Original Research Article

INVESTIGATION OF NITRATES, SULPHATES AND PHOSPHATES LEVELS IN SOIL FROM SELECTED FARMLANDS IN KAIAMA AND IMIRINGI IN BAYELSA STATE, NIGERIA

ABSTRACT: The levels of sulphate, nitrate, and phosphate in soil samples taken from farmlands in Kaiama and Imiringi have been determined. Soil samples were taken from various depths using hand auger and analyzed for nitrate, sulphate and phosphate content. The concentrations of nitrate in the soil samples collected from Kaiama farmland ranged from 4.09 ± 0.014 mg/L for 10 cm, 2.92 ± 0.076 mg/L for 20 cm and 2.53 ± 0.028 mg/L for 30 cm depth, while in the control samples, 4.13 ± 0.007 mg/L for 10 cm, 3.65 ± 0.354 mg/L for 20 cm and 3.10 ± 0.028 mg/L for 30 cm depth. The control samples had phosphate levels of 3.75 ± 0.028 mg/L for 10 cm, 4.20 ± 0.028 mg/L for 20 cm, and 4.98 ± 0.028 mg/L for 30 cm, while the control had a phosphate level of 4.37 ± 0.014 mg/L for 10 cm, 4.08 ± 0.028 mg/L for 20 cm, and 4.86 ± 0.028 mg/L for 30 cm for September. In October, the phosphate levels in the farmland were 2.65 ± 0.028 mg/L for 10 cm, 2.81 ± 0.014 for October. The farmland had sulphate levels of 6.93 0.043 mg/L at 10 cm, 7.11 0.014 mg/L at 20 cm, and 7.40 0.028 mg/L at 30 cm, while the control had sulphate levels of 7.45 0.014 mg/L at 10 cm, 8.11 0.014 mg/L at 20 cm, and 4.43 0.043 mg/L at 30 cm. In November, the phosphate levels observed in the soil samples from the farmland were 3.71 ± 0.014 mg/L for 10 cm, 3.9 ± 0.014 mg/L for 20 cm, and 4.30 ± 0.007 mg/L for 30 cm. The concentration of the control samples was 3.77 ± 0.014 mg/L for 10 cm, 5.64 ± 0.028 mg/L for 20 cm and 6.75 ± 0.035 mg/L for 30 cm. The control samples have sulphate concentrations of 5.85 ± 0.007 mg/L for 10 cm, 6.13 ± 0.013 mg/L for 20 cm, and 6.06 ± 0.042 mg/L for 30 cm. Imiringi farmland has sulphate levels of 5.77 ± 0.020 mg/L for 10 cm, 6.84 ± 0.020 mg/L for 20 cm and 6.90 ± 0.020 mg/L for 30 cm for the month of September. The statistical analysis showed significant differences in the means of nitrate, sulphate, and phosphate levels between the control and farmland at all depths and months except the nitrate level in November at 10 cm, which showed no significant difference (p = 0.28) in the means between the control and farmland.

Keywords: Soil, fertility, plant growth, supplements

INTRODUCTION

Mineral (inorganic) materials, organic matter, water, air, and organisms are all part of the soil system (Mussa, 2009). The mix of minerals and organic compounds that make up the soil determines the chemical characteristics of the soil (Sinaj, Traore, & Frossard, 2002). Soil fertility in Sub-Saharan Africa has diminished due to continuous land agriculture and insufficient use of organic and inorganic fertilizers (Henao and Baanante, 2006). As a result, agricultural productivity and farm incomes are dropping, while urban migration is growing, and family and national food security is deteriorating (AGRA, 2007). Fertilizer nutrients account for roughly 30 percent to 50 percent of crop yields (Stewart, Dibb, Johnson, & Smyth, 2005). As a result, nutrient utilization efficiency, which is defined as nutrient absorption per unit of applied nutrient, is a useful tool for determining the destiny of applied nutrient fertilizer and its contribution to increased crop yields (Fageria and Baligar, 2005). Between 1995 and 2030, as the world's population and grain output grow, relative fertilizer consumption is predicted to rise (FAO, 2003). Sulphur is normally supplied in adequate quantities via sulphate deposition and organic sulphur mineralization from the environment (Radojevic and Bahkin, 1999). With rain and irrigation, the accessible form of nitrogen is highly soluble in water and travels quickly across the soil profile (Bar Tal, 2004).

Poor nutrition is considered a serious threat to agriculture productivity in Nigeria, mostly in the south-south zone (Bayelsa State). Certain crops have a poor growth rate while others do not grow, such as yams, rice, pepper, carrots, onions, etc. This may be as a result of a lack of soil nutrients such as nitrate, sulphate and phosphate in the soil, which are the major nutrients in soil fertility, hence the study. The purpose of this study was to look for sulphate, nitrate, and phosphate anions in soil samples collected from Kaiama in the Kolokuma/Opokuma Local Government Area and Imiringi in the Ogbia Local Government Area of Bayelsa State.

Soil quality definitions have evolved through time, with soil scientists developing new ideas to characterize soil quality in the recent decade (Davidson, 2000; Tóth, Stolbovoy, and Montanarella, 2007). Soil is a complex substance whose properties are difficult to quantify (Karlen, Andrews and Doran, 2001).

Soil quality is a term used to describe the usability and overall health of soils (Rodrigues de Lima, Hoogmoed and Brussard, 2008). The ability of the soil to offer ecological and societal benefits by completing its duties under changing conditions is characterized as soil quality (Toth et al., 2007).

