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ORIGINAL RESEARCH ARTICLE

Comparative Assessment of Soil Fertility in Irrigated and Rainfed Farmlands Using Exchangeable Cations and Cation Exchange Capacity in Kura, Kano State

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ABSTRACT
The productivity of all farming methods is largely dependent on the soil's fertility, and soil's ability to provide nutrients to crops is the most common way that soil fertility is characterized. The aim of this study was to compare the Exchangeable Cations and Cations Exchange Capacity (CEC) between selected irrigated and rain-fed farmlands of Kura Local Government, Kano State. Soil samples were collected from selected irrigated and rain-fed farming plots at a depth (0-20cm). The BaCl2 Compulsive Exchange method was used to assess the Exchangeable Cations and Cations Exchange Capacity (CEC) samples. The study revealed that the soil samples from irrigated plots have medium to high Ca (2.60-4.05Cmol/kg), Mg (1.625-2.250Cmol/kg), K (0.534-0.897Cmol/kg), and Al (0.094-0.367Cmol/kg) concentrations. Rain-fed plots samples analyzed also had medium to high Ca (3.00-4.90Cmol/kg), Mg (1.625-2.250Cmol/kg), K (0.240-0.897Cmol/kg) and Al (0.094-0.367Cmol/kg) concentrations. The irrigated soil samples had low to medium CEC (5.3 cmol/kg to 7.30 cmol/kg), while the rain-fed soil samples had medium CEC (6.07 cmol/kg to 8.90 cmol/kg). The mean values of the soil parameters analyzed were obtained, and the results were compared with the standard critical limits. The results indicate that soil samples from rain-fed farmlands have higher levels of Exchangeable Cations and Cation Exchange Capacity (CEC), except for potassium, which was found to be higher in the samples from irrigated farmlands. Statistical analysis revealed significant differences ($p<0.05$) between the irrigated and rain-fed samples mean of Magnesium Cation, while the analysis revealed insignificant differences ($p>0.05$) between the means of Calcium, Potassium, Aluminium, and CEC. However, both the values fell within the range of fertile soil. These findings fit with the existing literature on semi-arid West Africa, stressing the importance of CEC-driven approaches and tailored strategies for increasing agricultural productivity. The research supports the use of combined organic and inorganic fertilizers, referred to as integrated nutrient management, to maintain soil fertility in both systems. Regular testing of the soil is encouraged in order to monitor the nutrients and modify the amendments accordingly.

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INTRODUCTION
Irrigation is essential for crop production in the dry subtropical regions and the quality of the soil quality may be impacted in several ways by using irrigation water (Okur & Örçen, 2020). Increasing crop productivity and resource usage efficiency is crucial to ensuring food security and environmental quality in Nigeria, given the country's rapidly expanding population. Instead of increasing the cultivated area, the greatest strategy to achieve this goal is to enhance yield per unit area (Sultana *et al.,* 2016). Rain-fed farming accounts for roughly 51% of the country's net sown area and nearly 40% of total food production. Rain-fed agriculture is complex, diverse, and risky. It is distinguished by low levels of productivity and input usage resulting in wide variation and instability in crop yields. The four essential components of soil are mineral solids, water, air, and organic matter. Sand, silt, and clay are mineral solids that mostly contain Silicon, Oxygen, Aluminum, Potassium, Calcium, and Magnesium (Fred and Harold, 2009). Soil fertility guides such as texture, pH, organic matter content, Exchangeable Cations and Cation exchange capacity are essential to soil chemical properties influencing nutrient availability and retention in Soil (Bunu 2019).

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Soil exchangeable Cations are positively charged ions that are held on the negatively charged surfaces of soil particles. These Cations play a crucial role in nutrient availability for plants and soil fertility. The nutritional Cations that plants use the most are Magnesium (Mg^{2+}), Calcium (Ca^{2+}), and potassium (K^{+}) (Saha 2022). The negatively charged sites on the surfaces of the clay mineral and organic matter components of soil absorb and retain positively charged ions (cations) through the process of electrostatic force. Since many minerals are found as Cations (such as Calcium, Magnesium, and potassium), this electrical charge is essential to plants' nutrition. Large amounts of negative charge generally result in more productive soils because they hold onto more Cations (McKenzie *et al.* 2004).

