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# Impact Of Poultry Manure And Groundnut Shell On Soil Fertility, Growth And Tomato Yield (Lycopersicon Lycopersicum L.) In The Gambia's West Coast Region.

**[1*]Michael Rotimi Olojugba and [2]Ebrima Sanyang**

[1]*Department of Crop, Soil and Pest Management, Olusegun Agagu University of Science and Technology, Okitipupa, Nigeria.*

[2]*National Agricultural Research Institute, Horticultural Section, Brikama, The Gambia.* ;Corresponding author: mr.olojugba@oaustech.edu.ng

## Abstract

*The study explored the use of groundnut shells to improve soil fertility and enhance tomato growth and yield in an Inceptisol at the National Agricultural Research Institute in The Gambia from April to July 2022 and August to November 2022. Four treatments were tested using a Randomized Complete Block Design (RCBD) with three replications: groundnut shells at 5 tonnes per hectare, poultry droppings at 5 tonnes per hectare, a mixture of both at 2.5 tonnes per hectare each, and a control group. Results showed that organic manure effectively boosts soil fertility, serving as a viable alternative to inorganic fertilizers in central Gambia.Groundnut shells provided higher levels of potassium, calcium, magnesium, and organic carbon. The combination of poultry droppings and groundnut shells led to significant improvements in plant height, diameter, leaf area, and fruit yield compared to the control group. Additionally, soil pH increased from 5.4 to 6.5, and nitrogen levels rose from 0.34 g/kg to 0.77 g/kg with the combined treatment, achieving a 44% increase.Overall, the study recommends using groundnut shells and poultry droppings to optimize tomato.*

Key words: Groundnut shell, Tomato, Poultry dropping, Soil fertility

**Introduction**: In Gambia, tomatoes are ranked among the top three vegetable crops, alongside cabbage and onions, in order of importance (TAHAL, 2000). Groundnut (Arachis hypogaea) is the third most widely cultivated oilseed in the world and plays a significant role in the economies of several West African countries, including Gambia, Nigeria, Ghana, and Senegal (Nwanosike, 2011). In Africa, groundnuts are primarily grown in Nigeria, Gambia, Sudan, Senegal, Chad, Ghana, Congo, and Niger (Varela, Seif and Lohr. 2011). In 2007, the total harvested area for ground nuts in Africa was 9.04 million hectares, producing a total of 8.7 million tons. The average productivity index was reported as 1,720 kg per hectare for Nigeria, 500 kg per hectare for Sudan, and 700 kg per hectare for Senegal (Varela *et al*, 2011). It is important to note that hulls make up about 25% of the total mass of groundnuts produced, yet they are not utilized (Nwanosike, 2011). This study established that combining poultry droppings with NPK fertilizer enhances the growth and fruit yield of tomatoes. Additionally, this combination increased soil nitrogen, organic carbon, calcium, magnesium, phosphorus, potassium, and cation exchange capacity (Olojugba and Opeyemi, 2019). Groundnut cultivation is common as a major food crop in many countries. According to the World Food and Agriculture Organization, the leading groundnut-producing countries are India, China, the USA, Indonesia, and Myanmar. Globally, groundnut cultivation covers approximately 22.2 million hectares, with 16.3 million hectares in Asia, 7.39 million hectares in Africa, and 0.7 million hectares in South and Central America.

Combining compost with ashes may significantly contribute to soil security in tropical regions by mitigating nutrient leaching (Agegnehu, Nelson, & Bird, 2016). Furthermore, compost is known to enhance plant yield by adding essential nutrients (Mbau, Karanja, & Ayuke, 2014; Zhang et al., 2016). Additionally, allowing some trees to grow within agricultural fields can increase the soil's organic matter content through litter decomposition (Nair, 2013). Food is one of the most essential needs of humanity. However, a decline in soil fertility after several years of cropping poses a significant challenge. The necessity to improve soil fertility and crop production to meet the demands of a rapidly growing population has rekindled interest in using organic nutrient sources alongside mineral fertilizers for soil maintenance. Moreover, the continuous use of mineral fertilizers adversely affects soil chemical and physical properties, leading to nutrient imbalances, increased soil bulk density, and reduced water infiltration rates (Ojeniyi, 1995; Nottidge, Ojeniyi and Asawalam, 2005). Therefore, it is crucial to explore alternative nutrient sources that are less damaging to the soil, making research of this nature essential. The aim of this study was to assess the impact of groundnut shells and poultry droppings on plant growth, yield, and soil fertility improvement. Vegetable farmers in sub-Saharan Africa are increasingly aware of declining soil fertility, which could lead to decreased crop productivity in the region. This awareness has prompted a search for affordable soil fertility management solutions that utilize local materials. One such material in The Gambia is groundnut shell, which has become an environmental issue in the country. This study aims to raise awareness about the potential of using groundnut shells and poultry manure as alternatives to mineral fertilizers..

