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# Influence of irrigation regimes, variety and cow dung rates on selected chemical properties of a sandy clay loam soil in Sokoto, Nigeria

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## ABSTRACT

Adoption of appropriate soil, water and crop management practices could be the gate way to enhanced soil chemical quality, crop productivity as well as national and global food security. A study was undertaken to assess the influence of irrigation regimes, with two rice varieties and varying cowdung manure application rates on some selected chemical properties of a sandy clay loam soil in a semi-arid zone of Sokoto, Nigeria. The study evaluated four water management practices [alternate wetting and drying (AWD) treatments: AWD1: irrigating when water level was 10 cm below the soil surface, AWD2: irrigate when water level was 15 cm below the soil surface, AWD3: irrigate when water level fell to 20 cm below the soil surface and CF: continuous flooding] with two rice varieties (FARO 44 and TOFA) and with four rates of cowdung amendment (0, 5, 10 and 15 t ha$^{-1}$). The Plots were arranged in a split-split plot design replicated three times. Rice was grown on the field in 2020 and 2021 seasons. Measurements of chemical properties of the soils were carried out using standard procedures. The results revealed that water management and rice varieties had no significant effect on the chemical properties of the soils. The results showed significant effects of cow dung rates on OC, Ca and K contents of the soils with 5, 10 and 15 t ha$^{-1}$ better than 0 t ha$^{-1}$. The study recommended that similar research should be extended to 3-4 years to assess residual effects of the management practices imposed on soil chemical quality.

**Keywords:** Rice varieties; cow dung; soil chemical properties

## INTRODUCTION

Sound water, soil and crop management practices are necessary for enhancing soil chemical quality, crop productivity likewise national and global food security. Savanna soils are inherently low in fertility and chemical quality (Loks *et al.*, 2014). This coupled with inappropriate water management practices such as continuous flooding (CF) and use of rice

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varieties with poor nitrogen use efficiencies could further jeopardize the soils' ability to produce crops sustainably thereby aggravating national and global food insecurity.

On the other hand, adoption of water saving irrigation regimes had been shown to reduce nitrogen leaching (Mustapha *et al.*, 2017) while appropriate fertilization regimes involving organic fertilization had been shown to improve soil chemical quality including OC, TN, exchangeable potassium (K) and CEC (Iqbal *et al.*, 2019; Haque *et al.*, 2021) leading to increased rice yield (Iqbal *et al.*, 2019) thereby mitigating national and global food insecurity. This study therefore aimed at evaluating the influence of irrigation regimes, rice varieties, and cow dung application rates on selected chemical properties of the soil in view of identifying the best management options for enhanced soil quality and national food security.

## MATERIALS AND METHODS

### Study Area

The experiment was conducted near the Usmanu Danfodiyo University Teaching and Research Fadama Farm, Kwalkwalawa, about 5 km from Sokoto, located at Latitude 13° 09' 1'' N and longitude 5° 20' 1'' E at an altitude of 300 meters above sea level (Lukman *et al*., 2016). Soil of the study area is classified as Inceptisol (Noma, 2005). The location is in the northern Sudan savanna ecology of Nigeria, in an environment described as semi-arid. Tropical wet and dry climate prevails in the area, which is characterized by scattered trees and fewer grasses. Rainfall distribution is monomodal with an average annual rainfall of 629 mm. Minimum and maximum temperature ranges between 15 and 40°C, respectively (SERC, 2013).

### Treatments and Experimental Design

The experiment was established as split-split plot design consisting of four (4) irrigation regimes {3 alternate wetting and drying regimes: AWD1, AWD2, AWD3 and 1 conventional flooding (CF)}, two (2) rice varieties (FARO 44 and local variety TOfA/Zakkama) and four (4) cow dung manure rates (0 t $ha^{-1}$, 5 t $ha^{-1}$, 10 t $ha^{-1}$ and 15 t $ha^{-1}$) giving 4 x 2 x 4 (32 treatments) replicated thrice (total of 96 treatment plots). Irrigation regimes were assigned to the main plots, variety as sub-plots, while cow dung rates were allocated to the sub-sub plots respectively. The conventional flooding (CF) practice involved keeping the soil flooded throughout the growing season which is the common practice by rice farmers in the area, while alternate wetting and drying (AWD) consisted of intermittent irrigation using observation wells. The observation wells consisted of PVC pipes of 12 cm diameter and 40 cm height perforated to a height of 20 cm. Trials were conducted for two (2) consecutive rice growing seasons (2020 and 2021). The gross plots for each treatment were 3m x 2m ($6m^2$).