The soil's capacity to retain positively charged ions is measured by its cation exchange capacity (CEC). It is a very important soil property influencing soil structure stability, nutrient availability, pH, and the soil's reaction to fertilizer (Hazleton and Murphy 2007). The total amount of the Cations that the soil can contain is the CEC. Cation Exchange Capacity is measured as meq100g^{-1} of soil or as Cmol (+) kg^{-1} (Lal and Shukla, 2004).

Research conducted on soil in the Lower River Benue Development Authority (LRBDA) project site shows that the CEC values of the soil are low due to low clay, organic matter content, and proportion and consequently, the poor water holding capacity of the soil. The amount of pH influences CEC, hence, CEC is a direct indication of available soil nutrients. (Oklo *et al.,* 2021). Another research conducted by Adamu *et al.* (2014) on fertility assessment of soils under rice cultivation in Kadawa, Garun Mallam local government of Kano state, indicates that the Cation Exchange Capacity (CEC) varied between 5.0 and 11.0 Cmol/kg. 7.57 Cmol/kg was determined to be the mean CEC. This figure was within the range that ILACO (1985) and Landon (1991) recommended as a middle ground.

Comparative studies of irrigated and rainfed systems throughout Nigeria or general research on soil fertility throughout Kano State may exist, but there is not much-localized data unique to the Kura Local Government Area. This research could provide special insights into the fertility of the Soil beneath Kura.

The objectives of this study are to compare the Soil Exchangeable Cations and Cations Exchange Capacity (CEC) between selected irrigated and rain-fed farmlands of the Kura local Government area of Kano state in order to provide valuable information on these nutrients and their levels, increase productivity and achieve sustainable and wise soil use.

MATERIALS AND METHOD

All the reagents used for this analysis were of analytical grade and used without further purification.

Description of the study area

The study site for this current study is Kura Local Government Area located in Kano State, Nigeria. The Local government headquarters are in the town of Kura on the A2 highway. It has an area of 206 km^2 and a population of 144,601 at the 2006 census. The area's postal code is 711. Kura lies within latitude 11^0 46'17.47'N of the equator and longitude 8^0 25'48.60'E of the Greenwich Meridian.

Sampling

The soil samples were collected from some selected irrigated and rain-fed farmlands at random intervals along Kano-Zaria of Kura local government using a random sampling method to form composite samples. Composite samples were collected because soils can vary greatly even over small distances, so gathering soil in a single area is frequently insufficient due to this heterogeneity (Ackerson 2018). The plant litter on the surface (zero horizon) was swept off. A total of 100 samples were randomly collected at a depth (0-20cm) using soil auger and trowel, 10 samples from each sampling area (farmland). The ten (10) Samples obtained from each sampling area (farmland) were mixed together to form one sample, making the total of the samples collected to ten (10), Five (5) soil samples from irrigated farmland and five (5) soil samples from rain-fed farmlands. The samples were stored in labeled polyethylene sampling bags and stored at room temperature in the laboratory.

Laboratory analysis

Each procedure was repeated three times for each sample in order to ensure statistical robustness.

pH

To 10g of soil, 50cm^3 of deionized water was added to a beaker, stirring the suspension several times for 30 minutes. The suspension was allowed to stand for another 30 minutes. The pH of the soil suspension was measured using a pH meter (Oklo *et al.,* 2021).

Organic Matter Content

The organic matter of the soil samples was determined by the ashing method (Cuniff, 2022). The crucibles used in this method were weighed to 4 decimal places and recorded as W_1. About 5.0 g of dried and ground soil samples were transferred into crucibles. The crucibles containing the samples were heated in an oven at 105°C for 2 hours. The samples were removed from the oven with tongs and placed in a desiccator to cool down for 20 minutes. After cooling, the crucibles were weighed again and recorded as W_2. The crucibles were then transferred to a muffle furnace set at 360°C and ashed for 3 hours. The samples were taken out of the furnace, placed in a desiccator to cool for 45 minutes, weighed again, and recorded as W_3.

The percentage of organic matter for the samples was calculated using the formula:

$$\% \text{ Organic Matter} = \frac{W2 - W3}{W2 - W1} X\ 100$$

where W1 was the weight of the crucible alone, W2 was the weight of the crucible + soil after 105°C heating, and W3 was the weight of the crucible + soil after 360°C heating.