**Materials And Methods: The experiment on the comparative effect of poultry and groundnut shell on the growth and yield of tomato (*Lycopersicon lycopersci*) was conducted at National Agricultural Research Institute NARI Horticultural Unit. The village is situated from coastal road about 30km southwest of capital city of Banjul The Gambia. The varieties used as checks were commercial tomato Mongal F1 variety from Brikama Horticultural vegetable seeds Enterprise, the rationale for using the above materials was that the checks are readily available and popularly grown by Yundum woman vegetable cultivar in the west coast region.**

**Experiment Design:** The experiment was designed in a randomized complete block design (RCBD) that included four treatments and three replicates. A plot measuring 12m × 15m was established at the teaching and research farm of the National Agricultural Research Institute (NARI) Horticultural Unit in Brikama, The Gambia. This plot was divided into three blocks, each measuring 4m × 15m, with a 1.0m buffer separating them. Each 4m × 15m block was further subdivided into four plots, each measuring 3m × 3m, also separated by a 1.0m wide buffer.

The treatments applied were:; a. Control (no treatment applied); b. Groundnut shell (GNS) at 5kg/ha; c. Poultry manure (PM) at 5.0 t/ha; d. Groundnut shell (GNS) at 2.5 t/ha + Poultry manure (PM) at 2.5 t/ha (Olojugba and Chinedu, 2019) All treatments were randomly assigned to the plots within each block. GNS and PM were applied before transplanting by spreading them over the respective plots, while the control plot received no amendments. Weeding, disease management, and pest control were performed at appropriate times throughout the experiment.

Tomato seedlings of the Mongal F1 variety were sourced from the Brikama Horticultural Vegetable Seeds Enterprise. The seedlings were raised in boxes for four weeks prior to transplantation. In the nursery, where no treatments were applied, shade was provided to protect against direct sunlight, and the boxes were kept weed-free and watered daily. Before transplanting the seedlings into the field, the soil was watered to field capacity. Vigorous seedlings, three weeks old and transplanted after optimal rainfall, were planted at a spacing of 60 cm × 30 cm, resulting in a total of 55,556 plants per hectare, or 50 plants per plot. Preventive sprays of Abmetrin were applied against red spider mites on March 10, 2022, and March 30, 2022. Additionally, Dithane M45 was used as a preventive measure against blight on March 17, 2022. Weeding was conducted using hand hoes, and spraying was performed with a knapsack sprayer.

**Groundnut shell collection:** Groundnut shells were collected from local village during the harvest season, dried, part taken to laboratory for analysis and the remaining kept in bags, stored for future used.

**Poultry Manure Collection:** Poultry manure was collected from the battery cage system. Contaminants such as feathers and raw feeds were carefully sorted out, heaped and allowed to "cake-up" and dried for two weeks, ground and part taken to laboratory for analysis.

**Proximate analysis of Groundnut Shell (GNS) and Poultry Manure (PM):** pH was determined using a glass electrode pH meter in 1:2 soil water ratios [Crockford and Norwell, 1956]. Organic carbon content of the soil samples was determined by dichromate oxidation method [Walkley and Black, 1934]. The percentage organic matter content of the samples was calculated by multiplying the values of organic carbon by a factor of 1.724 based on the assumption that soil organic matter contains 58% carbon [Allison, 1982]. Total N was determined by the Kjeldahl method [Bremner, 1996]. Available phosphorus was extracted by Bray-1-method [Bray and Kurtz, 1945] and the P in the extract was determined colourimetrically. Potassium content was determined by method described by [Jackson, 1962].