### Determination of Chemical Properties of the Soil

Composite soil samples were collected before the commencement of the research and after harvest of each growing season. Soil samples for determination of textural composition and chemical properties of the soils were collected at 0-15 and 15-30 cm soil depths with the aid of auger. The chemical properties of the soil were measured using standard methods. Soil pH was measured by glass electrode pH meter using soil water suspension of 1:2.5 (Bates, 1954), electrical conductivity (EC) using conductivity meter, organic carbon (OC) by wet oxidation method (Walkley and Black, 1934) while organic matter was calculated by multiplying the percent organic carbon by 1.729 (IITA, 1979). The total nitrogen (TN) content of the soils was determined by the Micro Kjeldahl method (Jackson, 1962). Available phosphorus (AP) was determined by Bray-1 method (Bray and Kurtz, 1945) while exchangeable bases (calcium: Ca, magnesium: Mg, sodium: Na and potassium: K) were extracted using 1N neutral ammonium acetate. Ca and Mg were determined by Atomic Adsorption Spectrophotometry (AAS) while Na and K were read using flame photometer. The percentage base saturation (PBS), exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) of the soils were determined using the following relations:

$$\% BS = \frac{Na^{+}+K^{+}+Ca^{2+}+Mg^{2+}}{CEC} \times 100 \text{ ....... eq. 1}$$

$$ESP\ (\%) = \frac{exchangeable\ Na^{+}}{CEC} \times 100 \text{ ....... eq. 2}$$

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \text{ ....... eq. 3}$$

## RESULTS AND DISCUSSION

### Characterization of the Soils of the Study Site and Cow dung Used

The result of the physical and chemical properties of the soils of the study area before the commencement of the research is presented in Table 1. Characterization of the study site revealed that soils of the study area is sandy clay loam, slightly acidic, low in organic carbon (OC), available phosphorus (AP) and exchangeable calcium (Esu, 1991).

Table 1: Initial physical and chemical properties of the soils before commencement of the research

| Parameter | Value |
|---|---|
| pH | 6.30 |
| EC ($dSm^{-1}$) | 0.07 |
| OC (%) | 0.35 |
| OM (%) | 0.61 |
| TN (%) | 0.05 |
| AP ($mg\ kg^{-1}$) | 0.78 |
| Ca ($cmol\ kg^{-1}$) | 1.00 |
| Mg ($cmol\ kg^{-1}$) | 0.98 |
| Na ($cmol\ kg^{-1}$) | 0.52 |
| K ($cmol\ kg^{-1}$) | 0.59 |
| CEC ($cmol\ kg^{-1}$) | 14.8 |
| Sand (%) | 64.9 |
| Silt (%) | 13.7 |
| Clay (%) | 21.4 |
| Textural class | Sandy Clay Loam |

EC- electrical conductivity, OC- organic carbon, OM- organic matter, TN- total nitrogen, AP- available phosphorus, Ca- calcium, Mg- magnesium, Na- sodium, K- potassium, CE C- cation exchange capacity

The site is further medium in magnesium (Mg), high in sodium (Na), potassium (K), total nitrogen (TN) and cation exchange capacity (Esu, 1991) and non-saline (Schoeneberger *et al*., 2002). Thus, response of the soil to organic amendments is expected due to low organic carbon (OC) content, while pH of the study site is within the range characterized as good for crop production (Landon, 1991).

**Chemical Properties of the Cow dung Manure Used**

The results of the chemical properties of the cow dung manure used for the study across the two seasons (2020 and 2021) as revealed in Table 2., showed that the manure is rich in organic matter and mineral elements (Esu, 1991; Landon 1991) and thus, good for use as organic amendment.

**Influence of Water Management, Variety and Cow Dung Rates on Soil Chemical Properties**

Results of the influence of different water management practices (AWD1, AWD2, AWD3 and CF), variety and cow dung rates on soil chemical properties are presented in Tables 3 and 4.

Table 2**:** Chemical properties of the cow dung used for the experiment

| Parameters | Values | |
|---|---|---|
| | 2020 | 2021 |
| pH (water) 1:2.5 | 8.65 | 8.70 |
| EC (dS $m^{-1}$) | 4.25 | 4.27 |
| OC (%) | 21.47 | 21.50 |
| OM (%) | 37.12 | 37.17 |
| N (%) | 0.40 | 0.40 |
| P (%) | 0.73 | 0.75 |
| Ca (cmol $kg^{-1}$) | 0.87 | 0.89 |
| Mg (cmol $kg^{-1}$) | 1.65 | 1.67 |
| Na (cmol $kg^{-1}$) | 9.45 | 9.59 |
| K (%) | 1.92 | 1.90 |
| CEC (cmol $kg^{-1}$) | 26.15 | 27.00 |
| Moisture content (%) | 10.10 | 9.90 |

EC = electrical conductivity, OC = organic carbon, OM = organic matter, N = nitrogen, P = phosphorus, Ca = calcium, Mg = magnesium, Na = sodium, K = potassium, CEC = cation exchange capacity

