the macronutrients (N, P, K and Ca) by using the technique of Ghosh *et al*. (1983).

Micronutrient analysis process

The micronutrient concentration of the soil was measured using CP-OES. Two grams of each grounded air-dried soil sample was digested in 8 ml of aqua regia (6 ml of HNO_3 and 2 ml of HCl) with microwave digester Anton Paar (Multiwave 5500). The extract was filtered with Whatman filter paper No.1 and then made up to 50 ml with MilliQ water. The sample's solution was analyzed using ICP-OES and water was used as a blank.

Statistical analysis

The difference between soil characteristics was analyzed with the descriptive statistical method. The relationship between the micronutrient concentrations in investigated

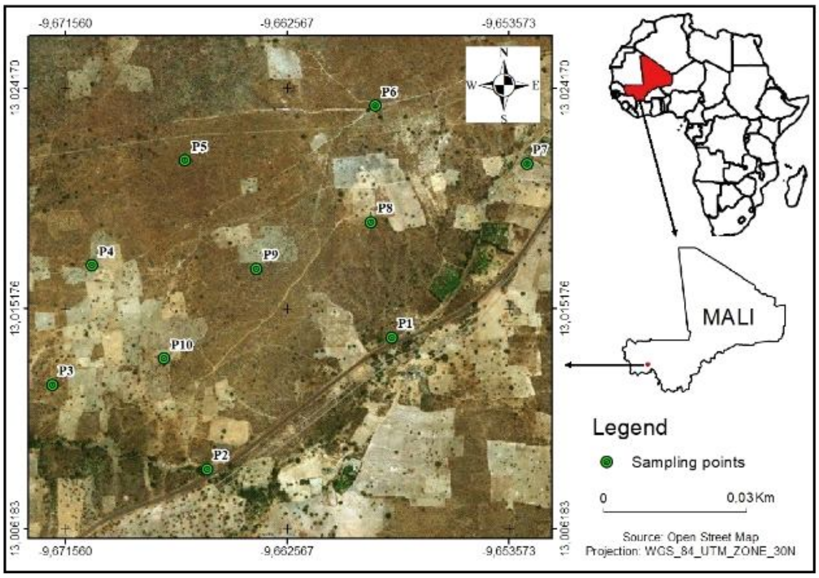

Fig 1: Map of the study area and sampling points.

soils was determined using SPSS software 26 with Pearson correlation coefficients.

RESULTS AND DISCUSSION

Physicochemical properties of soil

Based on Stoke's law, the texture was measured using the hydrometer method. The particle size analysis of the soil samples showed that the studied soil has a low proportion of clay (12.62%) and silt (7.46%) and a very high sand content (79.92%). The percentages of the fine earth have been recorded in Table 1. According to the grain size, the studied soil has a sandy texture.

The contents of physicochemical elements in the soil have been analyzed and the descriptive data, for instance, the mean, maximum and minimum of all the elements, are recorded in Table 2. The analyses have shown that the soil has poor organic matter (C= 6.7 g/kg and N= 0.24 g/kg) and poor decomposition with a C/N of less than 27 (Bhuyan *et al*., 2021). The lack of organic matter in this area may be explained by the intense utilization without rotation of various food crops, as confirmed in the study held by Gore *et al*., (2017). It is a vital parameter that plays a leading role in crop production management, sustainable development and promoting the maximum utilization of chemical inputs. The pH value ranges from 4.85 to 6.37 in the different soil samples. The pH values indicated that the investigated soil was strong to slightly acidic in nature. Many reasons are behind the acidity of the area, including the massive use of synthesized fertilizers, pesticides and herbicides due to cotton production in that area (Nwite *et al*., 2022). The electrical conductivity ranged from 0.16 to 0.25 EC (mS/m). The minimum and maximum conductance values were 0.16 and 0.25 mS/m. This research indicated that the EC values of Mansala-Kayikoro soil are free from salt according to the interpretation of the Indian Society Of Soil Science, which stipulates that the soil EC values comprised between 0 to 2 mS/m are salts-free (Yamini and Anilkumar, 2022). The lowest and highest values of calcium carbonate were 5 and 8, respectively, as reported in Table 2 (Sakarvadia *et al*., 2021). The CEC is a valuable indicator of soil fertility, indicating the soil's ability to hold cations in soil solution. The CEC value of soil samples was below 10, which means that the capacity of the soil to hold the cations is low (AGvise laboratory, 2021; Ross and Ketterings, 1996).