Exchangeable Cations and Cations' Exchange Capacity

The digestion, measurement of exchangeable Cations, and the calculation of the Cations exchange capacity of the soil samples were conducted according to Ross and Quirine (2011).

Digestion

The digestion of the soil samples for the determination of exchangeable Cations and Cations exchange capacity (CEC) was done by the compulsive exchange method. 2.0g of the soil sample was weighed into the centrifuge tube. 20 ml of 0.1M $BaCl_2.2H_2O$ was then added to the tube. The tube was caped and shaken for two (2) hours. The sample was Centrifuged at about 10,000 rpm and decanted carefully. (Ross and Quirine, 2011).

Measurement of Exchangeable Cations

The digested samples were used to measure the concentration of Ca^{+2}, Mg^{+2}, K^{+}, and Al^{+3} Cations by spectrophotometric method (Ross and Quirine, 2011) using data logging DR-2500 (HACH) spectrophotometer.

Cations Exchange Capacity

The Cations exchange capacity of the soil samples was calculated from the concentration of the exchangeable Cations measured above, using the formula below:

$$\text{CEC} = \frac{Ca}{20} + \frac{\text{Mg}}{12} + \frac{\text{K}}{39} + \frac{\text{Al}}{9}$$

Where CEC is the Cations exchange capacity and Ca, Mg, K and Al are the concentrations of the exchangeable Cations Ca^{+2}, Mg^{+2}, K^{+}, and Al^{+}, respectively, obtained from the spectrophotometric method above. 20, 12, 39, and 9 are the equivalent weight of the Cations which were determined by dividing the atomic weight of each Cation by the number of its valences.

Statistical Analysis

All data were subjected to statistical analysis. The mean ± standard deviation (SD) of the values. T-test and One-way ANOVA were used to test for significant differences or otherwise between the means of irrigated and rain-fed farmlands parameters analyzed using Microsoft Excel data analysis. The differences between the mean values were considered significant at *P*-values of less than 0.05 that is at 95% confidence level ($P < 0.05$), and insignificant at *P*-values greater than 0.05 ($P > 0.05$).

RESULTS

Table 1.0: pH and Organic matter of the irrigated farmlands samples

S/N	Sample	pH	%OM
1	IR1	7.10±0.1732	1.60±0.1671
2	IR2	6.80±0.2646	1.85±0.0810
3	IR3	6.50±0.2645	1.67±0.0266
4	IR4	6.90±0.1732	1.39±0.0165
5	IR5	6.70±0.2000	2.85±0.1748

Values are mean ± SD of triplicate analysis.

Table 2.0: pH and Organic Matter of the rainfed farmlands samples

S/N	Sample	pH	%OM
1	RF1	6.20±0.2082	1.61±0.0234
2	RF2	5.60±0.0800	4.39±0.1204
3	RF3	5.90±0.2179	3.72±0.0354
4	RF4	6.20±0.0500	2.91±0.1991
5	RF5	6.80±0.0850	3.23±0.1650

Values are mean ± SD of triplicate analysis.

Table 3.0: Exchangeable Cations and Cations Exchange Capacity of the Irrigated (IR) farmlands samples

S/N	Sample	Ca^{+2} (Cmol/kg)	Mg^{+2} (Cmol/kg)	K^{+} (Cmol/kg)	Al^{+3} (Cmol/kg)	CEC (Cmol/kg)
1	IR1	2.60±0.3271	1.830±0.0093	0.770±0.0200	0.094±0.0026	5.30
2	IR2	3.10±0.5014	1.625±0.1148	0.640±0.0275	0.130±0.0030	5.50
3	IR3	3.40±0.1336	2.125±0.1761	0.897±0.1363	0.128±0.0045	6.60
4	IR4	3.15±0.0480	2.000±0.1872	0.534±0.0171	ND	5.70
5	IR5	4.05±0.0780	2.250±0.2203	0.640±0.0215	0.367±0.0045	7.30

Values are mean ± SD of triplicate analysis. ND means Not Detected.