**Influence of Water Management, Variety and Cow dung Rates on some Selected Soil Chemical Properties**

The results of the effects of different water management practices, rice varieties and cow dung rates on soil pH and electrical conductivity (EC) across 2020 and 2021 season for the 0-15 and 15-30 cm depths are presented in Tables 3 and 4. The results revealed there was no significant ($p>0.05$) effects of irrigation regimes and rice varieties on soil pH and EC in the seasons of investigation (2020 and 20021) and depths of 0-15 and 15-30cm except pH in 2020 season at 0-15 cm depth. The AWD3 treatment had the highest pH (6.59) while CF had the least (6.41) for the 2020 season at 0-15 cm depth (Table 3 and 4). Conversely, cow dung rates significantly ($p \leq 0.05$) affected soil pH at 0-15 and 15-30 cm depths for the 2020 and 2021 seasons. The application rates at 0 and 5 t $ha^{-1}$ had higher pH values, which were significantly higher than that of 15 t $ha^{-1}$. Averagely, fertilized treatments (5, 10 and 15 t $ha^{-1}$) had relatively lower pH than the control which is concomitant with the findings of Sarwar *et al.* (2008) who reported decreased soil pH in fertilized treatments than where fertilizer was not applied. Generally, the pH value obtained in this study ranged between 6.02-6.60, which is within the range of 5.5-7.0 reported to be good for crop production (Landon, 1991). Moreover, application of AWD1, AWD2, AWD3 and CF treatments increased soil pH by 2.65 %, 2.03 % and 2.81 % respectively compared to the CF water management in this study for the 2020 season at 0-15 cm soil depth which suggests that water saving irrigation techniques such as AWD increases soil pH compared to the traditional conventional flooding irrigation in paddy soils.

On the other hand, irrigation regimes and rice varieties had no significant effects on organic carbon (OC), total nitrogen (TN) and available phosphorus (AP) contents of the soil across 2020 and 2021 seasons and depths (0-15 cm and 15-30 cm). Nevertheless, the AWD treatments had relatively higher OC and TN contents than the CF treatment (Table 3 and 4). This means that, AWD water management has the potential of improving OC and TN than the CF treatment over time. The OC value obtained in this study ranged between 0.17-0.64 % while TN was between 0.035 % - 0.095 %. This shows that the soil under irrigation regimes, varieties and cow dung rates is low in OC but high in TN (Esu, 1991) suggesting the soils could require more time for differences to develop due to management practices imposed. However, cow dung rates significantly ($p<0.05$) affected organic carbon (OC) for the 2020 and 2021 seasons at 0-15 cm and in 2021 season for the 15-30 cm depth (Tables 3 and 4). Fertilized treatments had higher OC than no fertilization (0 t $ha^{-1}$). The fertilized treatments (5, 10 and 15 t $ha^{-1}$) increased OC by 28.89 %, 15.56 % and 35.56 % in 2021 season at 0-15 cm depth while same fertilization regimes increased OC by 45.45 %, 38.64 % and 38.64 % in 2021 season at 15-30 cm soil depth respectively (Table 3 and 4). This demonstrated that cow dung fertilization improves soil chemical property through improved OC content. The slightly higher OC and TN contents of AWD treatments than the CF water management in this study could be attributed to decreased frequency and volume of water applied under AWD treatments than the CF resulting in reduced loss of OC and TN with percolation water (Mustapha *et al.*, 2017), therefore higher OC and TN in AWD treatments than the CF treatment. While the greater OC in fertilized treatments (5, 10 and 15 t $ha^{-1}$) than the control treatment could be attributed to addition of organic matter (OM) through decomposition of the cow dung applied resulting in increased OC content. Similar observation was earlier made by Iqbal *et al.* (2019) in paddy Ultisols of Subtropical China. This suggests that cow dung fertilization could be a panacea to improvement in OC contents of paddy soils with best values observed in the application of 5 and 15 t $ha^{-1}$ cow dung (Table 3 and 4). Additionally, considering main effects of the treatments, OC values in this study ranged from 0.17-0.64 % respectively across treatments, depths and years of experimentation (Table 3 and 4). Interactions of irrigation regimes and cow dung rates on AP was significant ($p \leq 0.05$) in 2020 season at 15-30 cm depth. AWD2 and 5 t $ha^{-1}$ cow dung proved superior (1.02 cmol $kg^{-1}$) to all other combinations in improving AP content of the soils as all irrigation regimes combined with no fertilization (0 t $ha^{-1}$) had lower AP interactive values (Table 5).