The evaluation and maintenance of the broader ecological services that soils may provide with proper management, while yet maintaining sufficient food and energy production for a population projected to reach 9 billion by 2050, is a major challenge (Tilman, Cassman, Matson, Naylor, and Polasky, 2002; Rockstrom, Steffen, Noone, Persson, Chapin, Lambin, Lenton, Scheffer, Folke, Joachim, and Schellnhuber, 2009; 2009). Because of regional differences in soil attributes and management, no one collection of soil variables can be used to quantify these categories (Robertson and Swinton, 2005). Soil quality is frequently linked to agricultural production and long-term viability (Palm, Sanchez, Ahamed, and Awiti, 2007). Following that, Sanchez, Ahamed, Ahamed, Carre, Hartemink, Hempel, Huising, Lagacherie, Mcbratney, Mckenzie, Mendoncap, de Lourdes, Minasny, Montararella, Okoth, Palm, Sachs, Shepherd, Vagen, Vanlauwe, Walsh, & Winowiecki (2009) (Sanchez et al., 2009) argued that an ongoing effort to map soil properties globally and evaluate the condition of soils in conjunction with management recommendations The notion has been used for a variety of reasons all across the world (Ouedraogo et al., 2001; Tian and Feng, 2008). Concepts of soil quality are critical for the success of sustainable agriculture and environmental management (Karlen et al., 2001; Wienhold et al., 2004; ~~Kibblewhite, Ritz & Swift~~, Kibblewhite et al., 2008). Soil characteristics representing soil quality need to be selected and quantified (Karlen ~~et al.,~~ et al., 2001). Soil properties might be biological, chemical, or physical (Idowu et al., 2008). Visual, tactile, and morphological traits are utilized by both farmers and scientists to detect deteriorated soils (Doran and Parkin, 1994). Farmers primarily estimate soil quality by observation (Romig et al., 1995; Mwesigye, 1996); Pien et al. (1995) demonstrated farmers' awareness of recognizing soil depletion symptoms related to land and plant productivity.

Bones and ash, for example, can be utilized as organic fertilizers to boost performance (Rockstorm et al., 2009).

In the year 1840, the modern fertilizer business was born. Chemical products such as ammonia and sulphuric acid were used in experiments by chemists like Jasu Cybigg and John Valval Act. During the Green Revolution, modern approaches to chemical fertilizers emerged (Newton,

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2019). To boost crop yields, chemical fertilizers are used to augment the nutrients absorbed from the soil (Sharma and Chetani, 2017). The type of fertilizer used to augment vital plant nutrients has a big impact on crop production (Usman et al., 2015). A balanced fertilization strategy should be established and assessed, including chemical, organic, and biological fertilizers (Shaviv, 2000). Fertilizers can be categorized in a number of ways, including by the macronutrients they include, the sort of vital nutrients they contain, and so on (Neve, 1993).

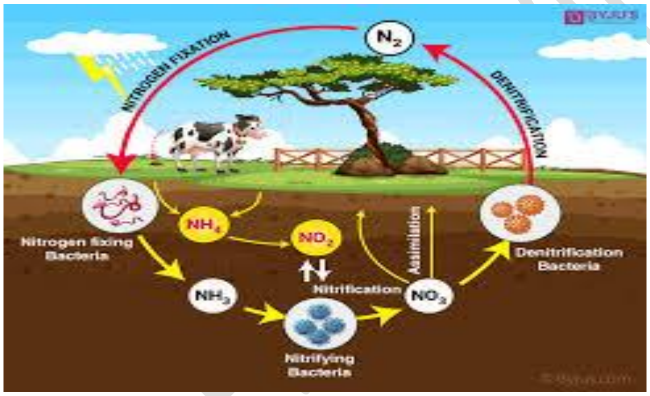

Figure 1.a: Nitrogen Cycle

Nitrogen in Soil

Plants can easily absorb nitrate and ammonium, as shown in Fig. 1.a, and these nutrients are favorable to plant development. Plants are poisoned by nitrite and ammonia (Camberat, 2001). The majority of plants consume nitrogen throughout their lifetimes, and as plant size grows, so does the demand for nitrogen (Tan, 2005).

In terms of fertilization and ecosystem development, the phosphorus cycle in soil has garnered a lot of attention (Figure 1.b). These minerals can be totally destroyed by reacting with dissolved carbon dioxide:

$$Ca_5\,(PO_4)_3OH+4CO_2+3H_2O\rightarrow 5Ca^{2+}+3HPO^{2-}{}_4+4HCO_3^-$$

Phosphorus is released from mineral particles in soil via a variety of methods. First, in the region of root hairs, the breakdown of organic waste and CO_2 from the airway causes a drop in pH, which dissolves phosphorus-containing minerals (mostly apatite) and releases phosphorus into the pore space. Second, organic acids created by plant roots can dissolve apatite minerals in the soil, releasing phosphorus into the pore spaces (Filippelli, 2009).

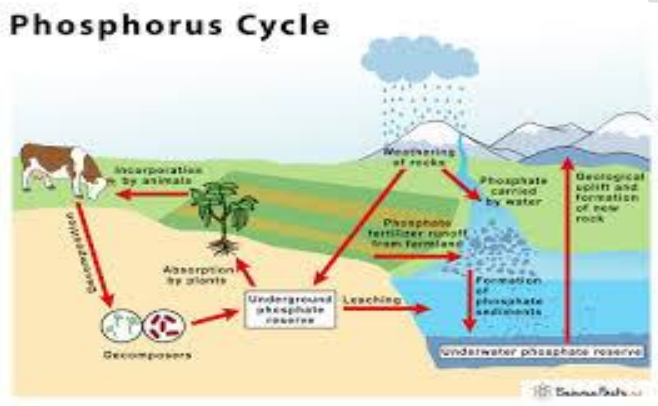

Figure 1.b: Phosphorus Cycle

Phosphorus in Soil

Phosphorus levels in animal feces are typically high. As a result of pastures and grazing, large volumes of phosphorous-rich manure were released into the environment (Camberati, 2001). Dissolved phosphorus contributes for 10% to 40% of the phosphorus transferred to water bodies by runoff and seepage from most agricultural soils (Sharply et al., 1992). Eutrophication is frequently accelerated when phosphorus concentrations in lake water exceed 0.02 mg/L. Understanding this link and detecting the source of phosphorus contamination on agricultural land requires selecting the proper soil test (Sharply et al., 1999).