DISCUSSION

pH

Soil's pH level is its most important characteristic, and it influences all other soil properties. As such, pH is taken into account while analyzing any type of Soil (Sunil et al. 2023). Table 1.0 of soil samples pH shows that the pH of the soil samples from irrigated farmlands (IR) ranged from 6.50 – 7.10. The sample from IR1 has the highest pH value (7.10), while the sample from IR3 has the lowest pH value (6.50). The pH values for the samples obtained from rainfed farmlands (RF) as shown in Table 2.0, ranged from 5.60 – 6.80, with soil samples from RF1 and RF2 having the lowest pH value of 6.20 while the sample from RF5 had the highest pH of 6.80. The mean pH values of the soil samples from irrigated farmlands (IR) and rainfed farmlands (RF) were found to be 6.80 and 6.14, respectively, as shown in Table 5.0. These mean values is an indication that both the irrigated and rainfed soil samples are slightly acidic when compared to the values of the critical limits of interpreting levels of soil analytical parameters according to Esu (1991) as reported by Sanda and Ismail (2012). The level of acidity in rainfed soil samples is higher than that of irrigated soil samples, which is very slightly acidic in another context, the United States Department of Agricultural National Resources Conservation Service groups soil pH values 6.6–7.3 as neutral (Burt, 2014). According to Sunil *et al.* (2023), soil is classified as acidic if its pH is less than 6, neutral soil is defined as having pH between 6 and 8.5, and alkaline soil is defined as having a pH of more than 8.5. The results obtained from both the t-test and ANOVA indicated a statistically significant difference ($P < 0.05$) in the mean pH scores between the irrigated and rainfed farmland samples. pH levels have a significant impact on the availability of nutrients; plants are most receptive to nutrients in the ideal pH range of 5.5 to 7.5, and generally speaking, slightly acidic to moderately alkaline soils are the best sources of macronutrients such as nitrogen (N), potassium (K), sulfur (S), Calcium (Ca), and Magnesium (Mg) (Oklo *et al.,* 2021). A number of factors may contribute to the soil's slight acidity, such as acidic precipitation (H^+ ions in precipitation), the deposition of acidifying gases and particles from the atmosphere, such as urea, ammonia, Sulphur dioxide (SO_2), nitric and hydrochloric acids (HNO_3, HCl), the growth of legumes, crop nutrient uptake, root exudates, and mineralization of organic matter (Goulding, 2016). Also, Tang *et al.,* (2022) reported that soil microorganisms can promptly convert urea to NH_4^+. This mechanism accelerates the soil's acidity by releasing H^+ into the soil. The result obtained agrees with the recent study by Yakasai and Rabiu (2024) in the same irrigated study area, where the findings revealed that soil samples are slightly acidic.

Table 4.0: Exchangeable Cations and Cations Exchange Capacity of the Rainfed (RF) farmlands samples

S/N	Sample	Ca^{+2} (Cmol/kg)	Mg^{+2} (Cmol/kg)	K^+ (Cmol/kg)	Al^{+3} (Cmol/kg)	CEC (Cmol/kg)
1	RF1	3.00±0.1493	2.330±0.1260	0.590±0.0098	0.150±0.0211	6.07
2	RF2	4.90±0.2521	2.920±0.1787	0.897±0.0304	0.183±0.0035	8.90
3	RF3	3.55±0.1680	2.790±0.0239	0.369±0.0159	0.410±0.0135	7.10
4	RF4	3.40±0.0905	2.380±0.0269	0.240±0.0165	0.044±0.0026	6.10
5	RF5	3.65±0.1532	2.460±0.0589	0.370±0.0115	0.178±0.0082	6.70

Values are mean ± SD of triplicate analysis.

Table 5.0: Mean values and standard deviation of the chemical parameters for the Irrigated farmlands (IR) and rain-fed farmlands (RF) samples.

