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# Comparative Effect of Organic and Inorganic Fertilizers on Soil Physicochemical properties and on the Quality of Yam (*Dioscorea rotundata*)

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**Abstract:** Field experiments were carried out at the Teaching and Research Farm of the Federal University of Technology Akure to evaluate the comparative effects of organic and inorganic fertilizers on soil physicochemical properties and the quality of yam. Six treatments were applied including NPK at 450Kg/ha (NPK), poultry manure at 2000 Kg/ha (PM), wood ash at 2000Kg/ha (WA), NPK + poultry manure at 225 and 1000 kg/ha (NPK + PM) poultry manure + wood ash at 1,000 Kg/ha each (PM + WA) and control (no fertilizer). The experiment was laid out in a randomized complete block design (RCBD) having 3 replications. The result revealed that organic manures significantly (P=0.05) improved the quality of yam compared to the inorganic fertilizers and control. PM + WA had a significant higher % crude protein (4.729), % dry matter (39.966), % Ash (1.2983) compared to other treatments. WA recorded a more significant higher value for carbohydrate (59.24%) compared to the other treatments. The % fibre was significantly higher in PM tubers. The soil pH increased more in areas where wood ash was applied compared to the other plots. No significant increase was observed in the % silt, clay, sand and gravel contents of the soil. Organic fertilizers in both single and mixed forms highly increased yam quality and soil pH.

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**Keywords:** soil chemical properties, organic fertilizers, soil pH, carbohydrate, protein, organo-minerals.

## Introduction

Yam is an important staple crop, grown in Africa for its edible tuber, and a major source of income to farmers in this continent (Emede et al., 2015). It is a major cash crop for millions of households in West Africa, where about 98% of the world crop is produced (Neine, 2021; Aighewi et al., 2020). The top four yam production country in west Africa includes Ghana, Nigeria, Benin and Cote d' Ivoire (Neine, 2021). Among these countries, Nigeria was recorded to be the top leading yam producing country in West Africa accounting for about 73% of total yam production in the region (FAOSTAT, 2021). While Ghana, Cote d' Ivoire and Benin accounts for 12.1%, 10.5% and 4.5% respectively. The crop's production rate has increased from 14.5million tons 1n 1988 to 66.8million tons in 2018 (FAOSTAT, 2020; Matsumoto et al., 2021). Yam plays a major role in the cultural systems and food of Africa (Matsumoto et al., 2021). It serves as a major source of income to over millions of farmers involved in its production (Neine, 2021). Among the cultivated species, the most produced and consumed is the white Guinea yam (*Dioscorea rotundata*) (Asfaw et al., 2020). Consequently, yam production in the region is hampered by a lot of constraints amoung which includes poor soil fertility status and the unavailability of seed yams (Neine, 2021). Low soil fertility is a major constraint in enhancing yam productivity because it is a high nutrient-demanding crop (Babalola et al., 2020). According to Aighewi et al (2018), poor soil fertility status is a major cause of poor tuber production in Africa. Yam requires an adequate supply of nutrients particularly Nitrogen, Phosphorus and Potassium (NPK) for good and high tuber yield (Adebola et al., 2018). Soil fertility in most soils has progressively declined due to increased pressure on land resources arising from rapid population expansion which is forcing farmers to adopt continuous cropping coupled with the use of an inadequate amount of manure or other soil amendment (Kamai *et al.*, 2020). This continuous cultivation of soils has led to the destruction of soil physical, chemical and biological properties and hence leaving most tropical soils with poor texture and structure and consequently low yields and quality in crops due to the mining and depletion of soil nutrients (Waziri et al., 2021). This calls for the use of external inputs in improving soil physical and chemical properties and hence reversing the loss of nutrients from the soil and decline in crop productivity.