SULPHUR CYCLE

The ocean is the world's largest sulphur deposit, with a substantial amount of sulphur present in the form of dissolved sulphate and sedimentary minerals (such as gypsum and pyrite). The natural release of volatile organic sulphur compounds in the ocean, mostly dimethyl sulfide (DMS), carries sulphur from the ocean to land regions while also influencing atmospheric chemistry and temperature (Figure 1c). Sulphur makes up around 1% of the dry weight of living things~~,~~ ~~2006,~~ Koblizek et al., 2006. Furthermore, as illustrated in Figure 1c below, the metabolism of organic sulphur compounds is an important part of the global sulphur cycle.

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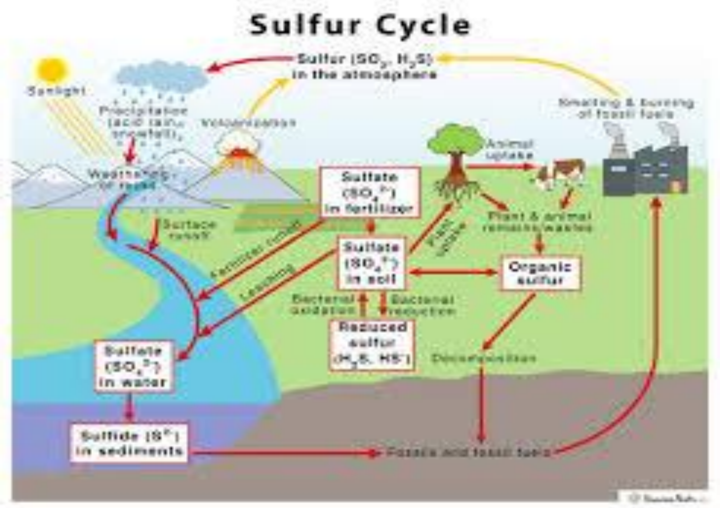

Figure 1c: Sulphur Cycle

Sulphur in Soil

Plants require sulphur as a macronutrient. The overall amount of sulphur in the soil varies depending on the kind of soil. Fertilizers like ammonium sulphate, superphosphate, and potassium sulphate are well recognized for adding a lot of sulphur to the soil (Tan, 2005).

MATERIALS AND METHODS

SAMPLE COLLECTION AND PREPARATION

Soil samples were collected from farmland in Kaiama (Lat. 5.11993^o Long. 6.299935^o) and Imirigi communities (Lat. 4.852444^o Long. 6.37616^o), both in Bayelsa State. Samples were collected in triplicates from each farmland using hand auger at three different depths (10 cm, 20 cm and 30 cm)~~.~~ and transferred into plastic bags, labeled appropriately and taken to the laboratory.

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Figure 2a. Kaiama Community

Figure 2b. Imiringi Community

The samples were sorted to remove grass and any external objects after air-drying and ground to break down the large masses of soil particles. The dry and reduced soil particles were then sieved using mechanical sieving apparatus with different mesh sizes. The sieved samples (2.0 mm) were preserved in labeled plastic bags for further experimental analyses.

Determination of Nitrates (NO_3^-)

The extracting solution was prepared by dissolving 50 g of sodium acetate in 250 mL distilled water in a 1L volumetric flask to which 30 mL of concentrated acetic acid was added and made up to the 1L mark with distilled water. Half spatula full of activated charcoal was added to the bottle followed by 20 mL of extracting solution. The bottle was shaken for 2 minutes and filtered. 1 mL of the filtrate was transferred into a test-tube to which 0.5 L of NO_3^- reagent (brucine) and 2 mL of H_2SO_4 were added. The content of the text tube was mixed for 30 seconds and allowed to stand for another 5 minutes. A further 2 mL of distilled water was added and mixed again and the test-tube allowed to cool for 15 minutes. This was run in a spectrophotometer set at 470 nm and the absorbance was obtained by extrapolation from a standard nitrate curve. (Grewelling and Peech, 1965).

2.3.2 Determination of Sulphate (SO_4^{2-})

Preparation of extracting solution: 0.5g of $KH_2PO_4.2H_2O$ was weighed and made up to 1liter with distilled water. 5 g of dried and sieved (2 mm) soil samples were weighed into 250 mL conical flask and 25 mL of extracting solution was added. This was agitated on the mechanical shaker for 10 minutes. The suspension was filtered and 10 mL of the filtrate was transferred into a 25 mL volumetric flask, some distilled water was added to bring the volume to 20 mL. 10% $BaCl_2$ (I mL) was then added and the final volume was made up to the mark. The mixture was shaken for 30 minutes. The spectrophotometer was set at 420 nm, and the % transmittance was determined and the concentration of SO_4^{2-} was obtained by extrapolation of a standard SO_4^{2-} laboratory graph (Tabataba, 1974).