**Data Collection & Analysis Soil Sample Collection and Analysis:** Soil samples were previously taken randomly and analyzed to know the nutrient status of the area using soil auger to the depth of 0-20cm. At planting, five soil samples in each plot were taken. Samples from each plot were bulked and composite were collected and taken to the laboratory for analysis.

**Particle Size Analysis:** This was done by hydrometer method [Bouycous, 1951] using sodium hexametaphosphate (Calgon) as dispersing agent.

**Chemical Properties:** The pH of the soil samples was determined using a glass electrode pH meter in 1:2 soil water ratios [Crockford and Norwell, 1956]. Organic carbon content of the soil samples was determined by dichromate oxidation method [Walkley and Black, 1934]. The percentage organic matter content of the samples was calculated by multiplying the values of organic carbon by a factor of 1.724 based on the assumption that soil organic matter contains 58% carbon [Allison, 1982]. Total N was determined by the Kjeldahl method [Bremner, 1996]. Available phosphorus was extracted by Bray-1-method [Bray and Kurtz, 1945] and the P in the extract was determined calorimetrically. Exchangeable Ca, K, Mg and Na were extracted with 1.0N NH40AC (Ammonium acetate) using a soil solution volume ratio of 1:10 [Jackson, 1962]. K and Na in the extract were read using flame photometer while Ca and Mg were determined by Atomic Absorption spectrophotometer. The exchangeable acidity was determined from 0.1N KCl extracts and titrated with 0.1N HCl [Maclean, 1954]. Cation exchange capacity was determined by the summation of NH4OAC – extractable cations plus 1.0N KCl extractable acidity.

**Plant sample collection:** This was done for four and six weeks after transplanting (WAT) and treatment application, plant height and diameter of ten randomly selected plant stems were taken with meter rule and veneer caliper The leaf area was measured using a measuring tape. The leaf length and breadth were measured to obtain the leaf area. The leaf area was estimated as its length multiplied by its maximum width multiplied by maize leaf calibration factor, 0.75 (Elings, 2000).

The leaf area index (LAI) was computed according to Msibi *et al*. (2014). $LAI = Y \times N \times LA / AP$ (1)

Where; Y = Population of plants per plot, N = Average number of leaves, LA = Leaf area ($cm^2$ ), AP = Area of plot ($cm^2$ ). Fruits were harvested per treatment, sorted, weighed and recorded.

**Statistical Analysis:** Data was subjected to analysis of variance using the general linear model procedure (GLM) for randomized complete Block design (RCBD) in SAS [SAS Institute, 2015]. Analysis of variance was computed to determine the significance of treatments. Mean separation was done using Duncan's New Multiple Range.

**Results and Discussion: Pysico-Chemical Properties of the Soils of the Experimental Site: Properties Soil of the experimental site:** Table 1 shows some of the physical and chemical properties of the soil of the experimental site before the treatments were applied. The texture of the soil in the study area was sandy clay with 54.0% sand and organic matter 1.32g $kg^{-1}$ The pH ($H_20$) show that the soil was slightly acidic (pH =5.4). The soil contains low organic matter, high total nitrogen but moderate phosphorus content.0.15% and 12.24 (mg dm-3) respectively. The effective cation exchange capacity was low (2.83cmolc kg-1) of soil.

**Some Chemical Properties of Ground Nutshell and Poultry Manure used in the Experiment** The characterization results of groundnut shells and poultry droppings used in the experiment are presented in Table 2. The organic carbon content in both groundnut shells and poultry droppings did not show significant differences between the two treatments. However, groundnut shells had a higher nitrogen (N) content of 7.0 g/kg, compared to 3.0 g/kg in poultry droppings, and there was a significant difference ($p < 0.05$) in N content between the two organic manures. Phosphorus levels in groundnut shells were significantly higher, measuring 18.7 g/kg, compared to only 0.38 g/kg in poultry droppings. For potassium, groundnut shells contained 11.9 g/kg, while poultry droppings had 12.07 g/kg, indicating a significant difference. Additionally, calcium and magnesium levels were significantly higher in groundnut shells than in poultry droppings. The pH of groundnut shells was moderately acidic at 6.5, while the pH of poultry droppings was slightly alkaline at 7.8.

