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PHYSICO-CHEMICAL ASSESSMENT OF SOILS USED FOR VEGETABLE CULTIVATION IN KURA REGION OF KANO STATE, NIGERIA

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ABSTRACT

The research was conducted with the aim of assessing the physico-chemical parameters of soils used for vegetable cultivation in Kura region of Kano State, Nigeria. Soil samples were collected from three onion plots, three tomato plots and three cucumber plots from the top (0-20cm) in the sites. Standard laboratory procedures were used to assess the samples for PH, organic matter, nitrogen, available phosphorous, and potassium contents. In addition, the mean values of soil parameters determined were computed and the results was compared with the critical limits in other to interpret level of the soils fertility. The results of the assessment revealed that the soil samples had low to moderate PH (5.28-6.71), and organic matter concentrations (0.44-1.86%), low potassium concentrations (0.05-0.21mol/kg), moderate to high nitrogen (0.14-0.44%) and high phosphorous concentrations (22.07-55.49mg/kg). Since nitrogen can be recycled in nature, efforts should be made to recycle the excess phosphorous in soils of vegetable crops plots. Furthermore, it is recommended to promote the use of bio-fertilizers such arbuscular mycorrhizal fungi (AMF) inoculants, which may dissolve and transfer essential nutrients from the soil to the plants.

Keywords: Physico-chemical, Soil, Vegetable, Cultivation

INTRODUCTION

The physio–chemical assessment of soil samples in agricultural ecosystems is highly beneficial in order to maintain or enhance soil quality and efficiently control soil fertility and plant nutrition (Suni *et al.,* 2023). The interdependent characteristics of physical, chemical, and biological qualities make up soil quality, which affect many processes in the soil that make it suitable for agricultural practice and other purpose (Adamu *et al.,* 2019). In vegetable crop production evaluation of the physico-chemical characteristics of soil is crucial because elements like pH, organic matter, nitrogen, and phosphorus have an impact on the growth and development of plants. A vegetable is any part of a plant that can be eaten, including the stalk and stem of celery, the root of carrot, the tuber of potato, the bulb of onion, the leaves of spinach and lettuce, the blossom of globe artichokes, the fruit of apples, cucumbers, pumpkins, strawberries, and tomatoes, and the seeds of beans and peas (IARC, 2023). According to Malhi *et al.* (2020), vegetables are a vital source of vitamins A, C, K, thiamin, pyridoxine, and carotenes, as well as minerals and trace elements. They also have a major impact on avoiding degenerative and chronic illnesses and preserving health (Begum *et al.,* 2019). During the cultivation of vegetable plants fertilizers are used in order to meet the nutritional demand of healthy crops and to improve yield. Also several fungicides and pesticides are utilized in other to cure diseases and pests (Shankar *et al.,* 2021). Although Proper fertilizer management can maximize plant biomass production, excessive fertilizer application can cause disease episodes that hinder nitrate accumulation, root and leaf development, and plant biomass production (Shi *et al.,* 2021). Chemical fertilization has been demonstrated to have a major impact on the physical and chemical characteristics of soil, as well as to encourage microbial exudation from the roots, as well as affect soil fast-acting nutrients that can be directly absorbed and utilized by the plant, which ultimately affects the yield (Brunetto *et al.,* 2015; Liu *et al.,* 2021).

Relevant studies have demonstrated that fertilizer can cause serious soil sloughing, which results in an imbalance of soil nutrients, which in turn limits the growth and development of the plant root system and induces leaf nutrient imbalance (Liu et al., 2024). Fertilizer can also cause acidification of the soil, which causes a severe nutrient imbalance and is one of the main sources of pollution in the soil, water, and air (Yang *et al.,* 2020; Zhang *et al.,* 2020). Fertilizer application can directly or indirectly change the physical and chemical properties of soil, thus altering soil productivity.

Hence, in order to apply appropriate nutrient management methods and to support environmental sustainability, it is critical to identify priority regions through systematic assessment and monitoring of soil nutrient status (Reza *et al.,* 2019). Kura is the largest cluster in terms of vegetable plant cultivation in Kano State, Nigeria, however less is known about the physic-chemical status of the vegetable plots. The aim of the present study is to assess the physico-chemical parameters of onion, tomato and cucumber plots within Kura Local Government agro-ecological zone.