Table 3. Influence of irrigation regimes, variety and cow dung rates on some selected chemical properties of the soils at 0-15 cm soil depth

| Treatments | Chemical property of the soils | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Irrigation regimes (I) | pH | | EC (d S $m^{-1}$) | | OC (%) | | TN (%) | | AP (mg $kg^{-1}$) | |
| AWD 1 | 6.58$^{ab}$ | 6.02 | 0.115 | 0.091 | 0.37 | 0.57 | 0.090 | 0.043 | 0.98 | 0.98 |
| AWD 2 | 6.54$^{ab}$ | 6.26 | 0.108 | 0.096 | 0.42 | 0.62 | 0.095 | 0.042 | 0.99 | 0.97 |
| AWD 3 | 6.59$^{a}$ | 6.11 | 0.106 | 0.082 | 0.39 | 0.49 | 0.091 | 0.042 | 0.98 | 0.98 |
| CF | 6.41$^{b}$ | 6.02 | 0.113 | 0.086 | 0.35 | 0.48 | 0.088 | 0.040 | 0.97 | 0.98 |
| SE ((±) | 0.048 | 0.120 | 0.007 | 0.005 | 0.038 | 0.085 | 0.006 | 0.001 | 0.013 | 0.015 |
| Variety (V) | | | | | | | | | | |
| FARO 44 | 6.58 | 6.10 | 0.108 | 0.084 | 0.38 | 0.55 | 0.090 | 0.044$^{a}$ | 0.98 | 0.97 |
| TOFA | 6.48 | 6.10 | 0.113 | 0.094 | 0.39 | 0.54 | 0.090 | 0.041$^{b}$ | 0.98 | 0.98 |
| SE ((±) | 0.051 | 0.101 | 0.005 | 0.008 | 0.037 | 0.019 | 0.001 | 0.001 | 0.004 | 0.010 |
| Cow dung rates (C) t $ha^{-1}$) | | | | | | | | | | |
| 0 | 6.60$^{a}$ | 6.14 | 0.103 | 0.084 | 0.30$^{b}$ | 0.45$^{b}$ | 0.089 | 0.041 | 0.98 | 0.97 |
| 5 | 6.57$^{a}$ | 6.08 | 0.110 | 0.086 | 0.39$^{ab}$ | 0.58$^{ab}$ | 0.090 | 0.042 | 0.99 | 0.97 |
| 10 | 6.55$^{ab}$ | 6.13 | 0.113 | 0.092 | 0.45$^{a}$ | 0.52$^{ab}$ | 0.094 | 0.041 | 0.98 | 0.99 |
| 15 | 6.41$^{b}$ | 6.05 | 0.114 | 0.093 | 0.39$^{ab}$ | 0.61$^{a}$ | 0.088 | 0.043 | 0.98 | 0.99 |
| SE ((±) | 0.051 | 0.096 | 0.005 | 0.005 | 0.065 | 0.050 | 0.003 | 0.001 | 0.007 | 0.011 |
| Interactions | | | | | | | | | | |
| IR x VAR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| IR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| VAR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| IR x VAR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

means followed by the same letter(s) in the same column are not significant at $p \leq 0.05$ using Tukey HSD, *- significant at $p \leq 0.05$, NS- not significant, AWD- alternate wetting and drying, CF- continuous flooding, , SE- standard error

Table 4: Influence of irrigation regimes, variety and cow dung rates on some selected chemical properties of the soils at 15-30 cm soil depth

| Treatments | Chemical property of the soils | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Irrigation regimes (I) | pH | | EC (d S $m^{-1}$) | | OC (%) | | TN (%) | | AP (mg $kg^{-1}$) | |
| AWD 1 | 6.53 | 6.18 | 0.091 | 0.088 | 0.27 | 0.61 | 0.080 | 0.037 | 0.97 | 0.96 |
| AWD 2 | 6.53 | 6.32 | 0.087 | 0.094 | 0.33 | 0.60 | 0.088 | 0.039 | 0.98 | 0.97 |
| AWD 3 | 6.50 | 6.15 | 0.090 | 0.081 | 0.30 | 0.56 | 0.083 | 0.035 | 0.98 | 0.96 |
| CF | 6.37 | 6.14 | 0.088 | 0.088 | 0.17 | 0.54 | 0.080 | 0.037 | 0.97 | 0.95 |
| SE ((±) | 0.053 | 0.143 | 0.006 | 0.005 | 0.057 | 0.062 | 0.006 | 0.002 | 0.010 | 0.013 |
| Variety (V) | | | | | | | | | | |
| FARO 44 | 6.53 | 6.21 | 0.088 | 0.083 | 0.25 | 0.59 | 0.083 | 0.038 | 0.97 | 0.95 |
| TOFA | 6.44 | 6.19 | 0.090 | 0.093 | 0.28 | 0.57 | 0.082 | 0.037 | 0.98 | 0.96 |
| SE ((±) | 0.051 | 0.101 | 0.004 | 0.007 | 0.039 | 0.017 | 0.002 | 0.001 | 0.004 | 0.016 |
| Cow dung rates (C) t $ha^{-1}$) | | | | | | | | | | |
| 0 | 6.54[a] | 6.27 | 0.091 | 0.083 | 0.23 | 0.44[b] | 0.080 | 0.036 | 0.97 | 0.94[b] |
| 5 | 6.54[a] | 6.16 | 0.085 | 0.085 | 0.25 | 0.64[a] | 0.084 | 0.038 | 0.98 | 0.96[ab] |
| 10 | 6.47[ab] | 6.23 | 0.085 | 0.095 | 0.32 | 0.61[a] | 0.085 | 0.037 | 0.98 | 0.97[a] |
| 15 | 6.39[b] | 6.13 | 0.094 | 0.089 | 0.26 | 0.61[a] | 0.083 | 0.037 | 0.98 | 0.96[ab] |
| SE ((±) | 0.048 | 0.094 | 0.007 | 0.006 | 0.044 | 0.046 | 0.002 | 0.001 | 0.007 | 0.012 |
| Interactions | | | | | | | | | | |
| IR x VAR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| IR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | * | NS |
| VAR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| IRx VAR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