**Effect of Groundnut shell and Poultry droppings on Length, Diameter, Leaf Area, Leaf Area Index and Tomato yield.:** In Table 3, the groundnut shell treatment recorded the highest values for both plant length and diameter compared to other treatments, achieving 45.52 cm and 1.61 cm at four weeks after planting (WAT), respectively. In contrast, the control plot demonstrated the lowest values, measuring 39.44 cm in length and 1.36 cm in diameter. A similar trend was observed in the sixth week after planting, with groundnut shell exhibiting greater length and diameter values.

Additionally, the combination of groundnut shell and poultry droppings (GNS + PD) achieved the highest leaf area, measuring 970.1 cm², while the control plot recorded the lowest leaf area at 523.2 cm². Although there were no significant differences among the treatments of GNS, GNS + PD, and poultry droppings (PD), all three showed significant improvement compared to the control.Furthermore, groundnut shell (GNS) demonstrated significantly higher values for leaf area index, measuring 0.43, while the control plots had the lowest value at 0.16. Regarding tomato yield, there were no significant differences among GNS, GNS + PD, and PD; however, all three treatments exhibited significantly higher yields than the control.

**Changes in Soil Chemical Properties of the Experimental Site as Influenced by the Application Groundnut shell and Poultry Dropping**: Table 4 presents the results of the analysis conducted to determine the effect of organic fertilizer on the soil. A comparison of Tables 1 and 4 shows that the soil pH of the experimental site was slightly acidic, measuring 5.4 before the treatment was applied. After treatment, the pH values were 5.6 for the GNS plot, 5.95 for the GNS + PD plot, and 6.05 for the PD plot. These treatments resulted in a significant increase in soil pH compared to the control group.

Organic carbon (OC) levels also increased significantly across all treatment plots, with the highest values recorded in the plot treated with GNS. Additionally, several macro-nutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), improved across all treatment plots. The effective cation exchange capacity (ECEC) was highest in the plot treated with GNS + PD, demonstrating a significant increase compared to the other treatments. All treated plots exhibited higher ECEC values than the control group. Furthermore, exchange acidity significantly decreased in all treated plots compared to the control, with the greatest reduction observed in the plot treated with GNS, which recorded a value of 1.38 mg/kg of soil.

**Discussion: Pre-soil Analysis of the Study Site:** The soil in the experimental site had a pH of 5.4 before the application of manure, indicating a medium level of acidity. According to Brady and Weil (1999), soils with a pH range of 5.2 to 5.6 are classified as moderately acidic. This provided a rationale for investigating the use of groundnut shells and poultry droppings as soil amendments. The acidic nature of the soil may have been caused by the leaching of soluble cations in the area, as well as the presence of exchangeable acidity. The leaching of sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg) significantly contributed to the soil's acidity. The low organic matter content observed in the soil could be attributed to its texture and continuous cropping practices without proper soil management. This aligns with the principle of using soil amendments in non-alkaline soils; on highly alkaline soils, essential elements such as iron, manganese, and zinc become locked away and unavailable to plants (Demeyer et al., 2001; Adekayode and Olojugba). The generally low levels of plant nutrients in the experimental plot, as well as in similar locations across Africa, are likely due to the continuous cultivation of crops like maize and cassava without adequate soil management practices, such as applying manure to replenish nutrients. Tisdale et al. (2003) discussed Mitscherlich's principle, which emphasizes that plants respond positively to nutrients that were previously limited in the soil. In the study area, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) were all found to be in low supply. This deficiency can be attributed to cropping practices and soil texture, which promote the leaching of soluble cations, soil erosion, and a lack of effective land management practices.

**Nutrient Concentration in Groundnut shell and Poultry Dropping (PD) Used for the Experiment:** The organic carbon (OC) content in both groundnut shell (GNS) and poultry droppings (PD) indicates that they are both effective sources of organic matter, contributing to soil fertility, crop growth, and yield. However, there was no significant difference between the two. The pH of groundnut shells is 6.5, while poultry droppings have a pH of 7.8. This suggests that more nutrients are likely to be available and soluble when using ground nut shells compared to poultry droppings. This finding aligns with research by Pagani and Mallarino (2015), who noted that nutrients such as nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), and magnesium (Mg) are most available within a pH range of 6.5 to 7.5. Additionally, the higher levels of calcium and magnesium found in groundnut shell suggest it may be a superior source of these nutrients, which is consistent with the findings of Adeoye I. (2001).