Soil macronutrients

The main macronutrients are primary nutrients (Nitrogen, Phosphorus, Potassium and Sulphur). The contents of exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}) were also determined. In this study, the Nitrogen content in different soil samples ranged from 0.18 to 0.24%. Nitrogen excesses or deficiencies may adversely affect both plant health. Too much nitrogen can cause excessive vegetative growth and weak plant cells. The nitrogen content in analyzed soil samples is found in the optimum range, as confirmed by Baethgen and Alley that a value of around 0.15% of nitrogen would represent cultivated soils (Baethgen and Alley, 1987). The phosphorus levels were 22.58-27.90 Cmol/kg. The phosphorus content in Mansala-Kayikoro soils was low according to the previous studies on the phosphorus status in soil (Sharpley and Tunney, 2000). The minimum content of available potassium was recorded at 225 kg/ha; simultaneously, the maximum level was 260.34 kg/ha. The statistical average of the available potassium was recorded at 241.33 kg/ha, which is low to satisfy the plant's need in terms of good productivity. The potassium content in the analyzed samples was below the required quantities for adequate production of crops (Murugan and Sivagnanam, 2022). Sulphur's minimum and maximum values were recorded at 27 and 40.08 Cmol/kg (Table 3).

The large amounts of exchangeable cations, such as calcium, magnesium and sodium, are major mineral constituents in most soils. Due to their importance, these elements were quantified (Table 3). Calcium was found in the range of 38.32-45 Cmol/kg. Calcium is uptaken by the plants in ionic form (Ca^{2+}) and its deficiency causes yellowish to brownish plant leaves. This statement was confirmed in a study by Tanvi Kiran (Kiran, 2018). Magnesium content was also low and ranged between 58.97-70.00 Cmol/kg, which is inadequate according to the interpretation of Mg value in the soil (Wolf and Beegle, 2011). The total sodium in the soil ranged between 134.39 and 201.89 Cmol/kg. The sodium concentration seemed to be high; for instance, the mean of Na was recorded at 174.77 Cmol/kg, above the plant's permissible level (Raymond and well, 2014). The

Table 1: Granulometric constituents of the soil.

	Granulometric constituents of soil		
Constituent	Clay	Silt	Sand
Percentage	12.62	7.46	79.92

Table 2: Soil physicochemical parameters.

Statistic	Soil physicochemical properties					
	pH	C/N	OM (%)	EC (mS/m)	CEC (cmol.kg)	$CaCO_3$ (%)
Mean	5.64	23.85	7.85	0.30	5.10	6.73
Std deviation	0.71	3.43	3.10	0.33	0.71	1.32
Maximum	6.37	27.90	12.00	0.80	6.14	8.08
Minimum	4.85	19.87	5.00	0.12	4.56	4.98
Range	4.85-6.37	19.87-27.90	5-12	0.12-0.80	4.56-6.14	4.98-8.08

most commonly found macronutrients in Mansala-Kayikoro soil were below the limit range. This means that the additional fertilizer and manure needed to increase the plant's growth will be required.

Soil micronutrients status

The concentrations of micronutrients were determined and the statistics such as mean, maximum, minimum, standard deviation and range were evaluated, as indicated in Table 4. The iron content in the analyzed samples was high compared to other elements, as its concentration ranged between 200.20-409.40 ppm. The acidic condition of the area may explain this high concentration of Iron and the solubility status of ion cations in soil solution (Kakar *et al*., 2018).

At the same time, the copper and zinc contents were low in the investigated samples. The Copper content ranged from 43.80 to 52.23 ppm, with a mean value of 49.19 ppm, indicating its sufficiency in these soils. Nevertheless, the mean value of zinc concentration was 47.54 ppm indicating an optimum level for plant growth compared to its deficiency level fixed at 0.8 ppm (Fig 2). The acidic condition of the medium might cause the high zinc concentration in Mansala-Kayikoro soils. Similar results were also reported by Day and Aillery P that Zinc was sufficient in 32.63 ppm of the samples against the critical level of 0.80 ppm (Day and Aillery, 1988).

The natural abundance of manganese in the soil is around 1000 ppm. The manganese concentration ranges

Table 3: Soil macronutrient and exchangeable bases (Descriptive statistical parameters).

Available macronutrients	Statistical descriptive parameters				
	Mean	Maximum	Minimum	Std deviation	Range
(N) Nitrogen (kg/ha)	0.21	0.24	0.18	0.026	54-72
(P) Phosphorus (cmol/kg)	25.35	27.90	22.58	2.19	22.58-27.90
(K) Potassium (cmol/kg)	241.33	260.34	225.00	14.51	225-260.34
(S) Sulphur (cmol/kg)	34.63	40.08	27.00	5.95	27-40.08
(Ca^{2+}) Calcium (cmol/kg)	40.08	45.00	38.32	2.90	38.32-45
(Mg^{2+}) Magnesium (cmol/kg)	64.58	70.00	58.97	4.88	58.97-70
(Na^{+}) Sodium (cmol/kg)	174.77	201.89	134.39	28.99	134.39-201.89

Table 4: Micronutrients in soil.