means followed by the same letter(s) in the same column are not significant at $p \leq 0.05$ using Tukey HSD, *- significant at $p \leq 0.05$, NS- not significant, AWD- alternate wetting and drying, CF- continuous flooding, , SE- standard error

Table 5. Interactions of irrigation regimes and cow dung rates on available phosphorus (AP) content of the soils at 15-30 cm soil depth

| Treatments | AP (mg kg$^{-1}$) | | | |
|---|---|---|---|---|
| | Cow dung rates (t ha$^{-1}$) | | | |
| | 0 | 5 | 10 | 15 |
| Irrigation regimes | 2020 season | | | |
| AWD 1 | 0.96$^{b}$ | 0.97$^{ab}$ | 0.97$^{ab}$ | 0.99$^{ab}$ |
| AWD2 | 0.96$^{b}$ | 1.02$^{a}$ | 0.98$^{ab}$ | 0.98$^{ab}$ |
| AWD3 | 0.97$^{ab}$ | 0.98$^{ab}$ | 0.98$^{ab}$ | 0.99$^{ab}$ |
| CF | 0.97$^{ab}$ | 0.97$^{ab}$ | 0.98$^{ab}$ | 0.97$^{ab}$ |
| SE (±) | 0.016 | | | |

Means followed by the same letter (s) across columns and rows are not significant at $p \leq 0.05$ using Tukey HSD, AWD- alternate wetting and drying, CF- continuous flooding, SE- standard error

## Effects of Irrigation Regimes, Variety and Cow dung Rates on Exchangeable Bases and CEC

The irrigation regimes (AWD1, AWD2, AWD3 and CF) and rice varieties (FARO 44 and TOFA) investigated in this study had no significant ($p>0.05$) effects on exchangeable bases and CEC of the soils across all seasons and depths of measurement (Table 6 and 7). However, cow dung rates significantly ($p \leq 0.05$) affected calcium (Ca) content at 15-30 cm in 2020 season and K at 0-15 cm depth for the 2021 season. Fertilized treatments (5, 10 and 15 t ha-1) had higher Ca and K contents than without fertilization (0 t ha-1). In this study, Ca and K values ranged between 1.71-2.15 cmol kg-1 and 0.49-0.89 cmol kg-1 respectively considering the treatments main effects (Table 6 and 7). The application rates of 5, 10 and 15 t ha-1 cow dung increased Ca by 5.26 %, 7.60 % and 6.43 % in 2020 season and increased the K content by 74.51 %, 49.02 % and 33.33 % respectively in 2021 season over the control treatment (Table 6 and 7) thus, showing the superiority of fertilization over no fertilization in improving exchangeable bases concentrations of the soil. The greater Ca and K contents in fertilized treatments (5, 10 and 15 t ha-1) than without fertilization is attributed to the mineralization of the cow dung applied releasing mineral elements to soil resulting in increased Ca and K contents in fertilized treatments. Similar observations were made by Haque *et al*. (2021) in paddy clay soils of Malaysia. On the other hand, irrigation regimes, variety and cow dung rates have no significant ($p>0.05$) effect on CEC of the soils across all seasons and depths of measurement (Table 6 and 7) in this study. Rice production involved greater addition of water than other cereal crops such as sorghum and maize, therefore, leaching of mineralized elements such as Ca, Mg, Na, and K might have been responsible for the comparable CEC observed across treatments and depths of measurement investigated. However, variety and cow dung rates interaction were significant ($p \leq 0.05$) with FARO 44 and 15 t ha-1 as well as TOFA and 10 t ha-1 combinations having higher Ca contents than all other combinations (Table 8). Additionally, irrigation regimes and rice varietal interactions on CEC of the soils were also significant ($p \leq 0.05$) for the 2020 season at 0-15 cm soil depth with AWD2 and TOFA interaction having the highest CEC (8.87 cmol kg-1) than other combinations (Table 9). Generally, the result showed that most of the interactions involving no fertilization had lower values of chemical properties than that involving fertilization. Moreover, range of values observed in this study showed low OC and AP, low-medium Ca and high TN and K contents (Esu, 1991) across irrigation regimes, rice varieties and cow dung rates investigated, suggesting the need for more time for differences to develop between treatments tested particularly in OC, AP and Ca and Mg contents of the soil. Also, most of the values of OC, Ca, Mg, Na, K and CEC reported in this study are similar to those observed by Adamu *et al*. (2019) in Kano, northwestern Nigeria. Mustapha *et al*. (2017) also observed no significant effects of water management and fertilization regimes on most chemical properties of the soil they studied therefore corroborating the findings of this study.