**Changes in Leaf Area, Leaf Area Index and Yield as a Results of Addition of Cocoa Bean Testa Ash (CBTA) and Poultry Dropping (PD):** The order of total leaf area, leaf area index, and yield values was significantly higher in plots treated with groundnut shell plus poultry droppings (GNS+PD) and groundnut shell (GNS) compared to the control and poultry droppings (PD) plots. This difference can be attributed to the higher levels of potassium (K), calcium (Ca), magnesium (Mg), moderate pH, and organic carbon (OC) observed in the GNS and GNS+PD plots, which also positively influenced the yield. This supports the assertion made by Cheema et al. (2012) that potassium enhances carbohydrate utilization and thereby increases leaf area index, contributing to greater dry matter accumulation and ultimately higher crop yields. Similarly, Subedi and Ma (2005) emphasized that leaf area is crucial for optimizing light interception and photosynthate production. Potassium plays a key role in photosynthesis by facilitating sunlight interception. When K levels are insufficient, both the leaf surface area and sunlight interception are markedly diminished (Mirza et al. 2018, Le et al. 2016). A deficiency in potassium leads to a reduction in both the number of leaves and their size, resulting in a decreased photosynthetic rate per unit leaf area. Consequently, this reduction limits the quantity of photosynthetic assimilates available for plant growth (Mirza, Borhannuddi, Kamrun, Jubayer , Md. Shahadat , Abdul Awal, ID Moumita and Masayuki et al, 2018 ).

The highest fruit yield of 0.39 t ha-1 was recorded in the GNS and GNS+PD treatments compared to other treatments, indicating that using groundnut shell (GNS), either alone or in combination with other organic manure, effectively improves soil fertility and enhances crop production. The elevated fruit yield in plots fertilized with GNS or GNS+PD is likely due to the high concentrations of K and OC present in GNS. According to Cheema et al. (2012), potassium improves carbohydrate utilization, increases leaf area index, and promotes greater dry matter accumulation, thereby boosting field crop yields. Additionally, the total leaf area, leaf area index, and chlorophyll content showed a positive correlation with maize grain yield ($r = 0.96$, 0.97, and 0.95, respectively), further confirming the findings of Mohamed et al. (2008).

**Changes in Some Soil Chemical Properties as a Results of Addition Groundnut shell (GNS) and Poultry Dropping (PD):** The lowest exchangeable soil acidity values, recorded at 1.27 and 1.28 in plots with groundnut shell (GNS) and a mixture of groundnut shell plus poultry droppings (GNS+PD), may be attributed to the liming effects of GNS due to its high potassium (K) concentration (Adeoye et al., 2001). Marcel et al. (2016) suggested that the increase in pH can be primarily attributed to the release of K carbonate resulting from the reaction of ash in the soil. Additionally, Demeyer et al. (2001) noted that the significant increases in nitrogen, potassium, calcium, and phosphorus levels could be related to their higher concentrations in groundnut shell (GNS).

**Conclusion and Recommendation:** The improvement in soil fertility and the subsequent increase in tomato fruit yield, achieved through the application of 0.39 t ha-1 of groundnut shell (GNS) and 0.39 t ha-1 of GNS combined with 2.5 t ha-1 of poultry droppings (PD), confirmed that using both organic sources together produced a higher tomato yield than when each was applied individually. Groundnut shell (GNS) contained a greater quantity of potassium (K), calcium (Ca), and magnesium (Mg), which contributed to its superior performance over poultry droppings (PD) in enhancing soil fertility. This included an improvement in pH levels as well as boosts in other nutrients such as nitrogen (N), phosphorus (P), calcium (Ca), magnesium (Mg), and sodium (Na). GNS also resulted in better tomato fruit yield compared to PD. The application of both GNS and PD demonstrated superior effectiveness in improving soil fertility and increasing tomato fruit yield, likely due to the higher concentrations of K in GNS and organic carbon (OC) in PD. Therefore, I recommend using groundnut shells to enhance tomato fruit yield and improve certain soil chemical properties at the study site.