2.3.3 Determination of Phosphate (PO_4^{3-})

An extracting solution for phosphate determination was prepared by adding 15 mL of 1.0 M ammonium fluoride solution into a 500 mL volumetric flask and making up to the 500 mL mark with distilled water.

1 g of air-dried soil sample was weighed into a centrifuge tube and 7 mL aliquots of the extracting solution were transferred into the tubes; which were placed on the orbital shaker and were shaken for 5 minutes. The tubes were then placed in the centrifuge machine and centrifuged at 2000 rpm for 10 minutes. 2 mL of aliquots of the clear supernatant were transferred into boiling tubes, 5 mL of distilled water and 2 mL of ammonia solution were added and mixed by shaking the tubes.

Finally, 1 mL aliquots of stannous chloride were added to the tubes and mixed. The spectrophotometer was set at 660 nm. Absorbance values were taken. The amount of phosphate in the soil was determined from the standard curve which was preferred with standard phosphate solutions.

STATISTICAL ANALYSIS

Data analysis was carried out using Microsoft Excel 2007 Software to calculate the mean and standard deviation, while t-test was also carried out using same software in determining the significant differences among the control and soil samples. Significance was accepted at 0.05 level of probability.

RESULTS

The Analytical Result obtained from the laboratory analysis of NO_3^-, SO_4^{2-} and PO_4^{3-} levels of soil samples collected from Kaiama and Imiringi Farmlands and Controls and the scientific data from this study are given from Table **1 to 6** below.

Table 1: Mean and standard deviation (±) of NO_3^-, SO_4^{2-} and PO_4^{3-} results of soil samples collected from different depth in Kaiama farmland and control for September, 2021.

PARAMETERS	SAMPLING SITES	10 cm	20 cm	30 cm
	Farmland	4.09 ± 0.014	2.92 ± 0.163	2.26 ± 0.028
NO_3^-	Control	4.53 ± 0.014	3.75 ± 0.014	3.17 ± 0.014
	Farmland	6.94 ± 0.028	7.68 ± 0.468	8.03 ± 0.028
SO_4^{2-}	Control	3.77 ± 0.014	5.64 ± 0.028	6.75 ± 0.035
	Farmland	3.49 ± 0.014	4.11 ± 0.040	4.44 ± 0.014
PO_4^{3-}	Control	4.39 ± 0.007	5.34 ± 0.021	5.12 ± 0.035

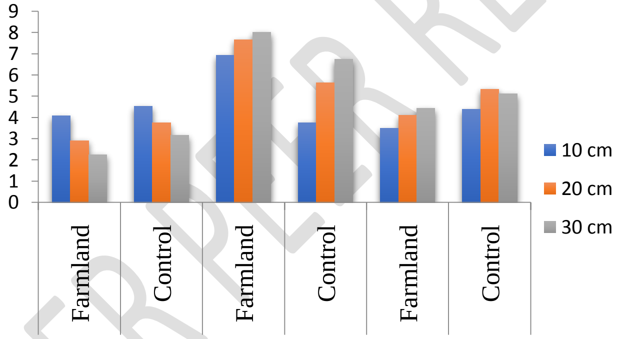

Figure 3a: *Chart showing the NO_3^-, SO_4^{2-} and PO_4^{3-} levels of soil samples collected from different depth in Kaiama farmland and control for September, 2021*

Table 2: Mean and standard deviation (±) of NO_3^-, SO_4^{2-} and PO_4^{3-} results of soil samples collected from different depth in imiringi farmland and control for September, 2021

PARAMETERS	SAMPLING SITES	10 cm	20 cm	30 cm
	Farmland	3.74 ± 0.015	3.70 ± 0.02	3.55 ± 0.020
NO_3^-	Control	4.75 ± 0.007	4.08 ± 0.014	4.62 ± 0.028

SO_4^{2-}	Farmland	5.77 ± 0.020	6.84 ± 0.020	6.90 ± 0.020
	Control	4.20 ± 0.028	5.78 ± 0.014	5.67 ± 0.014
PO_4^{3-}	Farmland	2.80 ± 0.020	2.94 ± 0.020	3.20 ± 0.020
	Control	3.75 ± 0.028	4.20 ± 0.028	4.98 ± 0.028

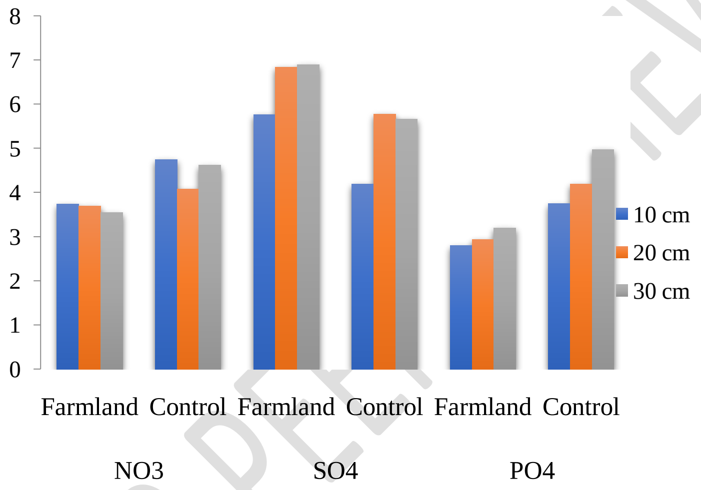

Figure 3b: Chart showing the NO_3^-, SO_4^{2-} and PO_4^- levels of soil samples collected from different depth in Imiringi farmland and control for September, 2021