Fertilizers are the major sources for nutrient replenishment in the soil. It could be from natural (organic), synthetic (inorganic) or the combination of both natural and synthetic materials (organo-minerals). These materials are applied to soils or to plant tissues (usually leaves) to supply one or more plant nutrients essential to the growth of plants (Adekayode, 2017). These elements include the macro nutrient elements (carbon, oxygen, hydrogen, nitrogen, phosphorus, potassium, calcium, magnesium and Sulphur) and the micronutrient elements (iron, manganese, zinc, copper, boron, molybdenum and chlorine) (Adekayode, 2017). Fertilizers have been known for their inherent ability to improve soil fertility status. According to Khoiru et al (2020), application of Poultry manure improves the soil moisture content by increasing the soil infiltration level. Organic manures have been known for improving soil productivity and crop yield through improvement of the physical, chemical and microbiological properties of the soil as well as nutrient supply (Timsina, 2018). It has been known to be effective in the maintenance of an adequate supply of organic matter into the soil which enhances crop performance (Timsina, 2018). Organic fertilizers improves soil physical properties and in addition reduces the soil bulk density thereby making appreciable difference in the root growth and proliferation of crops including cereals and tubers (Adeyemo et al., 2019; Adesodun et al, 2005; Aluko and Oyeleke, 2005).

Poultry manure increases soil infiltration, improves soil organic matter status, nutrients availability and high crop yield (Adeyemo et al., 2019). Wood ash has been known for its potential in developing an alternative liming material that not only supplies lime but also provides potassium, phosphorus and trace minerals (Adebola et al., 2018). Application of wood ash significantly increases the effective cation exchange capacity and base saturation and decreases the concentration of exchangeable aluminum in the soil (Ajala et al., 2019).Recent literatures has shown the efficacy of mineral fertilizers to release nutrients to plants in concentrates rapidly. Adekayode and Adewumi 2013 in comparative effects of organic and inorganic fertilizers in improving soil fertility and cassava yield and quality reported that plots treated with NPK 12:12:18 with higher potassium level had higher yield when compared to other plots. It is easier to ensure a balance adequate supply of nutrients by applying mineral fertilizer because of its fast mineralization and hence a fast release of nutrients to the growing plant (Adebola et al., 2018).

Yam is highly exerting on nutrient levels and soil moisture, and the root volume extends more broadly and deeply than other plants. Yam removes about 148, 41.2 and 199.2 Kg/ha of N,P,K respectively from soils where they are planted (Agbede et al., 2013).Hence, continuous cultivation of yam on the same land will lead to high rate of soil nutrient mining, degradation of soil health and quality and consequently low yield. Most local farmers cultivate yam yearly on the same piece of land due to unavailability of land, hence most land used for yam cultivation requires high input of fertilizers for optimum production. Despite the many benefits associated with fertilizers application, there are certain constraints to their usage. The organic manure are relatively low in nutrients and takes longer periods to be available for plants (Babasola et al., 2018). It is applied usually in large quantity and requires bulk transportation to farming areas. According to Babasola et al (2018), the cost of transporting these manures to farm areas and the inconveniences associated with the offensive odours from its decomposition process pose a major challenge to its usage in conventional agriculture. The use of mineral fertilizer by farmers is limited because of scarcity and high costs. Its continuous use leads to degradation of soil health and long term adverse effects on soil microorganisms (Adeniyan and Ojeniyi, 2005; Geisseler and Scow, 2014). According to Ajala et al (2019), inorganic fertilizers, which are the principal source of N to farmers, are oftentimes overused or applied incorrectly thereby leading to the buildup of phosphorus and potassium on the surface of the soil. This makes the soil to become acidic leading to a reduction in crop yields (Ajala et al., 2019). According to Agbede et al (2013), the use of inorganic fertilizers to supply all the nutrients needs of plants should be limited or totally avoided because of its long-term deleterious effect on soil productivity. It has been known for its high cost, ability to enhance nutrient leaching, soil acidity, soil properties degradation and nutrient imbalance (AAgbede et al., 2008; Ojeniyi, 2000).

Despite, the drawbacks associated with organic manure, its role on soil properties and functioning cannot be over emphasized. There is an arising need to use organic manures to address the environmental and health challenges posed by the continuous used of inorganic fertilizers (Agbede et al., 2013). The cumulative effect of continuous use of chemical fertilizers has been reported to affect soil fertility adversely and results in soil acidity in some instances where ammonia fertilizers were used. Future strategies for improving agricultural productivity is tendered towards maximizing available nutrient resources more effectively, efficiently and sustainably than in the past (Agbede et al., 2008).