Available micronutrients (ppm)	Statistics				
	Mean	Maximum	Minimum	S.D.	Range
Iron (Fe)	315.008	209.40	200.20	45.91	200.20-409.91
Copper (Cu)	49.19	52.23	43.80	2.43	43.80-52.23
Zinc (Zn)	47.54	60.49	32.47	8.28	32.47-60.49
Manganese (Mn)	258.66	295.55	232.48	12.31	232.48-295.55
Boron (B)	33.45	48.87	25.47	5.90	25.47-48.87
Nickel (Ni)	8.97	18.12	4.89	2.67	4.89-18.12

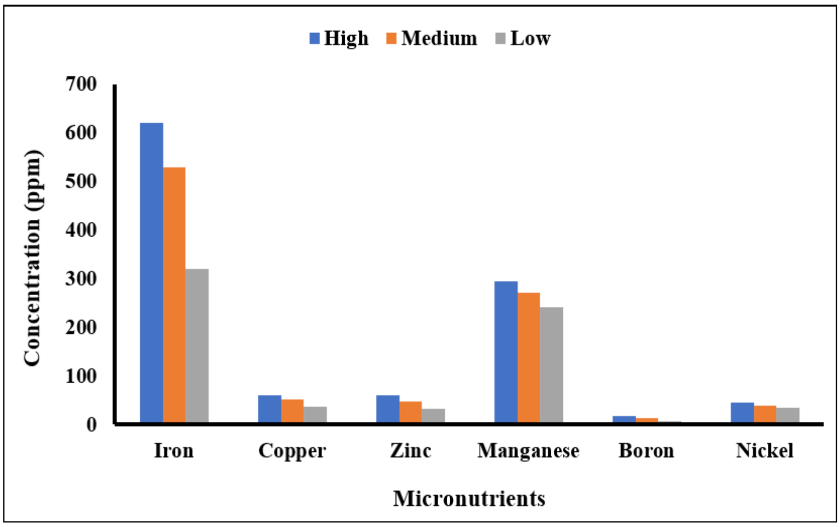

Fig 2: Micronutrient contents in soils.

Table 5: Correlation coefficient of Micronutrients in Mansala-Kayikoro soil.

	Fe	Cu	Zn	Mn	Ni	B
Fe	1					
Cu	.505*	1				
Zn	.983**	.819**	1			
Mn	.077	.079	.462*	1		
Ni	.322*	.678**	.690**	.646**	1	
B	.632**	.851**	.580*	.874**	.693**	1

*.Correlation is significant at the 0.05 level (2-tailed).

**.Correlation is significant at the 0.01 level (2-tailed).

from 232.48 to 295.55 ppm, with a mean of 258.66 ppm. According to the results, Manganese content was found to be above the permissible levels of 5.7 and 55 ppm (Kihara *et al*., 2020). The Nickel level in soils varied from 4.89-18.12 ppm, with an average of 8.97 ppm. The deficiency level of nickel is 1.50 ppm. However, the Nickel threshold value of toxicity for plant growth is set at 50 ppm, indicating a good Nickel content in the analyzed samples (Kuraz *et al*., 2021). In the studied soils, most micronutrients in Mansala-Kayikoro soil were above the limit range, such as Manganese, Iron and Nickel. However, zinc and copper were found deficient in the soil. This means that the study area needs some improvement, like the input of fertilizer and manures, to increase the plant's growth and yield capacity.

Pearson correlation analysis of micronutrients revealed a significant relationship in Mansala-Kayikoro soils. However, a negative correlation was observed between Manganese, Iron and Copper, as shown in Table 5. The correlation in the study area soil indicated a solid and positive correlation in Zn-Fe; Cu-Fe; B-Mn; Ni-Zn; Zn-Cu and Cu-Ni; with an 'R-value' of .983; .505; .874; .690 and .678 respectively. This statement indicates that the same geochemical factors controlled the elements from the same source (Laniyan and Morakinyo, 2021). A weak and negative correlation was observed between Mn-Fe and Mn-Cu, indicating the poor availability of Mn in the study regions (Mugo *et al*., 2020).

CONCLUSION

According to the results obtained from Mansala-Kayikoro soils, the status of nutrients was found in the low fertility range. Apart from Nitrogen and sodium, the other macronutrients, such as potassium, phosphorus and sulphur, were below the recommended level for good crop production. The soil was found to be acidic, with a low value of electrical conductance. The low levels of macronutrients in soil samples indicated that it would require additional fertilizer and manures to increase plant growth. The concentration of Iron and Manganese was high in soils and other micronutrients like copper, zinc, nickel and boron were in the limited range, suitable for plant growth. The simultaneous use of organic manures and some chemical fertilizers can enhance the efficiency of these micronutrients.

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Conflict of Interest

The authors declare no conflict of interest regarding this research article.

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