Table 3: Mean and standard deviation (±) of NO_3^-, SO_4^{2-} and PO_4^{3-} results of soil samples collected from different depth in Kaiama farmland and control for October, 2021

PARAMETERS	**SAMPLING SITES**	**10 cm**	**20 cm**	**30 cm**
NO_3^-	Farmland	4.33 ± 0.036	3.96 ± 0.021	3.54 ± 0.028
	Control	3.74 ± 0.014	2.94 ± 0.028	2.63 ± 0.014

SO_4^{2-}	Farmland	5.14 ± 0.035	5.42 ± 0.014	6.25 ± 0.001
	Control	7.28 ± 0.028	7.83 ± 0.043	8.02 ± 0.014
PO_4^{3-}	Farmland	3.84 ± 0.028	4.26 ± 0.014	4.48 ± 0.014
	Control	5.57 ± 0.014	6.14 ± 0.014	6.44 ± 0.028

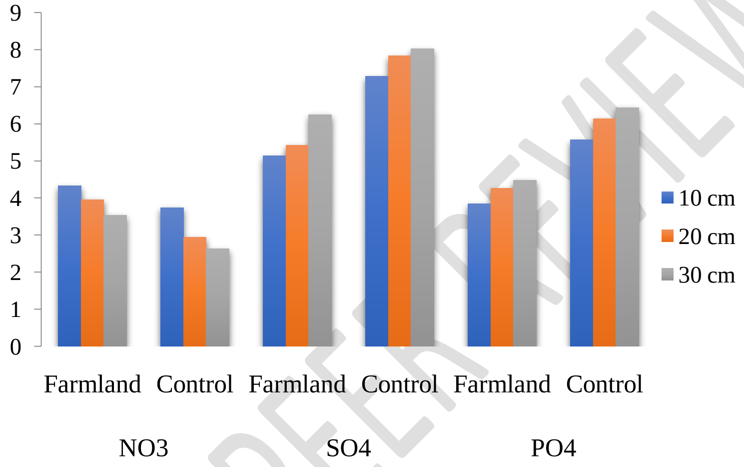

Figure 3c: *Chart showing the NO_3^-, SO_4^{2-} and PO_4^- levels of soil samples collected from different depth in Kaiama farmland and control for October, 2021*

Table 4: Mean and standard deviation (±) of NO_3^-, SO_4^{2-} and PO_4^{3-} results of soil samples collected from different depth in Imiringi farmland and control for October, 2021

PARAMETERS	SAMPLING SITES	10 cm	20 cm	30 cm
NO_3^-	Farmland	3.82 ± 0.014	3.77 ± 0.007	3.65 ± 0.014
	Control	3.12 ± 0.021	2.92 ± 0.021	2.44 ± 0.014

SO_4^{2-}	Farmland	6.93 ± 0.043	7.11 ± 0.014	7.40 ± 0.028
	Control	7.45 ± 0.014	8.11 ± 0.014	8.43 ± 0.043
PO_4^{3-}	Farmland	2.65 ± 0.028	2.81 ± 0.014	2.89 ± 0.014
	Control	4.37 ± 0.014	4.08 ± 0.028	4.86 ± 0.028

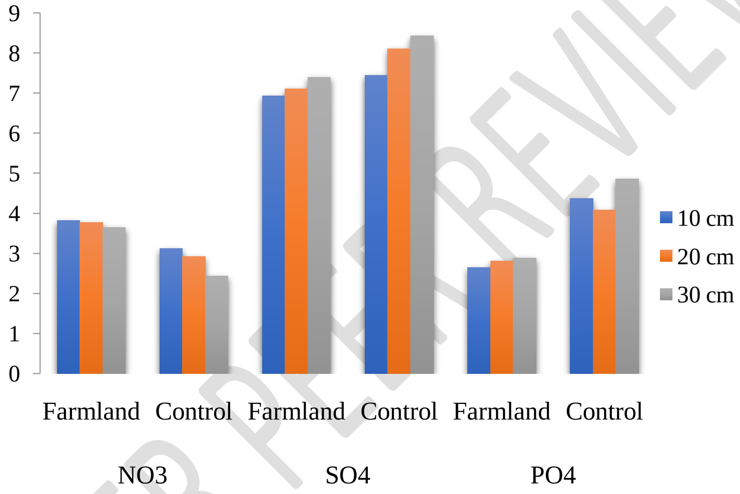

Figure 3d: Chart showing the NO_3^-, SO_4^{2-} and PO_4^{3-} levels of soil samples collected *from different depth in Imiringi farmland and control for October, 2021*

Table 5: Mean and standard deviation (±) of NO_3^-, SO_4^{2-} and PO_4^{3-} results of soil samples collected from different depth in Kaiama farmland and control for November, 2021

PARAMETERS	SAMPLING SITES	10 cm	20 cm	30 cm
NO_3^-	Farmland	4.15 ± 0.012	4.40 ± 0.020	3.80 ± 0.020
	Control	4.13 ± 0.007	3.65 ± 0.354	3.10 ± 0.028

SO_4^{2-}	Farmland	5.10 ± 0.020	5.14 ± 0.040	4.94 ± 0.010
	Control	5.51 ± 0.007	5.66 ± 0.155	5.14 ± 0.014
PO_4^{3-}	Farmland	4.46 ± 0.020	4.52 ± 0.011	4.20 ± 0.020
	Control	4.95 ± 0.014	5.14 ± 0.014	5.87 ± 0.028