Parameters	IR Mean±SD	RF Mean±SD
pH	6.80±0.22361	6.14±0.44497
%OM	1.87±0.57098	3.17±1.11576
Ca^{+2} (Cmol/kg)	3.26±0.52844	3.70±0.71502
Mg^{+2} (Cmol/kg)	1.96±0.245901	2.576±0.262926
K^+ (Cmol/kg)	0.696±0.139994	0.493±0.258427
Al^{+3} (Cmol/kg)	0.144±0.135478	0.193±0.133664
CEC (Cmol/kg)	6.08±0.84380	6.97±1.15991

Organic Matter

As shown in Table 1.0, the value of organic matter content for the irrigated farmland samples ranges from 1.39% to 2.85%. IR4 has the lowest value with 1.39% and IR5 has the highest value with 2.85%. Samples from rainfed farmlands have organic matter content ranging from 1.61% to 4.39%. RF1 has the lowest value, while RF2 has the highest organic matter content value, as indicated in Table 2.0. Table 5.0 shows that the mean organic matter content values for irrigated farmland samples and rainfed farmland samples were 1.87% and 3.17%, respectively.

The result revealed that the mean organic matter content in the rainfed farmlands samples was higher than the mean in irrigated farmlands. The findings of this research show that the soil samples from the irrigated farmlands had low organic matter content according to the guidelines for rating soil fertility indicators by ILACO (1985) and Landon (1991), while the samples from rainfed farmlands revealed that the organic matter content was within medium range and also within the optimum range for fertile soil (2% to 8%) as recommended by MPCA (2024). Statistical analysis conducted revealed a statistically significant difference ($P=0.0272$ for t-test and $P=0.0395$ for ANOVA) between the mean values for the organic matter of irrigated and rainfed soil samples analyzed.

The low organic matter content of the irrigated samples can result from ongoing cultivation removal of crop wastes without return (Sanda and Ismail, 2012). This could be one of the reasons for this low organic matter content in the irrigated farmlands of Kura because the area is always under continues cultivation all year round without a break. In most irrigated systems of agriculture, the addition of organic residues, which determine the amount of organic matter in the soil, is typically low, and their loss through mineralization is high (Binns *et al.,* 2003). Continuous small-scale farming, especially in irrigated systems, provides favorable moisture levels for the breakdown of organic matter. This leads to a decomposition of soil organic matter (SOM) exceeding its build-up and, hence, an overall decline in SOM, with the associated reduction in the mineralization of nutrients (Getaneh *et al.,* 2007).

Exchangeable Cations and Cations Exchange Capacity

The results for exchangeable Cations of the irrigated and rainfed soil samples are shown in Table 3.0 and Table 4.0, respectively, and their mean values are shown in Table 5.0 and Figure 1. Critical limits for interpreting levels of soil analytical parameters by Esu (1991), and Sanda and Ismail (2012) were used in interpreting the results obtained in this analysis.

Calcium

The result revealed that the Calcium content (Ca^{+2}) in the irrigated farmlands samples ranged from 2.60Cmol/kg to 4.05Cmol/kg. IR1 has the lowest Calcium content, while IR5 has the highest value among the irrigated samples. The mean value for the Calcium in the irrigated samples was 3.26Cmol/kg. The Calcium content in the rainfed farmlands samples ranged from 3.0Cmol/kg to 4.90Cmol/kg with the mean value of 3.70Cmol/kg. RF1 was the lowest while RF2 was the highest in terms of Calcium content. These mean concentrations for both the irrigated and rainfed samples were rated as medium concentrations (moderate fertility range 2.0-5.0Cmol/kg). The difference between mean values is statistically insignificant (P>0.05) according to the T-test and ANOVA statistical analyses conducted.