MATERIALS AND METHODS

Soil Sampling

Soil samples were collected from three farmlands for each crop (tomato, onion, and cucumber plots) that had no previous history of microbial inoculation, within the Kura local government agro-ecological zone. Kura is one of the major vegetable production clusters in Kano state, as it lies within the Kano state river irrigation project (Baseline Report on Horticulture, 2020). Its geographical coordinates are latitude 11^{0} 46^{I} 30^{II} North and longitude 8^{0} 25^{I} 49^{II} East. The samples were collected from three sites for each crop, the sites are Katsinawa, Daneji and Fegin Zabi. The soil samples (0-20 cm depth) were collected from five location points to obtain composite sample. Samples from each plot were mixed thoroughly to make a homogenous composite sample. The composite sample from each farm was packed independently in sterile paper bags, sealed, labeled and transported to the laboratory.

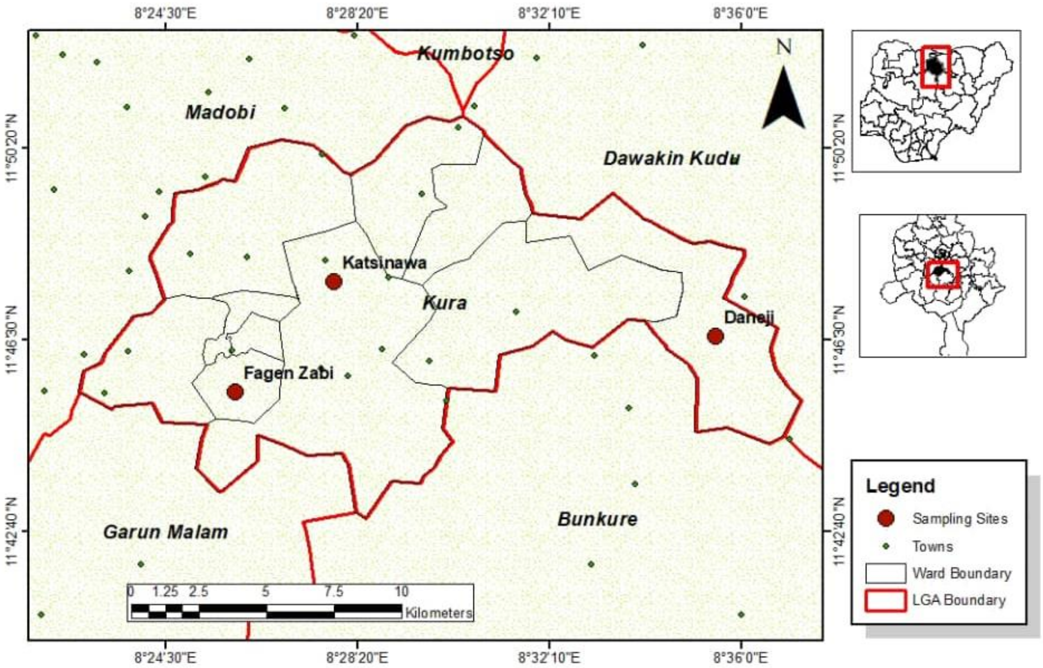

Figure 1: Map of the Sampling Sites

Determination of Soil Physicochemical Parameters

Soil pH in H_20 (1:2.5)

Ten grams (10g) of air-dried soil were weighed into a 50ml beaker and 25ml of distilled water was added. The suspension was stirred several times during the next 30 minutes with a glass rod. The soil suspension was then allowed to stand for 30minutes allowing most of the suspended clay to settle out of the suspension. The pH meter (Janway, 3520) was then calibrated, where the electrode of the pH meter was inserted into the partly settled suspension and the pH of the suspension was recorded (Eno *et al.,* 2009).

Organic Matter (O.M)

One (1g) air-dried (2mm) Sieved soil sample was weighed into a 500ml conical flask. Ten milliliters (10ml) of 1M $K_2Cr_20_7$ solution was introduced accurately into each flask and swirled gently to disperse the soil. Twenty milliliters concentrated H_2S0_4 were added gently and immediately swirled the flask gently until soil and reagents were mixed and then swirled more vigorously for one minute. It was then allowed to stand for 30minutes for oxidation to complete and then 100ml of distilled water and 4 drops of phenanthroline indicator were added and titrated against a standard 0.5N ferrous sulphate solution to obtain an end point. A blank was also prepared with same procedure but without sample (Eno *et al.,* 2009). The result was calculated with the formula as follow:

$$\%\ \text{Organic M} = \frac{(\text{Blank titre – actual titer})\text{x } 0.003 \text{ x N x F x } 100}{\text{w}}$$

Where:

F = Organic matter correction factor = 1.33
N= Normality of $FeSO_4$ used (0.5N)
W= Weight of sample
0.003= Milliequivalent of carbon

Determination of Total Nitrogen

The Kjeldhal method of Eno *et al.* (2009) was used to determine total nitrogen (N) in the soil sample. One gram of each soil sample was taken in individual kjeldhal flasks. Then, 2 grams of a catalyst (a mixture of Na_2SO4, $CuSO_4$ and selenium powder in 100:10:1 proportion) and 30 mL of H_2SO_4 were added into each flask and heated gently until frothing ceased. After the formation of clear solution in each flask, the digestion was continued for 30 minutes. Then, 50 ml of distilled water and 30 mL of 40% NaOH were added. After cooling, the mixtures were then transferred to a Kjeldhal distillation flask. Ten milliliters (10ml) of boric acid solution and two drops of indicator (bromocresol green and methyl red) solution were taken in three different volumetric flasks. Furthermore, the distillation flasks were heated for 30 minutes and the distillate of each sample was collected in their separate flasks and titrated against 0.025N HCl. The percent of nitrogen was calculated as follows:

$$\%\ \text{of Nitrogen} = \frac{A - B \times N \times 0.014 \text{ x } VD}{At \text{ x } W} \times 100$$

Where:

A= Volume of sample required for titration of the sample,
B= Volume of sample required for titration of blank,
N = Normality of HCl,
0.014 = Miliequivalent weight of nitrogen.
At = Aliquot taken
W = Weight of sample
VD = Volume of Digest

Determination of Phosphorous Content

The Bray method was used to determine the amount of available phosphorous (P) in the soil sample (Eno *et al.,* 2009). The 2.5g of soil sample was individually taken in three conical flasks. Then, 50 mL of P-extraction solution (NH_4F + HCl) was added to each flask and the flasks were kept on shaker (Innova 4000) operated at 180 rpm for 30minutes. The blank was also prepared without soil. Further, each mixture was filtered through Whatman No. 42 filter paper and 5 ml of filtrate was transferred to a volumetric flask. To each reaction mixture, 20 mL of distilled water and 4 mL of ascorbic acid were added and incubated for 10 minutes for blue color formation. The optical density of this solution was determined at 883 nm and the phosphorous content in soil was thus calculated as follows:

$$P\ (mg/kg) = \frac{(Abs)}{Slope} \times \frac{VF}{W}$$

Where:

VF = Volume of flask, W = Weight of sample, Abs = Absorbance

Determination of Potassium Content

2.5g of soil sample was transferred into an extraction cup, and 15 ml of NH_4OAc was added using a dispenser. The solution was stirred using for 15 minutes using mechanical stirrer (1550 rpm). The solution was allowed to settle and filtered using Whatman paper no 42. Using custom laboratory diluter, each sample was diluted 25 times with 1N NH_4OAc as diluent. A flame photometer was used to take the readings following the instructions on the manual.

Calculation

$$\frac{15\text{ml extract x concentration in}\frac{\mu g}{ml}}{2.5g} = \text{mol/g of K}$$

Statistical Analysis

Values were expressed as mean ± standard deviation. One-way analysis of variance (ANOVA) was used to compare the means of the variables, and multiple comparison was performed using Fishers least significance different (LSD) at $p<0.05$.

RESULTS AND DISCUSSION

Table 1is the results of the physico-chemical assessment of the three onion farms soils. The pH concentrations of site A and site C are slightly acidic but the pH of site B is normal. All the three plots have high O.M and Phosphorous concentrations. Also site A and site C have high nitrogen concentrations, while all the three sites were characterized with low potassium concentrations.

Table 2 shows the results of the physico-chemical assessment of the three tomato farm soils. The pH of site A is normal while site B and site C have slightly acidic pH. The O.M and phosphorous concentrations of all the three sites were high, while the nitrogen concentration of site A and site C were also high. Site A has moderate potassium, while the remaining two sites have low potassium concentrations.

Table 3 is the results of the physico-chemical assessment of the three cucumber farms soils. The pH concentrations of site C was acidic the remaining two sites had normal pH. All the three sites were characterized with low O.M, and potassium concentrations, while the value of phosphorus and nitrogen were moderately high.