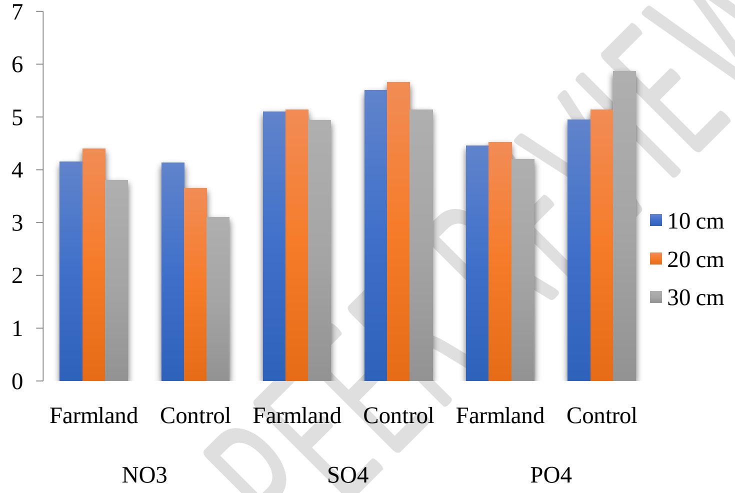

Figure 4: Chart showing the NO_3^-, SO_4^{2-} and PO_4^{3-} levels of soil samples collected from different depth in Kaiama farmland and control for November, 2021.

Table 6: Mean and standard deviation (±) of NO_3^-, SO_4^{2-} and PO_4^{3-} results of soil samples collected from different depth in Imiringi farmland and control for November, 2021

PARAMETERS	SAMPLING SITES	10 cm	20 cm	30 cm
NO_3^-	Farmland	2.20 ± 0.021	3.90 ± 0.028	3.84 ± 0.021
	Control	3.9 ± 0.014	4.52 ± 0.021	8.85 ± 0.014
	Farmland	5.02 ± 0.007	5.26 ± 0.014	5.39 ± 0.014

SO_4^{2-}	Control	5.85 ± 0.007	6.13 ± 0.014	6.06 ± 0.042
	Farmland	3.71 ± 0.014	3.90 ± 0.014	4.30 ± 0.028
PO_4^{3-}	Control	4.07 ± 0.007	4.95 ± 0.085	5.23 ± 0.035

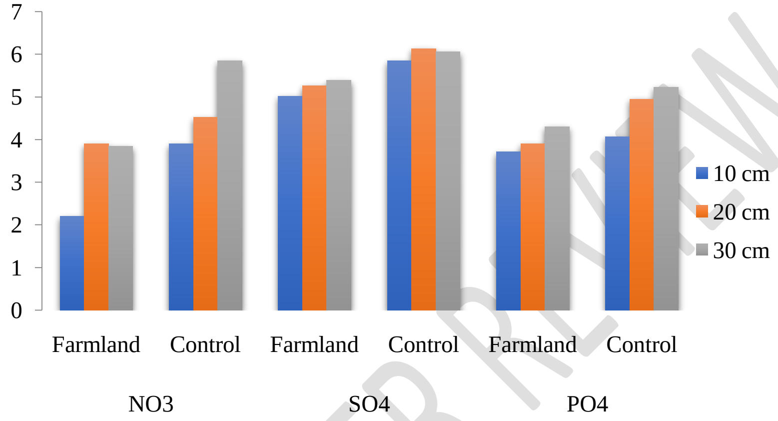

Figure5: *Chart showing the* NO_3^-*,* SO_4^{2-} *and* PO_4^{3-} *levels of soil samples collected from different depth in Imiringi farmland and control for November, 2021*

DISCUSSION

Results of the laboratory analysis of nitrate, sulphate and phosphate concentrations in soil samples collected from Kaiama and Imiringi farms are presented in Tables (1 - 6) and Figures (1 - 5) above are discussed below:

Nitrate Level in Soil

As seen from Figures 1 to 5 above showing the concentrations of nitrates in soil samples collected from the farmlands of Kaiama and Imiringi with the control, the concentrations of nitrate in the soil samples collected from Kaiama farmland from different depths and months were 4.09 ± 0.014 mg/L for 10 cm, 2.92 ± 0.076 mg/L for 20 cm, and 2.53 0.028 mg/L for 30 cm. while the control samples were 4.53 ± 0.014 mg/L for 10 cm, 3.75 ± 0.014 mg/L for 20 cm and 3.17 ± 0.014 mg/L for 30 cm in September. In October, a slight variation was observed compared to September, for both the farmland and the controls. It was observed that the mean concentrations of nitrates for the reporting period in the farmlands were 4.33 ± 0.036 mg/L for 10 cm, 3.96 ± 0.021 mg/L for 20 cm and 3.54 ± 0.028 mg/L. While the concentrations of nitrates in the control samples were 3.74 ± 0.014 mg/L for 10 cm, 2.94 ± 0.007 mg/L for 20 cm, and 2.63 ± 0.014 mg/L for 30 cm. In November, it was observed that, there was a little decrease of nitrate concentration in the soil in farmland at 10 cm depth, while an increase was seen at 20 and 30 cm. Nitrate concentration values in the farmland were 4.15 ± 0.012 mg/L for 10 cm, 4.40 ± 0.020 mg/L for 20 cm and 3.8 ± 0.020 mg/L. While in the control samples, 4.13 ± 0.007 mg/L for 3.65 ± 0.354 mg/L for 20 cm and 3.10 ± 0.028 mg/L for 30 cm were found. From the nitrate results, it was also observed that the deeper the depths, the higher the concentration of nitrates in the soil samples from the farmland. Also, nitrate concentrations increased from month to month, both in the farmland and the control. Statistical analysis carried out showed that the nitrate concentration in the month of September from Kaiama at 10-30 cm depth showed significant differences ($p < 0.05$) in the means between the controls and the farmland, with the controls at various depths having higher concentrations of nitrate than the farmland. In October, the difference in the mean nitrate level in both control and farmland soil samples also showed significant differences ($p < 0.05$). In November, the nitrate composition between the control and farmland soil samples at 10 cm showed no significant difference ($p = 0.288$). However, there was a significant difference ($p < 0.05$) in the means for nitrate levels at 20 and 30 cm for both control and farmland soil samples.