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**Competing Interests**

Authors have declared that no competing interests exist.

Study Area

**Yundum is a small coastal town located in Kombo north in The Gambia. Yundum is located around the coastal zone with the geographical coordinates of 13˚, 20˚, 44˚w. The elevation is 19 meters above sea level. The experiment site received an average annual rainfall of between 800 mm to 1200 mm with maximum and minimum temperatures of 30˚C and 22˚C, respectively (Figure 4.1).**

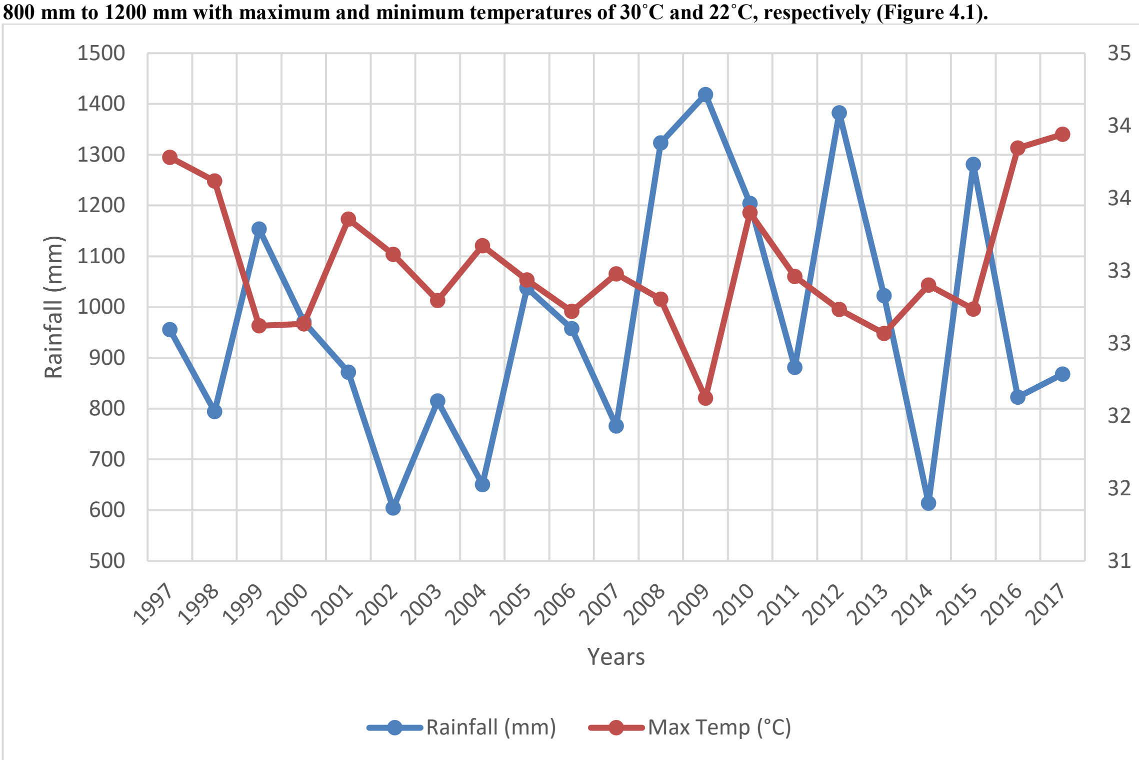


**Figure 1:** Average rainfall and temperature in study area


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**Table 1. PYSICO-CHEMICAL PROPERTIES OF THE SOILS OF THE EXPERIMENTAL SITE**

| SOIL PROPERTIES | SOIL TEST VALUES |
|---|---|
| SAND % | 54 |
| SILT % | 5.92 |
| CLAY % | 40.08 |
| Textural Class | Sandy Clay |
| pH in $H_2O$ | 5.4 |
| OC g/kg-1 | 0.94 |
| OM g/kg-1 | 1.62 |
| Total N g/kg-1 | 0.35 |
| Available P g/kg-1 | 17.32 |
| K g/kg-1 | 0.08 |
| Ca g/kg-1 | 0.27 |
| Mg g/kg-1 | 0.06 |
| ECEC g/kg-1 | 0.48 |