Table 1: Physicochemical Parameters of Onion Farms Soils

SITES	PH	0M (%)	N (%)	P (mg/kg)	K (mol/kg)
Site A	5.59 ± 0.05^{b}	1.64 ± 0.02^{a}	0.23 ± 0.01^{b}	36.84 ± 0.18^{b}	0.14 ± 0.01^{a}
Site B	6.39 ± 0.03^{a}	1.13 ± 0.01^{b}	0.14 ± 0.01^{c}	31.16 ± 0.43^{b}	0.09 ± 0.01^{b}
Site C	5.51 ± 0.04^{b}	0.99 ± 0.02^{c}	0.42 ± 0.01^{a}	55.49 ± 0.04^{a}	0.12 ± 0.01^{a}

Values are expressed as mean ± standard deviation.
Site A: Katsinawa; Site B: Daneji; Site C: Fegin Zabi

Table 2: Physicochemical Parameters of Tomato Farms Soils

SITES	PH	0.M (%)	N (%)	P (mg/kg)	K (mol/kg)
Site A	6.71 ± 0.06^{a}	1.86 ± 0.02^{a}	0.17 ± 0.01^{b}	48.68 ± 0.46^{a}	0.21 ± 0.01^{a}
Site B	5.43 ± 0.02^{c}	0.84 ± 0.01^{c}	0.43 ± 0.01^{a}	27.06 ± 0.14^{b}	0.09 ± 0.01^{b}
Site C	5.86 ± 0.02^{b}	1.14 ± 0.02^{b}	0.44 ± 0.01^{a}	46.09 ± 0.08^{a}	0.07 ± 0.01^{b}

Values are expressed as mean ± standard deviation.
Site A: Katsinawa ; Site B: Daneji; Site C: Fegin Zabi

Table 3: Physicochemical Parameters of Cucumber Farms Soils

SITES	PH	0M (%)	N (%)	P (mg/kg)	K (mol/kg)
Site A	6.05 ± 0.02^{a}	0.68 ± 0.01^{a}	0.24 ± 0.01^{b}	22.07 ± 0.12^{c}	0.13 ± 0.01^{a}
Site B	6.17 ± 0.01^{a}	0.58 ± 0.01^{b}	0.31 ± 0.01^{a}	26.91 ± 0.18^{b}	0.05 ± 0.01^{c}
Site C	5.28 ± 0.01^{b}	0.44 ± 0.01^{c}	0.32 ± 0.01^{a}	31.43 ± 0.08^{a}	0.08 ± 0.01^{b}

Values are expressed as mean ± standard deviation.
Site A: Katsinawa; Site B: Daneji; Site C: Fegin Zabi

Discussion

Soil pH refers to the acidity or alkalinity of the soil. It measures how much of the soil's free hydrogen ions (H+) are present (Bello *et al.,* 2021). It is an important parameter in assessing soil samples. If the pH is less than 6 then it is said to be an acidic soil, While a pH of 6 to 8.5 is considered normal, soil that is higher than 8.5 is considered alkaline. (Adamu *et al.,* 2019; Sunil *et al.*, 2023). In the present study the pH concentrations of site A and site C onion farms were acidic, so were site B and C tomato farms and Site C cucumber farm. The acidity in the soil may be attributed to over use of urea as reported by Liu *et al.,* (2024). According to Tang *et al.* (2022), soil microorganisms have the ability to convert urea quickly into NH4+. This process releases H+ into the soil, which speeds up the acidification of the soil. The acidity may also be caused by the composition of parent soil material, leaching, high organic matter decay or cultivation of high yield crops (Arnall, 2024).

Soil organic matter increases soil organic carbon and promotes soil health and fertility and is the foundation of soil fertility (Sunil *et al.*, 2023). In the present study the value O.M ranges from 0.44 - 1.86. According to Sunil *et al.* (2023) the normal value of O.M is 0.52 to 0.72. From the above results, we can conclude that onion and tomato soils have moderate to high organic matter, while all the three cucumber fields have low organic matter concentrations. The stoichiometric imbalance of N addition has been demonstrated to accelerate soil organic matter breakdown in order to preserve the soil C/N ratio, in accordance with the hypothesis of Hessen *et al.* (2004). The loss of microenvironments caused by recurrent tillage or burning of vegetation after harvest may be the cause of the low O.M. values in the soil of cucumber farms. This, in turn, leads to a decrease in the biomass and variety of the soil biota (FAO, 2019). Nitrogen is the most prevalent mineral needed by plant and acts as an important determinant of plant growth and development (Prinsi and Espen 2015). It is the essential component of proteins, nucleic acids, chlorophyll, and plant growth regulators, among other biological macromolecules. (Nguyen *et al.,* 2015; Sinhaan and Tandoon 2022). In the present study the value of total nitrogen within the study sites ranges from 0.14% to 0.44%, Sanda and Ismail. (2012) reported the ranges <0.1 of nitrogen concentrations be low of 0.1 – 0.2 to be moderate, while 0.2– 0.4 to be high for Kano farms. From the above results we can conclude that all the vegetable plots have moderate to high nitrogen concentrations. The high concentrations of N may be attributed to the over use of nitrogen and ammonium fertilizers (Liu *et al.,* 2024). Excess N fertilizer application might cause the soil to become acidic, as observed from the results of PH concentrations in the present study. It has been reported that over usage of nitrogen fertilizers cause nitrate buildup, particularly in green leaf vegetable crops, and they can contaminate groundwater through leaching (Altuntas, 2021). so also accessory pigments (Sinha and Tandoon, 2022), growth retardation and chlorosis (Sett and Soni 2013) reduced cell size and protein content (Yanagida *et al.,* 2011) and reduced yield (Ding *et al.,* 2005).