In Imiringi farmland, the nitrate content followed the same pattern as that in Kaiama farmland and control. For the three months, nitrate concentrations in the control samples were higher than those in the farmland. In September, the concentrations observed in farmland were 3.74 ± 0.015 mg/L for 10 cm, 3.70 ± 0.020 mg/L for 20 cm, and 3.55 ± 0.020 mg for 30 cm, while nitrate concentrations in control samples were 4.75 4.08 0.007 mg/L for 10 cm, 4.08 0.014 mg/L for 20 cm, and 4.62 0.028 for 30 cm. In October, nitrate concentrations were 3.82 ± 0.021 mg/L at 10 cm, 3.77 ± 0.007 mg/L at 20 cm, and 3.65 ± 0.014 mg/L at 30 cm in the farmland. The concentration of nitrate in the control samples was 3.12 ± 0.021 mg/L for 10 cm, 2.92 ± 0.021 mg/L for 20 cm, and 2.44 ± 0.014 mg/L for 30 cm. In November, nitrate concentrations were 2.20 ± 0.021 mg/L for 10 cm, 3.90 ± 0.025 mg/L for 20 cm and 3.84 ± 0.021 mg/L for 30 cm in the farmland. The results of the control samples were 3.39 ± 0.014 mg/L for 10 cm, 4.52 ± 0.021 mg/L for 20 cm and 4.85 ± 0.014 mg/L for 30 cm. The statistical analysis done for soil samples collected from Imiringi in the month of September showed that the difference in the means for the nitrate concentrations in the control and farmland is significant (p<0.05). There were also significant differences in the means for nitrate concentrations between the control and farmland soil samples in October and November, at various depths. The level of significance was not above the accepted level of probability ($p = 8.85E^{-7}$, $p = 4.08E^{-7}$ and $p = 9.94E^{-8}$) for October and ($p = 5.11E^{-8}$, $p = 2.87E^{-6}$ and $p = 6.77E^{-10}$) November.

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Sulphate Level in Soil

Figures 1 to 5 show the concentrations of sulphate in soil samples collected from the farmlands of Kaiama and Imiringi with the control. The level of sulphates in the soil samples varied with an increase in the different depths in both farmlands and controls (Kaiama and Imiringi, respectively). There were high sulphate levels observed in all the control samples collected in October and November except September, which had a low sulphate level in all the farmlands

(Kaiama and Imiringi, respectively). The concentration of sulphate in the soil sample collected from Kaiama farmland from different depths for the month of September was 7.68 ± 0.46 mg/L for 10 cm, 6.94 ± 0.028 mg/L for 20 cm, and 8.03 ± 0.028 mg/L for 30 cm. The concentration of the control samples was 3.77 ± 0.014 mg/L for 10 cm, 5.64 ± 0.028 mg/L for 20 cm and 6.75 ± 0.035 mg/L for 30 cm. The concentration of sulphate in the soil samples for October was 5.14 ± 0.035 mg/L for 10 cm, 5.42 ± 0.014 mg/L for 20 cm, and 6.25 ± 0.001 for samples collected from the farmland, while the control samples were 7.28 ± 0.028 mg/L for 10 cm, 7.83 ± 0.043 mg/L for 20 cm, and 8.02 ± 0.014 for 30 cm. In November, the concentrations of sulphate in farmland soil samples were 5.10 0.020 mg/L for 10 cm, 5.14 0.040 mg/L for 20 cm, and 4.94 0.010 mg/L for 30 cm. Sulphate concentrations in the control samples collected were 5.51 ± 0.007 mg/L for 10 cm, 5.66 ± 0.155 mg/L for 20 cm, and 5.39 0.014 for 30 cm. A statistical test carried out on the results in Table 1 shows that there were significant differences ($p<0.05$) in the means between the sulphate concentration in the control and farmland at all depths (10 cm–30 cm) in the month of September at Kiama. In October, the differences in the means for sulphate concentration between the control and farmland soil samples were statistically significant with levels of probability of $p = 1.02E^{-8}$, $p = 6.32E^{-9}$, and $p = 2.17E^{-8}$ for depths of 10, 20, and 30 cm, respectively. In November, there were also significant differences in the means for sulphate concentration in soil samples of control and farmland at 10 cm ($p = 0.00002$), 20 cm ($p = 5.80E^{-9}$) and 30 cm ($p = 0.0003$).

Imiringi farmland has sulphate levels of 5.77 ± 0.020 mg/L for 10 cm, 6.84 ± 0.020 mg/L for 20 cm, and 6.90 ± 0.020 mg/L for 30 cm for the month of September. The control had~~s~~ sulphate levels of 4.20 ± 0.028 mg/L for 10 cm, 5.78 ± 0.014 mg/L for 20 cm, and 5.67 ± 0.014 for 30 cm for September. In the month of October, the sulphate levels were 6.93 ± 0.043 mg/L for 10 cm, 7.11 ± 0.014 mg/L for 20 cm, and 7.40 ± 0.028 mg/L for 30 cm for the farmland, while the control had sulphate levels of 7.45 ± 0.014 mg/L for 10 cm, 8.11 ± 0.014 mg/L for 20 cm and 4.43 ± 0.043 mg/L for 30 cm depths. In November, the concentrations of sulphate in the soil samples were 5.02 ± 0.007 mg/L for 10 cm, 5.26 ± 0.014 mg/L for 20 cm and 5.39 ± 0.014 mg/L for 30 cm from the farmland. The control samples had~~ve~~ sulphate concentrations of 5.85 ± 0.007 mg/L for 10 cm, 6.13 ± 0.013 mg/L for 20 cm, and 6.06 ± 0.042 mg/L for 30 cm. The statistical analysis performed on the data from tables 2, 4, and 6 revealed significant differences ($p<0.05$) in sulphate concentrations in soil samples between the control and farmland in September, October, and November.