In tropical climates, specifically Nigeria, most farmers cultivate yam in small holdings under low fertility conditions except in some instances where short fallows are incorporated into the cropping systems to rejuvenate the soil fertility. Even though there are increases in land area being cultivated under yam yet, this could yield a gradual decline yield per unit area. Agbede et al (2017) suggested the use of organic fertilizers which are sustainable and environmentally friendly for optimum yam yield production. Much work have not been done on the use of organo-minerals on yam production. There is therefore need to test the effect of the combined fertilizers (organic and inorganic) with the aim of addressing the constraints associated with their individual use.

Since poor soil fertility has been identified as one of the major challenge of yam production, it is therefore expected that the application of organic fertilizers and organo-minerals would enhance soil fertility and subsequently improve yam quality. Therefore this study investigates the effect of organic, inorganic and organo-minerals on soil physicochemical properties and quality of white yam.

**Materials and Methods**

**The study area**

This study was carried out in Ondo State Nigeria. The study involved field experiments and laboratory experiments. The field experiment was carried out in two seasons in the Teaching and Research farm of the Federal University of Technology Akure Ondo State Nigeria in the year 2020 and 2021 respectively.

The study sites were both located at an altitude of 332m above sea level, lying between longitude 5 06E to 5 38'E and between latitude 7 07'N to 737'N in the rainforest south-western region of Nigeria. The site is characterized by a semi-arid climate (a bimodal rainfall pattern of about 1300mmyr$^{-1}$ , annual average temperature 26$^{0}$C, relative humidity 15%) with three distinct seasons that is summer (March to June), rainy (July to October) and winter (November to February). The soil at the site is an Alfisol by USDA classification having a textural class of sandy clay loam according to the USDA textural triangle. The previously cultivated crop based on the history of the area was yam and maize crop. The physicochemical analysis of the top soil (5cm) of the site is given in table 3 of chapter four.

**Materials.**

The materials used for these experiments are: Seed yams of varying sizes (0-99g, 100-199g and 199 and above) and manure (NPK, poultry manure, wood ash, NPK + poultry manure, wood ash + poultry manure, control). The seed yams were obtained from the market and the manures used were collected from the Federal University of Technology Animal Farm Akure Ondo State Nigeria.

**Land Preparation and Field Layout**

The land was manually cleared of existing vegetation with use of cutlass. The Site was properly laid out using split plot design with seed yam size occupying the main plot and manure occupying sub plot. The experiment was made up of 18 treatment combinations. The field layout was divided into three replicates with an alley road of 1m between each replicate constructed as a walkway. Each of the replicates was further divided into 18 heaps (3 x 6) and the heaps were spaced by 1m apart.

**Planting**

The seed yams were planted immediately after the first main rainfall for the 2 seasons. Holes were dug on each heap and the seed yams were covered with enough soil inside the holes. The seed yams were planted on heaps manually using hoe.

**Staking**

Staking was done two weeks after planting with bamboo sticks to support the yam growing plants.

**Weeding**

The plots were weeded at intervals to remove unwanted plants on the field. Weeding was done manually using hoes.

**Treatment Application/Fertilization**

The treatments (manures) were applied six (6) weeks after planting when the plant would have gotten enough roots for the absorption. Ring method of manure application was used and the manures were applied 10cm away from the plant stem. The quantities of the manure used are as follows:

NPK = 45g

Poultry manure = 200g

Woodash = 200g

NPK + wood ash = 100g + 22.5g

Poultry manure and wood ash = 100g + 100g.

**Harvesting**

Harvesting was done 6 months after planting when the yam was matured enough for harvest. Harvesting was done using earth chisel and hoe. Proper care was taken to ensure that the yams were not injured during harvest. The harvested yams were stored in the laboratory for analysis.

**Soil Sampling**

Soil samples for physicochemical analysis were collected randomly at a depth of 5cm from 12 points within the experimental layout prior to treatment application. The collected samples were bulked and homogenized to form a composite unit from which the physicochemical status of the soil was determined. During the course of the experiment, soil samples for data collection were sampled randomly from 18 sub-plots in each replicates at a depth of 0-15cm. Soil samples were sieved (0.2mm) and stored for laboratory analysis.

**Field Data Collection and Analysis**

Data on the stem girth was collected 6 weeks after manure application at 10cm, 20cm and 30cm respectively. The circumference of the plant was measured using vernier caliper and thereafter the stem girth was determined. The various stem heights were measured using tape in centimeters.