Table 6: Influence of irrigation regimes, variety and cow dung rates on exchangeable bases and CEC at 0-15 cm soil depth

| | Exchangeable bases and CEC | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Irrigation regimes (I) | Ca | | Mg | | Na | | K | | CEC | |
| | ………… cmol $kg^{-1}$ ………… | | | | | | | | | |
| AWD 1 | 1.86 | 2.15 | 2.08 | 2.93 | 0.32 | 0.48 | 0.63 | 0.74 | 8.47 | 8.63 |
| AWD 2 | 1.89 | 1.93 | 2.05 | 2.61 | 0.32 | 0.44 | 0.62 | 0.68 | 8.25 | 8.79 |
| AWD 3 | 1.90 | 2.09 | 2.09 | 2.73 | 0.31 | 0.45 | 0.68 | 0.75 | 8.25 | 8.30 |
| CF | 1.85 | 1.79 | 2.06 | 2.70 | 0.33 | 0.46 | 0.59 | 0.68 | 8.25 | 7.92 |
| SE ((±) | 0.031 | 0.142 | 0.031 | 0.150 | 0.022 | 0.021 | 0.031 | 0.148 | 0.518 | 0.336 |
| Variety (V) | | | | | | | | | | |
| FARO 44 | 1.88 | 1.95 | 2.08 | 2.75 | $0.30^{b}$ | 0.47 | 0.63 | 0.66 | 8.38 | 8.41 |
| TOFA | 1.87 | 2.02 | 2.06 | 2.74 | $0.34^{a}$ | 0.44 | 0.63 | 0.75 | 8.23 | 8.41 |
| SE ((±) | 0.023 | 0.079 | 0.023 | 0.137 | 0.014 | 0.016 | 0.015 | 0.080 | 0.137 | 0.179 |
| Cow dung rates (C) t $ha^{-1}$) | | | | | | | | | | |
| 0 | 1.84 | 1.93 | 2.03 | 2.59 | 0.31 | 0.46 | 0.62 | $0.51^{b}$ | 8.16 | 8.18 |
| 5 | 1.88 | 2.01 | 2.08 | 2.72 | 0.33 | 0.45 | 0.63 | $0.89^{a}$ | 8.63 | 8.77 |
| 10 | 1.89 | 1.94 | 2.08 | 2.84 | 0.33 | 0.46 | 0.64 | $0.76^{ab}$ | 8.16 | 8.35 |
| 15 | 0.89 | 2.08 | 2.09 | 2.83 | 0.31 | 0.45 | 0.61 | $0.68^{bc}$ | 8.26 | 8.34 |
| SE ((±) | 0.029 | 0.069 | 0.035 | 0.112 | 0.018 | 0.015 | 0.023 | 0.074 | 0.331 | 0.224 |
| Interactions | | | | | | | | | | |
| IR x VAR | NS | NS | NS | NS | NS | NS | NS | NS | * | NS |
| IR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| VAR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| IRx VAR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

means followed by the same letter(s) in the same column are not significant at $p \leq 0.05$ using Tukey HSD, *- significant at $p \leq 0.05$, NS- not significant, AWD- alternate wetting and drying, CF- continuous flooding, , SE- standard error

Table 7: Influence of irrigation regimes, variety and cow dung rates on exchangeable bases and CEC of the soil at 15-30 cm soil depth