In the present study the value of available phosphorus ranges from 22.07 – 55.49 within the study sites. According to Chude *et al.* (2012) and Sanda and Ismail (2012), phosphorous value above 20 mg is considered high in Nigerian farm soil. Thus, all the vegetable plots in the present study have high phosphorous concentrations. Phosphorous is one of the major constituents of plants growth as it is one of the vital macronutrients needed for many vital physiological and biological activities throughout plant growth, including energy metabolism, membrane integrity and synthesis, and many other physiological functions. (Hasan *et al.,* 2016). Additionally, phosphorus aids plants in absorbing, storing, and transforming solar energy into biomolecules like adenosine triphosphate (ATP), which power biological processes like photosynthesis. (Chakraboty and Prasad, 2021). While most plants may not noticeably suffer from excessive phosphorus, certain crops may experience nutritional imbalances as a result of excessive phosphorus, especially when combined with a high soil pH (over 6.5), which can result in micronutrient shortages in zinc and iron. (Smith *et al.,* 2021). Phosphorus farm runoff can result in algal blooms that create toxins that contaminate drinking water, deplete dissolved oxygen in streams, and kill fish and other aquatic life. (Rosen, 2020)

The high concentration of phosphorous may be caused by over use of phosphate fertilizers which build up in the farms soil (Albrechtova *et al.,* 2012). According to Begum *et al.,* *(*2019) vegetable cultivation is largely dependent on high chemical fertilization in order to increase maximum yields of the crops. The high concentration of phosphorous maybe attributed to the fact that NPK fertilizers increased the amount of leftover fast-acting phosphorus nutrients in the soil, and fertilizers encouraged P-rich microbial activity in the soil. (Bindraban *et al.,* 2020).

Potassium element helps plant perform essential processes such as enzyme activation, osmotic adjustment, turgor creation, cell expansion, modulation of membrane electric potential, and pH homeostasis (Ragei *et al.,* 2019). According to Sanda and Ismail (2012) potassium concentrations of < 0.15 are considered low, while 0.15-0.3 is moderate and > 0.3 is high for Kano agricultural soils. In the present study the value of potassium within the study sites was low within all the sampling plots with the exception of Site A tomato farm which has a moderate value (0.22mg).

Potassium deficiency has been reported to cause decreased in growth of the roots (Liu *et al.,* 2024) harm to membranes and organelles within cells as well as the accumulation of black particles in the cell walls of the roots (Jia *et al.,* 2008) and increase in activities of antioxidant enzymes, namely superoxide dismutase, ascorbate peroxidase, glutathione reductase and catalase (Liu *et al*,. 2013). The variability in the physico – chemical measurements between the farm soils may be attributed to dfferent crop management techniques and soil management techniques, such as variances in fertilizer application, across various land use regimes (Srinivasarao *et al.,* 2014).

CONCLUSION

It can be concluded that the soil of the vegetable farms in the present study is characterized with low to moderate PH, low potassium concentrations, high nitrogen and phosphorous concentrations. Thus, when applying chemical fertilizers, a general balance is needed. to vegetable fields within Kura local government area, Kano. Since nitrogen can be recycled in nature, efforts should be made to recycle the phosphorous in the soils of Kura agricultural plots, this may become the subject of further study. In addition, the used of bio-fertilizers such as arbuscular mycorrhizal fungi (AMF) and phosphate solubilizing bacteria which can solubilize and transport essential nutrients from the soil and deliver them to the crops should be encouraged.

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