Statistical analysis of data was conducted using the analysis of variance (ANOVA) procedure in MINITAB Statistical Software Release 17 (MINITAB Inc., 2007). The significant difference test was conducted using Tukey at $p<0.05$ to pinpoint significant differences among the treatment means.

**Determination of Soil pH**

The soil pH in distilled water at soil to water ratio of 1:1 was determined using a pH meter. Twenty (20) grams of soil was weighed in duplicates into 50-mL beakers and 20 mL of distilled water was added. The soil-liquid suspension was stirred for 30 minutes and allowed to stand for an hour for equilibration. The pH meter was standardized using buffer solutions of pH 4.0, 7.0 and 9.0. The soil pH was then determined by inserting the pH meter electrode into the sample suspension and readings were recorded.

**Results and Discussions**

The pretreatment soil analysis results shown in table 1 revealed that the nitrogen, phosphorus and potassium were low and so this justifies the use of treatment types to test the effect of manure on the fertility status appropriate. The pretreatment status assessment corroborated with results of Dennis et al 2017. His results categorized soil fertility into low, medium and high levels. According to his rating, soil nitrogen <0.28(%) were classified low, 0.28-0.56(%) were medium and > 0.56 (%) were high. The Soil calcium (Ca) and magnesium (Mg) were also low according to his ratings. Based on the results, poultry manure and wood ash had sufficient nutrient to increase the soil nitrogen content. Biratu et al (2019) observed relative increase in soil nitrogen content following poultry manure application. The soil organic carbon was high according to the ratings of TNAU (2022) and Dennis et al (2017). This shows that the soil has optimum amount of carbon nutrient needed to sufficiently increase the physical characteristics of the soil such as water holding capacity, soil porosity, and permeability. Yam being a tuber crop requires a soil rich in organic matter content with enhanced physical characteristics for good tuberization. The results of the soil pH revealed that the soil is very strongly acidic (Wikipedia). This necessitated the use of the treatments to increase the soil pH and hence reduce the soil acidity. Wood ash has been known for its ability to increase soil pH following application. Hassan et al., 2017 observed a relative increase in soil pH following wood ash application. Wiklund (2017) recorded a significant increase in soil pH in wood ash applied soils compared to the control. According to Qin et al (2017), wood ash increased soil pH without causing damage to the mesofauna. Based on the ratings of Wikipedia, the bulk density is ideal for a sandy clay soil (< 1.4 g/cm$^3$).

The low nutrient concentration of the site prior to treatment application can be attributed to the continuous cultivation of the site with the same tuber crop (yam) year in year out which may have exposed the site to nutrient depletion. The fertility status of the soil is expected to benefit from manure application since organic manure will be used. Rayne and Aula (2020) investigated "The impact of livestock manure to soil health". Their results showed that the poultry manure increased the inherent soil fertility status of the plot used. Inorganic manure has been known for its fast release of necessary nutrients that are needed by plants, and its continuous use may lead to soil degradation (Roba, 2018). The sandy clay textural class of the experimental site implies a high water retention capacity because of the quantity of clay contained (31.2%). Even though yam being a tuber crop requires a sandy loam soil for good tuberization (Bassey, 2017), this justifies the need for fertilizers use to improve the soil physical properties.

**Table 1: Pre-cropping soil physicochemical properties and Nutrient composition of the Fertilizer types used**

| Property | Soil | Poultry manure | Wood ash |
|---|---|---|---|
| Gravel (%) | 42 | - | - |
| Sand (%) | 44.8 | - | - |
| Silt (%) | 24 | - | - |
| Clay (%) | 31.2 | - | - |
| Textural Class | Sandy Clay | - | - |
| Bulk density (g/cm$^3$) | 1.21 | - | - |
| pH ($H_2O$) | 4.55 | 5.45 | 9.85 |
| Organic Carbon (%) | 1.60 | 26.5 (%) | 12.8 (%) |
| Nitrogen (%) | 0.12 | 3.60 (%) | 1.54 (%) |
| Phosphorus (mg kg$^{-1}$) | 3.68 | 1.09 (%) | 3.20 (%) |
| Potassium (cmol kg$^{-1}$) | 0.10 | 3.72 (%) | 8.82 (%) |
| Calcium (cmol kg$^{-1}$) | 2.12 | 3.04 (%) | 8.96 (%) |
| Magnesium (cmol kg$^{-1}$) | 0.91 | 1.14 (%) | 1.02 (%) |
| Sodium (cmol kg$^{-1}$) | 0.13 | 0.44 (%) | 0.68 (%) |
| C:N | 13.33 | 7.36 | 8.3 |