| | Exchangeable bases and CEC | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Irrigation regimes (I) | Ca | | Mg | | Na | | K | | CEC | |
| | …………….. cmol kg$^{-1}$ …………….. | | | | | | | | | |
| AWD 1 | 1.77 | 1.92 | 2.02 | 2.77 | 0.29 | 0.42 | 0.54$^{ab}$ | 0.57 | 7.75 | 8.42 |
| AWD 2 | 1.81 | 1.82 | 2.03 | 2.41 | 0.28 | 0.40 | 0.50$^{b}$ | 0.54 | 7.38 | 8.28 |
| AWD 3 | 1.80 | 1.87 | 2.07 | 2.63 | 0.28 | 0.40 | 0.57$^{a}$ | 0.59 | 7.54 | 7.90 |
| CF | 1.79 | 1.84 | 2.07 | 2.36 | 0.29 | 0.43 | 0.49$^{b}$ | 0.54 | 7.63 | 7.70 |
| SE ((±) | 0.018 | 0.170 | 0.033 | 0.184 | 0.017 | 0.037 | 0.017 | 0.116 | 0.455 | 0.383 |
| Variety (V) | | | | | | | | | | |
| FARO 44 | 1.79 | 1.82 | 2.06 | 2.58 | 0.30 | 0.40 | 0.52 | 0.54 | 7.55 | 8.15 |
| TOFA | 1.79 | 1.90 | 2.04 | 2.49 | 0.28 | 0.42 | 0.53 | 0.59 | 7.59 | 7.99 |
| SE ((±) | 0.017 | 0.061 | 0.021 | 0.118 | 0.011 | 0.011 | 0.015 | 0.068 | 0.127 | 0.150 |
| Cow dung rates (C) t ha$^{-1}$) | | | | | | | | | | |
| 0 | 1.71$^{b}$ | 1.80 | 2.02 | 2.48 | 0.28 | 0.41 | 0.50 | 0.51 | 7.38 | 7.88 |
| 5 | 1.80$^{a}$ | 1.86 | 2.05 | 2.52 | 0.28 | 0.41 | 0.53 | 0.58 | 7.55 | 8.09 |
| 10 | 1.84$^{a}$ | 1.82 | 2.05 | 2.61 | 0.30 | 0.42 | 0.55 | 0.61 | 7.53 | 8.24 |
| 15 | 1.82$^{a}$ | 1.97 | 2.08 | 2.55 | 0.29 | 0.41 | 0.52 | 0.55 | 7.83 | 8.09 |
| SE ((±) | 0.024 | 0.084 | 0.036 | 0.071 | 0.017 | 0.014 | 0.032 | 0.061 | 0.248 | 0.231 |
| Interactions | | | | | | | | | | |
| IR x VAR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| IR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| VAR x CDR | * | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| IRx VAR x CDR | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |

means followed by the same letter (s) in the same column are not significant at $p \leq 0.05$ using Tukey HSD, *- significant at $p \leq 0.05$, NS- not significant, AWD- alternate wetting and drying, CF- continuous flooding, , SE- standard error

Table 8: Interactions of variety and cow dung rates on calcium content of the soils at 15-30 cm depth in Sokoto, Nigeria

| Variety | Calcium (cmol kg$^{-1}$) at 15-30 cm soil depth | | | |
|---|---|---|---|---|
| | Cow dung rates (t ha$^{-1}$) | | | |
| | 0 | 5 | 10 | 15 |
| | 2020 | | | |
| FARO 44 | 1.74$^{bc}$ | 1.76$^{abc}$ | 1.82$^{ab}$ | 1.85$^{a}$ |
| TOFA | 1.68$^{c}$ | 1.84$^{ab}$ | 1.85$^{a}$ | 1.78$^{abc}$ |
| SE (±) | 0.034 | | | |

Means followed by the same letter (s) across columns and rows are not significant at p≤0.01 level of probability using Tukey HSD, AWD- alternate wetting and drying, CF- continuous flooding, SE- standard error

Table 9: Interactions of irrigation regimes and variety on cation exchange capacity (CEC) of the soil (2020)

| Treatments | CEC (cmol kg$^{-1}$) at 0-15 cm soil depth | |
|---|---|---|
| | Variety | |
| Irrigation regimes | FARO 44 | TOFA |
| AWD 1 | 8.46$^{ab}$ | 8.48$^{ab}$ |
| AWD 2 | 7.63$^{b}$ | 8.87$^{a}$ |
| AWD 3 | 8.22$^{ab}$ | 8.28$^{ab}$ |
| CF | 8.60$^{ab}$ | 7.91$^{ab}$ |
| SE (±) | 0.554 | |

Means followed by same letter(s) across columns and rows are not significant at 5 % level of significance using Tukey HSD, *- significant at 5 % level of probability; AWD- alternate wetting and drying; CF- continuous flooding; SE-standard error

**Influence of water management, variety and Cow dung rates on percentage base saturation (PBS), ESP and SAR**

Similar to treatments effects on exchangeable bases and CEC of the soil, the treatments tested had no significant (p>0.05) effects on percentage base saturation (PBS), exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) in all seasons and depths (Table 10 and 11). This could be due to leaching of salts and exchangeable bases with percolation water in all treatments resulting in similar PBS, ESP and SAR across irrigation regimes, rice varieties and cow dung rates (Table 10 and 11). Considering the treatments main effects, PBS, ESP and SAR values across treatments and depths ranged between 59.03-73.28 %, 3.69-5.83 and 0.20-0.31 respectively (Table 10 and 11).

Literature on the effects of irrigation regimes, rice varieties and cow dung rates on PBS, ESP and SAR are rare, but as these parameters unveils potentials of soils to be salt affected (ESP and SAR) and to have enough exchangeable base concentrations to support healthy crop production, reports on these properties are needed to identify best management practices for the production of rice and other crops, reducing salt build up and enhancing national and global food security.