*ECEC: effective cation exchangeable capacity*

**TABLE 2: SOME CHEMICAL PROPERTIES OF GROUND NUTSHELL AND POULTRY MANURE USED IN THE EXPERIMENT**

| PROPERTIES | GROUNDNUT SHELL | POULTRY MANURE | MEANS DIFERENCE | T-VALUE |
|---|---|---|---|---|
| Organic Carbon g/kg-1 | 3.0 | 2.88 | 0.38 | $0.342^{ns}$ |
| Nitrogen g/kg-1 | 7.0 | 3.17 | 3.91 | 0.000* |
| Phosphorous g/kg-1 | 18.7 | 0.38 | 18.34 | 0.000* |
| Potassium g/kg-1 | 13.9 | 11.87 | -1.91 | 0.001* |
| Calcium g/kg-1 | 5.65 | 0.23 | 5.51 | 0.000* |
| Magnesium g/kg-1 | 3.11 | 0.32 | 2.81 | 0.000* |
| Ph | 6.5 | 7.8 | -1.87 | 0.001* |

**Table 3: Effect of Groundnut shell and poultry manure on some growth and yield parameters**

| | 4 WAT | | 6 WAT | | Leaf Area | Leaf Area index | Final Yield (t/ha) |
|---|---|---|---|---|---|---|---|
| Treatments | Ht. (cm) | Dia. (cm) | Ht. (cm) | Dia. (cm) | $cm^2$ | LAI | t/ha |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Control | 39.44[c] | 1.36[c] | 45.04[c] | 1.43[c] | 523.2[c] | 0.16[c] | 0.21[c] |
| GNS | 45.52[a] | 1.61[a] | 50.09[a] | 2.05[a] | 968.5[a] | 0.43[a] | 0.39[a] |
| PD | 44.82[ab] | 1.57[a] | 49.52[ab] | 1.85[b] | 967.8[ab] | 0.20[b] | 0.37[ab] |
| GNS + PD | 43.87[b] | 1.44[b] | 49.04[b] | 1.83[b] | 970.1[a] | 0.36[ab] | 0.39[a] |

*Means on the same column followed by the same letter are not significantly different at P ≤ 0.05.*
*GNS = Groundnut shell, PD = Poultry Manure, WAT = weeks after transplanting.*

**Table 4: Changes in Soil Chemical Properties of the Experimental Site as Influenced by the Application Groundnut shell and Poultry Dropping.**

| | **pH($H_20$)** | **OC (%)** | **N(g/kg-1)** | **P** | **Ca** | **Mg** | **K** | **Na** | **EA** | **ECEC** |
|---|---|---|---|---|---|---|---|---|---|---|
| Treatments | | | | mg/kg | | mg/kg of soil | | | | |
| CONTROL | 5.3[c] | 0.16[c] | 0.34[c] | 7.97[c] | 0.23[c] | 0.32[c] | 0.15[c] | 0.13[c] | 1.47[a] | 2.2[d] |
| GNS | 5.6[c] | 1.83[a] | 0.74[b] | 18.24[a] | 1.26[b] | 0.66[b] | 0.43[ab] | 0.32[ab] | 1.28[b] | 4.0[c] |
| GNS + PD | 5.95[ab] | 1.77[b] | 0.77[a] | 18.42[a] | 1.5[a] | 0.96[a] | 0.47[a] | 0.37[a] | 1.27[c] | 4.67[a] |
| PD | 6.05[a] | 1.68[ab] | 0.61[b] | 12.91[b] | 1.17[b] | 1.06[a] | 0.42[b] | 0.32[ab] | 1.29[b] | 4.34[b] |

*Means on the same column followed by the same letter are not significantly different at P ≤ 0.05.*
*PD: poultry dropping: GNS: groundnut shell, OC: organic carbon, N: nitrogen, P: phosphorus, Ca: calcium, Mg: magnesium, K: potassium, Na: sodium, EA: exchangeable acidity, ECEC: effective cation exchangeable capacity,*