Table 2 showed that there were no significant differences in the relative proportions of the soil particles. These results were in line with the results of Zhai et al 2020. His results showed that there were no significant differences observed in the multifractal dimensions of the soil particle size distribution (Sand, clay and silt). This could be attributed to the fact that the soil texture is a near permanent feature of the soil or a fixed soil characteristic which may remain unchanged except the soil is subjected to rapid erosion, removal and deposition (Zhai et al., 2020). In a long term research experiment conducted by Reddy (2017) using organic and inorganic fertilizers, no significant differences were observed in the percentages of clay, silt and sand compared to the control pots. His results were in line with the results of the present study and further confirms soil texture as a fixed characteristic of the soil. The soil gravel content did not change as well. This could be attributed to the short time period of application. It's been recorded that manure application can only alter soil physical properties mainly texture when applied in a long term duration usually (Fu et al., 2022). Lima et al (2021) noted no significant change in the soil physical properties of the treatments following a short term application 0f poultry manure and biochar.

**Table 2: Main effects of Manure on the Particle size distribution and the Soil Gravel content**

| Manure | %Clay | %Sand | %Silt | % Gravel |
|---|---|---|---|---|
| NPK | 31.00$^{a}$ | 44.90$^{a}$ | 24.10$^{a}$ | 42.10a |
| PM | 31.10$^{a}$ | 44.8$^{a}$ | 24.10$^{a}$ | 42.00a |
| WA | 31.10$^{a}$ | 44.8$^{a}$ | 24.10$^{a}$ | 42.00a |
| NPK + PM | 31.00$^{a}$ | 44.90$^{a}$ | 24.10$^{a}$ | 42.10a |
| PM + WA | 31.10$^{a}$ | 44.8$^{a}$ | 24.10$^{a}$ | 42.10a |
| Control | 31.00$^{a}$ | 44.90$^{a}$ | 24.10$^{a}$ | 42.00a |

Table 3 showed that significant higher pH values where observed with plots where organic fertilizers were used with wood ash with wood ash having the highest value. This result corroborated the results of Johansen et al (2021). Their results showed that the application of wood ash significantly increase soil pH, increase N mineralization with increased plant growth. Similar results were recorded by Mahmood et al (2017) that organic manures significantly reduced the soil pH of soil where maize was planted. Soil pH controls the mineralization of organic matter in the soil and this has implication on the functioning of the extracellular enzymes that aids in organic substrate transformation by microbes (Neine 2019). At higher pH, the mineralizable fractions of carbon and nitrogen increases because of the break of bonds between organic constituents and clay (Neine, 2019). In a study in the carbon and nitrogen mineralization between two upland soils using different organic fertilizers, Khalil et al (2004) found that the C/N ratio and pH were responsible for about 61% decomposition rate with high $CO_2$ effluxes. Qin et al (2017) also noted increase in pH following wood ash application. The poultry manure also increased soil pH significantly. The significant higher pH observed on soils where wood ash was added can be attributed to the high liming potential of the wood ash material used for the treatment as shown in table 1. The high calcium observed in the wood ash also suggest the potential of obtaining high pH from plots where they are applied since calcium is the major element in $Ca(OH)_2$ which is the main liming material in wood ash. When wood ash are added to the soil, it neutralizes acidity by adding a lot of carbonates to the soil which further reacts with acids in the soil to form a base rich compound known as $Ca(OH)_2$. This increases the soil pH and reduces soil acidity. Wood ash has been known to affect soil biology and chemistry in various ways including elevated pH, nutrient addition and availability (Johansen et al., 2021). Poultry manure also increased the soil pH by reducing soil acidity. This is in line with the results of Agbede et al (2013) who observed higher pH in plots where poultry manure was used as amendment.