Phosphate Level in Soil

The phosphate level of the soil samples collected from both the farmlands and the control from Kaiama and Imiringi for all the three months presented in Figures 1 to 5 indicates that, there is a high phosphate level in all control samples collected in the three months from all depths compared to the farmland soil samples. This implies that there is an increase in phosphate levels as you go deeper into the ground. In the month of September, the phosphate levels observed were 4.11 ± 0.040 mg/L for 10 cm, 3.49 ± 0.014 mg/L for 20 cm, and 4.44 ± 0.014 mg/L for 30 cm from Kaiama farmland. The control samples have phosphate levels of 4.39 ± 0.007 mg/L for 10 cm, 5.34 ± 0.021 mg/L for 20 cm, and 5.10 ± 0.035 mg/L for 30 cm depth. In October, the phosphate levels observed from the soil samples collected from the farmland were 3.84 ± 0.028 mg/L for 10 cm, 4.26 ± 0.014 mg/L for 20 cm and 4.48 ± 0.014 mg/L for 30 cm. While the control samples in the month of October had phosphate levels of 5.57 ± 0.014 mg/L for 10 cm, 6.14 ± 0.014 mg/L for 20 cm, and 6.44 ± 0.028 mg/L for 30 cm. The phosphate level of soil samples collected from the farmland for the month of November was 4.46 ± 0.020 mg/L for 10 cm, 4.52 ± 0.011 mg/L for 20 cm, and 4.20 ± 0.020 mg/L for 30 cm. The control samples have phosphate levels of 4.95 ± 0.014 mg/L for 10 cm, 5.14 ± 0.014 mg/L for 20 cm, and 5.87 ± 0.028 mg/L for 30 cm. The data presented in Table 1 and Figure 1 statistically revealed that there were significant differences ($p<0.05$) in the means between the phosphate concentrations in the control and farmland samples at 10, 20, and 30 cm in September. These differences in phosphate concentration were also revealed in Tables 3 and 5 for October ($p = 2.38E^{-7}$, $p = 1.71E^{-8}$, and $p = 1.45E^{-7}$) and November ($p = 4.76E^{-8}$, $p = 7.35E^{-6}$, and $p = 2.87E^{-6}$) at various depths (10, 20, and 30 cm, respectively) in Kaiama. While that of Imiringi farmland has phosphate levels of 2.80 ± 0.020 mg/L for 10 cm, 2.94 ± 0.02 mg/L for 20 cm and 3.2 ± 0.020 mg/L for 30 cm for the month of September. The control samples have phosphate levels of 3.75 ± 0.028 mg/L for 10 cm, 4.20 ± 0.028 mg/L for 20 cm, and 4.98 ± 0.028 mg/L for 30 cm. In October, the phosphate levels in the farmland were 2.65 ± 0.028 mg/L for 10 cm, 2.81 ± 0.014 mg/L for 20 cm and 2.89 ± 0.014 mg/L for 30 cm. while the control has a phosphate level of 4.37 ± 0.014 mg/L for 10 cm, 4.08 ± 0.028 mg/L for 20 cm, and 4.86 ± 0.028 mg/L for 30 cm. In November, the phosphate levels observed in the soil samples from the farmland were 3.71 ± 0.014 mg/L for 10 cm, 3.9 ± 0.014 mg/L for 20 cm, and 4.30 ± 0.007 mg/L for 30 cm. The control samples had~~ve~~ a phosphate level of 4.01 ± 0.007 mg/L for 10 cm, 4.95 ± 0.085 mg/L for 20 cm, and 5.23 ± 0.035 mg/L for 30 cm.

The statistical analysis performed in the study revealed that there were significant differences in the means for phosphate concentrations between the control and farmland soil samples in September, October, and November at various depths in Tables 2, 4 and 6. The level of significance was not above the accepted level of probability for September ($p = 2.61E^{-7}$, $p =$

$8.46E^{-8}$, and $p = 0.0005$), October ($p = 2.44E^{-8}$, $p = 8.19E^{-8}$, and $p = 1.42E^{-8}$) and November ($p = 0.00003$, $p = 3.5E^{-7}$, and $p = 5.69E^{-7}$).

CONCLUSION

From the results, it can be concluded that the nitrate level in the control samples in the month of November in Imiringi was higher than the control samples in the other months. Also, the nitrate level in soil samples collected from Kaiama farmland in November was higher than those collected in the other months in both Kaiama and Imiringi. The sulphate level in the control soil samples from Imiringi in the month of October is higher than those in September and November, even those collected in Kaiama. While the sulphate level in soil samples collected from Imiringi farmland in October is higher than those collected from Kaima farmland in all the months. The phosphate level in the soil samples collected from Kaiama farmland in the month of November is higher than those collected in the other months, including Imiringi farmland. The phosphate level in the control soil samples collected in the month of October is higher than those collected in the other months and the control samples collected from Imiringi farmland.

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