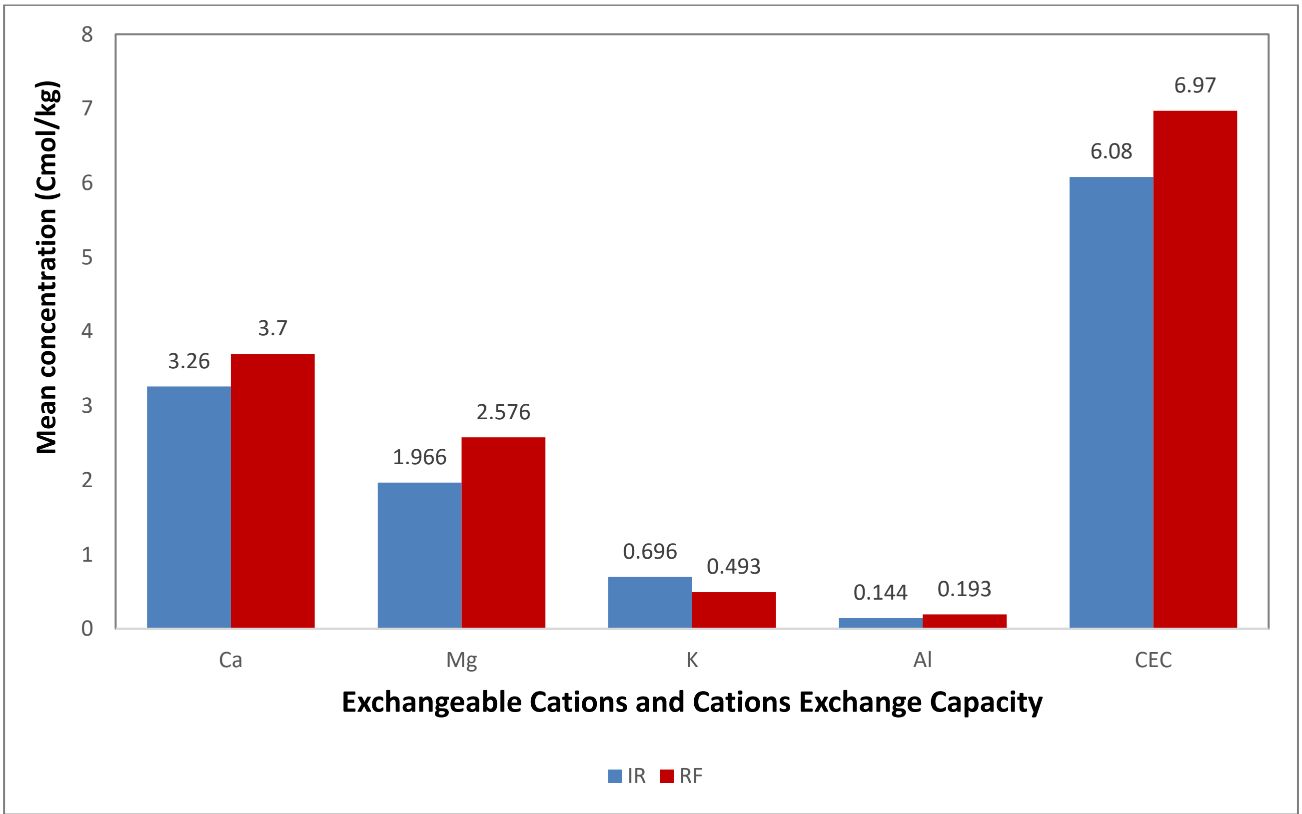

Figure 1: Mean Exchangeable Cations and Cation Exchange Capacity (CEC) chart

Magnesium

Exchangeable Magnesium values obtained varied from 1.625-2.250Cmol/kg for soil samples from irrigated farmlands, while those of rainfed farmlands ranged from 2.330-2.920Cmol/kg. The mean value of the exchangeable Magnesium for the irrigated and rainfed samples was 1.966Cmol/kg and 2.576Cmol/kg, respectively. These mean values were within a high concentration rating. The mean value of the rainfed farmland samples is higher than that of irrigated farmland samples. Based on the statistical analysis conducted in Appendix I, the difference is statistically significant (P<0.05).

Potassium

Potassium content ranged from 0.534 to 0.897Cmol/kg for the soil samples from irrigated farmlands with a mean value of 0.696Cmol/kg, rated as high according to Esu (1991). The potassium content of the rainfed soil samples ranged from 0.240 to 0.897Cmol/kg with a mean value of 0.493, also rated as a high concentration. The mean values revealed that irrigated farmland samples have higher potassium content than rainfed samples. The difference between the two means is statistically insignificant, as indicated in the t-test and ANOVA statistical analyses conducted.

Aluminium

Aluminium content ranged from 0.094 to 0.367Cmol/kg for the irrigated soil samples and 0.044 to 0.410Cmol/kg for the rainfed farmlands soil samples. The mean values of aluminium in both irrigated and rainfed soil samples are 0.1438 and 0.193Cmol/kg, respectively. T-test and ANOVA statistical analyses conducted revealed statistically insignificant differences between the means of the samples. These mean values were both within the limit allowed for agricultural Soil (<1.0Cmol/kg) as recommended by USEPA (2003), which was a relief because Aluminium level above 1.0 Cmol/kg in agricultural soil is seen as a threat to plant health.