Table 10: Influence of irrigation regimes, variety and cow dung rates on percent base saturation (BS), ESP and SAR at 0-15 cm depth

| Treatments | BS (%) | | ESP (%) | | SAR | |
|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Irrigation regimes (I) | | | 0-15 cm | | | |
| AWD 1 | 59.03 | 73.04 | 3.89 | 5.52 | 0.23 | 0.30 |
| AWD 2 | 60.70 | 65.59 | 3.96 | 5.09 | 0.23 | 0.30 |
| AWD 3 | 62.33 | 73.28 | 389 | 5.44 | 0.22 | 0.29 |
| CF | 59.38 | 71.72 | 4.09 | 5.83 | 0.24 | 0.31 |
| SE (±) | 4.042 | 3.514 | 0.383 | 0.370 | 0.015 | 0.014 |
| Variety (V) | | | | | | |
| FARO 44 | 60.73 | 70.51 | 3.76 | 5.65 | 0.21[b] | 0.31 |
| TOFA | 59.99 | 71.30 | 4.16 | 5.29 | 0.24[a] | 0.29 |
| SE (±) | 1.056 | 2.962 | 0.217 | 0.194 | 0.010 | 0.014 |
| Cow dung rates (C) t $ha^{-1}$ | | | | | | |
| 0 | 59.24 | 67.34 | 3.86 | 5.67 | 0.22 | 0.31 |
| 5 | 58.89 | 70.25 | 3.88 | 5.20 | 0.24 | 0.29 |
| 10 | 62.79 | 72.83 | 4.22 | 5.55 | 0.24 | 0.30 |
| 15 | 60.51 | 73.22 | 3.89 | 5.48 | 0.22 | 0.29 |
| SE (±) | 2.427 | 2.734 | 0.258 | 0.193 | 0.013 | 0.012 |
| Interactions | | | | | | |
| I x V | NS | NS | NS | NS | NS | NS |
| I x C | NS | NS | NS | NS | NS | NS |
| V x C | NS | NS | NS | NS | NS | NS |
| I x V x C | NS | NS | NS | NS | NS | NS |

Means followed by the same letter (s) in the same column are not significant at $p \leq 0.05$ level of probability using Tukey HSD, NS- not significant, AWD- alternate wetting and drying, CF- continuous flooding, SE- standard error

Table 11: Influence of irrigation regimes, variety and cow dung rates on percent base saturation (BS), ESP and SAR at 15-30 cm depth

| Treatments | BS (%) | | ESP (%) | | SAR | |
|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2020 | 2021 | 2020 | 2021 |
| Irrigation regimes (I) | | | | | | |
| AWD 1 | 60.74 | 67.89 | 3.82 | 4.99 | 0.21 | 0.27 |
| D 2 | 63.84 | 63.94 | 3.84 | 4.94 | 0.20 | 0.28 |
| D 3 | 64.31 | 70.16 | 3.81 | 5.18 | 0.20 | 0.27 |
| CF | 61.66 | 67.27 | 3.89 | 5.57 | 0.21 | 0.30 |
| SE (±) | 4.344 | 4.118 | 0.090 | 0.611 | 0.014 | 0.029 |
| Variety (V) | | | | | | |
| FARO 44 | 62.69 | 66.45 | 3.69 | 5.02 | 0.20 | 0.28 |
| TOFA | 62.59 | 68.18 | 3.99 | 5.31 | 0.22 | 0.27 |
| SE (±) | 1.194 | 1.915 | 0.165 | 0.128 | 0.008 | 0.007 |
| Cow dung rates (C) t $ha^{-1}$ | | | | | | |
| 0 | 61.55 | 66.56 | 3.79 | 5.22 | 0.20 | 0.28 |
| 5 | 62.65 | 67.81 | 3.72 | 5.21 | 0.20 | 0.28 |
| 10 | 64.71 | 66.67 | 4.05 | 5.15 | 0.22 | 0.28 |
| 15 | 61.65 | 68.22 | 3.78 | 5.09 | 0.21 | 0.27 |
| SE (±) | 2.115 | 2.593 | 0.217 | 0.226 | 0.013 | 0.010 |
| Interactions | | | | | | |
| I x V | NS | NS | NS | NS | NS | NS |
| I x C | NS | NS | NS | NS | NS | NS |
| V x C | NS | NS | NS | NS | NS | NS |
| I x V x C | NS | NS | NS | NS | NS | NS |

Means followed by the same letter (s) in the same column are not significant at $p \leq 0.05$ level of probability using Tukey HSD, NS- not significant, AWD- alternate wetting and drying, CF- continuous flooding, SE- standard error

## CONCLUSION

From the results obtained and discussions made, it can be concluded that irrigation regimes and rice varieties have no significant effects on chemical quality of the soil. Conversely, application rates of 5, 10 and 15 t $ha^{-1}$ cow dung significantly improved the soils chemical quality through increased OC, Ca and K contents than without fertilization and should therefore be employed for improving soil chemical quality. It is however recommended that similar research should be extended to 3-4 years to assess medium term effects of treatments tested on the soils' chemical quality.

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