**Table 3: Main effect of fertilizer types on Soil pH.**

| Treatments | 2020 |
|---|---|
| NPK | 4.67$^{c}$ |
| PM | 4.97$^{b}$ |
| WA | 5.67$^{a}$ |
| NPK + PM | 4.79$^{bc}$ |
| PM + WA | 5.03$^{b}$ |
| CONTROL | 4.64$^{c}$ |

The results of the proximate analysis are shown in table 4. The result showed that organic manure had significant higher values for % dry matter content, % protein, % carbohydrate, % fibre and % ash. Dry matter content is associated to the amount of protein, starch and mineral constituents of yam tuber (Naz et al., 2011). These results were in line with the results of Kaswala et al (2013). Their result showed enhanced starch and carbohydrate content from tubers produced from organic manure. It can be observed, that the control plots produced tubers with the highest value of fats followed by the NPK produced tubers. Carbohydrates are good sources of energy and plays vital role in boosting human immune system. Addition of organic manures amplified the proportion of fibre in yam. Fibre enhances digestion and provides bulk to food (Naz et al., 2017). The organic fertilizers in both sole and combined forms had the lowest values of fats. This implies that the organic fertilizers reduces fats contents while NPK enhances percentage fat. Fats are known to be very good source of energy to man and plays a vital role in enhancing the functionality of nervous system. They also lubricate the alimentary canal of man. But increased uptake of fat is harmful to human health leading to coronary heart disease, obesity and exposes the individual to high risk of cancer. Several factors would have been responsible for the high dry matter, ash, fibre, protein and carbohydrates found in the tubers from organic plots. The high ability of organic fertilizers to improve the soil physical properties would presumably have improved the nutrient status in the plots where they were applied (Kareem et al., 2020; Ezeocha et al., 2014). The high pH values observed from organic plots as shown in table 3 could have promoted the activities of microorganisms in the organic plots compared to the areas where inorganic manures were used. Organic fertilizers have been known for its potential in increasing soil microbial biomass. These organisms are known to play a vital role in decomposition thereby breaking down complex compounds to simpler forms where they can easily be taken up by plant. They add carbon to the soil through decomposition. Plots where farm yard manure were used induced the highest microbial population (Mandic et al., 2011). Suja and Sreekumar (2014) observed significant higher protein and dry matter contents from plots where organic manure were used. The results of Ezeocha et al (2014) did not corroborate with the result of the present study. Their result revealed that there was no significant effect of organic fertilizer on the dry matter content of the yam tuber from plots where organic fertilizers were applied. Their result further revealed that poultry manure significantly increased the moisture content compared to other field. The significant higher value of Carbohydrates, ash, moisture, protein and observed from plots where organic fertilizers were solely used or mixed could be attributed to the increase mineralization rates and soil quality enhancement associated with organic manures. The probable reason for the low % proximate composition of the NPK could be because of the low microbial activities in the plots where NPK was applied. Also, the low carbon content associated with the soil before planting could suggest a probable reason for the low dry matter content observed from the NPK tubers. NPK could not make up for the low carbon content because it contains no carbon element.

**Table: Main effect of fertilizer types on proximate composition**

| Manure | %Dry matter | %ASH | %FAT | %FIBRE | %PROTEIN | %CARBO HYDRATE |
|---|---|---|---|---|---|---|
| NPK | 32.253$^{d}$ | 0.28$^{d}$ | 5.75$^{b}$ | 1.867$^{d}$ | 3.127$^{b}$ | 54.91$^{c}$ |
| PM | 34.767$^{b}$ | 0.9456$^{b}$ | 4.20$^{d}$ | 3.68$^{a}$ | 2.137$^{e}$ | 56.92$^{b}$ |
| WA | 33.622$^{c}$ | 0.678$^{c}$ | 5.91$^{b}$ | 1.58$^{e}$ | 2.537$^{c}$ | 59.24$^{a}$ |
| NPK + PM | 33.623$^{c}$ | 0.677$^{c}$ | 4.06$^{d}$ | 2.84$^{c}$ | 2.351$^{d}$ | 54.66$^{d}$ |
| PM+WA | 39.966$^{a}$ | 1.2983$^{a}$ | 4.75$^{c}$ | 3.40$^{b}$ | 4.729$^{a}$ | 56.71$^{b}$ |
| CONTROL | 31.150$^{e}$ | 0.770$^{c}$ | 6.937$^{a}$ | 1.03$^{f}$ | 1.544$^{f}$ | 49.37$^{e}$ |

**Conclusion**

Application of sole or combined forms of organic manures significantly improved soil chemical properties and also enhanced the quality of yam tuber. Hence, the use of organic fertilizers is considered most effective for sustainable soil management and improvement of yam quality.

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