All the exchangeable Cations for the irrigated and rainfed samples analyzed were rated moderate to high concentration, but the concentrations were higher in rainfed farmland samples with the exception of potassium, which was higher in the irrigated samples. Though their values are not particularly low, the higher K content in the irrigated soils may have also contributed to the low Ca and Mg levels due to its higher capacity to compete for exchange sites (Foloronsho, 1998).

The higher exchangeable Cations concentration in the rainfed soil can result from their medium organic matter content (Sanda and Ismail, 2012). Exchangeable Cations manage the mineralization of organic matter in soils by altering the physicochemical characteristics of the soil environment. According to Uthappa *et al.* (2024), the higher Ca and Mg contents in the soil can be attributed to the input of more litter and significant amounts of nutrients and organic matter to the soil, and Muche *et al.* (2015) claim that exchangeable Calcium and Magnesium are depleted as a result of ongoing inorganic fertilizer use in farming. According to Sanda and Ismail (2012), low levels of clay content, low levels of organic matter, and a high percentage of sand can all contribute to the low mean value of all the exchangeable Cations, which causes their loss through leaching and a high infiltration rate. Mustapha et al. (2011) reported relatively medium to high concentrations of K and Mg in a similar investigation.

Cations Exchange Capacity (CEC)

The Cations Exchange Capacity of Soil values from irrigated farmlands ranged from 5.30Cmol/kg to 7.30Cmol/kg as shown in Table 1.0. IR1, IR2, and IR4 have CEC concentrations of 5.30Cmol/kg, 5.5Cmol/kg and 5.7Cmol/kg, rated low. This could be due to the low organic matter of the samples, which significantly increases a soil's CEC during the mineralization and decomposition processes and also results in the release of nutrients into the soil's physical facility, which improves soil moisture status and helps retain exchangeable Cations, particularly in soils with low clay content (Sanda and Ismail 2012). IR3 and IR5 have CEC values of 6.60Cmol/kg and 7.30Cmol/kg, rated as medium concentration. Also, given the soil samples' low level of organic matter, the clay concentration may have had a major role in the soil samples CEC values (Alhasan, 1996). The CEC mean value for the irrigated samples was found to be 6.08Cmol/kg, which was classified as a medium value. Rainfed samples, on the other hand, have CEC values from 6.10Cmol/kg to 8.90Cmol/kg, as shown in Table 2.0. RF1 has the lowest value, while RF2 has the highest value of 8.90Cmol/kg. All the samples from rainfed farmlands have their values within the medium range. The mean CEC value for the rainfed samples was 6.97Cmol/kg. The mean value revealed that the CEC was within the medium range. The results of the mean values showed that the CEC concentrations were higher in the rainfed farmlands samples than irrigated farmlands samples despite both being within the medium range. Statistical analysis reported a statistically insignificant difference between the two means. In a similar study on irrigated fields, Adamu et al. (2014) found that the Soil CEC was within the medium range.

CONCLUSION

This study analyzed the exchangeable Cations and Cation Exchange Capacity (CEC) of soil samples from both selected irrigated and rainfed farmlands in Kura Local Government, Kano State. All the exchangeable Cations for the irrigated and rainfed samples analyzed were rated moderate to high concentration. Still, the concentrations were higher in rainfed farmland samples except for potassium, which was higher in the irrigated samples. The CEC concentrations were higher in the rainfed farmlands samples than irrigated farmlands samples despite both being within medium range. This study revealed that the Exchangeable Cations and Cations Exchange Capacity of both the irrigated and rainfed farmlands samples were within the range of fertile soils. The lower values recorded in irrigated soil samples were due to continuous cropping in the area and could also be due to low organic manure application. The study, therefore, recommends improved soil fertility management and practices such as the application of organic manure in order to increase nutrient availability, especially in the irrigated farmlands where lower levels of such nutrients were recorded, and regular testing of soil nutrient levels should be encouraged which will make farmers to make informed decisions about the use of required fertilizers and soil amendments.

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