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Comparative effects of Struvite and Inorganic Fertilizers on Growth Parameters of *Cucurbita Maxima (*Ugbogulu / Anyu)

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Abstract

This study compared the effects of struvite (a slow-release organic fertilizer) and inorganic fertilizers (NPK 20:**10**:10 and urea) on the growth of Cucurbita (ugbogulu/anyu). Struvite, obtained from human urine was used. The main experiment was conducted at Biochemistry Laboratory, Nnamdi Azikiwe University after struvite recovery and growing of the Cucurbita maxima which lasted for a period of four (4) months. Four treatment groups and four modifications were successfully employed. Treatments included: control (no application), NPK 20:10:10, urea fertilizer and struvite group. Data on the following plant growth parameters were collected within 3 to 9 weeks after planting. These data included: plant height, number of leaves, stem girth (circumference) and leaf area of the plants. Chlorophyll content, vitamin C content and mineral content were also determined using standard method. The results showed that plants grown with struvite had a higher percentage change in plant height (91%) and the average plant height (cm) in 6-week harvest data was 23.78±1.08. The average number of the leaves in the struvite group was the highest (7.50±0.96), while the average number of the leaves in the urea group was the lowest (4.67±0.43). Struvite group had the highest average final stem girth (2.43±0.12) when compared with other groups. Also, plants treated with struvite fertilizer had the highest vitamin C content, highest average chlorophyll B content, and highest potassium content. Therefore, it is recommended to use struvite (organic fertilizer) as an alternative to inorganic fertilizers for promoting plant growth and reducing environmental impact.

Keywords: Struvite, *Cucurbita maxima*, Plant growth, Fertilizer, Urine

INTRODUCTION

Fertilizers are organic or inorganic, synthetic or natural substances added to the soil to provide nutrients necessary for plant growth. Fertile soil is necessary for plants growth; therefore, it is important to replace the poor soil by fertilizing, especially by increasing nitrogen (N), phosphorus (P), calcium (C), potassium (K)and magnesium (Mg) content of the soil. These nutrients can be added to the soil in the form of inorganic or organic fertilizers. Inorganic fertilizers contain various mineral salts, primarily nitrates, phosphates and potassium salts, which provide nitrogen, potassium and phosphorus. Most organic fertilizers are animal manure, compost, and other plant or animal products such as blood, urine and bone meal, fish meal and wood ash.

The rapid increase in the population in recent years has led to the consumption of agricultural products in large quantities. This sector now requires a constant supply of synthetic fertilizers to improve plant growth, ultimately leading to the need for organic fertilizers. However, through urine alkaline precipitation reactions, phosphorus may crystallize into an odourless powder: struvite ($MgNH_4PO_4 \cdot 6H_2O$), sometimes called magnesium ammonium phosphate hexahydrate. Struvite is a bio available, slow-release fertilizer; It is compact (low volume and weight), easy to store, transport, use and also odourless.

Various studies have shown that struvite crystals ($MgNH_4PO_4 \cdot 6H_2O$) can be formed from urine as fertilizer. Urine and even wastewater, providing high nitrogen (N) and phosphorus (P), are good for struvite recovery. According to Bouropoulos and Koutsoukos (2000), the reactions responsible for struvite formation are as follows:

$$Mg^{2+} + NH_4^+ + PO_4^{3-} + 6H_2O \rightarrow MgNH_4PO_4.6H_2O$$

Struvite is a dry, stored mineral that can be produced from urine by adding magnesium (Mg); e.g. magnesium sulphate ($MgSO_4$), pre-treated magnesite ($MgCO_3$ converted to MgO) or bittern/ brine (liquid obtained from salt products from seawater). Magnesium ions combine with phosphate (PO_4^{3-}) and ammonium (NH_4^+) molecules to form solid precipitates that can be visually detected (Maurer *et al.*, 2006). This struvite is readily available and usable as a slow-release phosphate fertilizer. Compared to liquid urine, problems of storage, transportation, handling, and odour no longer exist; and the use of struvite from mixed-source urine seems to be socially acceptable (Gantenbein and Khadka, 2009).

Struvite has emerged as a useful source for phosphate fertilizer as it contains cheap N (nitrogen) and P (phosphorus) nutrients that can be used as raw materials for the fertilizer industry (Rahaman, 2008). As a result of struvite low water solubility, it is often referred to as a slow-acting/ slow release fertilizer (Joanne *et al*., 2021). It is a crystalline mineral composed of magnesium, ammonium, phosphate in the same molar concentrations in alkaline conditionand has more benefits than the usual fertilizers. These benefits are as follows: Struvite releases nutrients at a slower rate, allowing plants to absorb nutrients before they are washed away, saving the use of commercial fertilizers, and enabling the production of important nutrients such as phosphorus (P), nitrogen (N), magnesium (Mg) among other components, can be absorbed simultaneously without using any other artificial components, and the heavy metal impurity content is 2-3 times lower than commercial fertilizers (Bhuiyan *et al.,* 2008).

The mechanism of struvite precipitation has been studied extensively. In the United States, Canada, Europe, and Japan, large municipal wastewater treatment plants use multipurpose systems to convert phosphorus to struvite (Ostara, 2010). Although this large-scale reactor relies on advanced technology to recover phosphorus, the challenge is to build a community-scale, low-cost struvite reactor that can be assembled from local materials and where magnesium products from appropriate activities may be effectively and easily used (Etter, 2009).

Cucurbita maxima plants, also called pumpkin are considered as human food and are valued for their medicinal properties. Despite the many benefits of pumpkin, farmers face many problems in pumpkin production due to decreased soil fertility, especially soil degradation. Therefore, it is necessary to improve the soil, increase its quantity and quality by using fertilizeras source of nutrients. There is interest in understanding how the proximate concentration and pigment concentration of *Cucurbita maxima* are affected by the type of fertilizer. According to Oloyede *et al*. (2012), the fertilizer type affects crop yield and food quality; In addition, vegetables planted in land treated with organic fertilizers are always larger than those planted in land treated with poor fertilizers, because organic fertilizers improve the structure of the soil, increase aeration, water retention rate and nutrient ions, promoting healthy growth (Orluchukwu and Amadi, 2022).

Statement of the Problem

Recovery of fertilizers from human urine; which is a waste product is very important because the use of poor quality/ inorganic fertilizer is known to cause negative consequences. First, these inorganic fertilizer products are very expensive and many people cannot afford them. They are not easily available in comparison with organic fertilizers. Most inorganic fertilizers are often produced or extracted from petroleum products and can therefore have a negative impact on the environment. Inorganic fertilizers do not increase the organic content of the soil and are easy to overuse, thereby damaging plants. They will also make the soil more acidic and the soil will need pH adjustment. When inorganic fertilizer is used, nutrients in the soil can easily be depleted. Some literature reviews of similar studies point out the presence of heavy metals in plants using inorganic fertilizers. The population is growing and more food production is needed; Therefore, we will not rely on inorganic fertilizer products to survive. Additionally, there is no control over the discharge of this waste (urine) into the aquatic environment which can cause serious damage to the environment and is of great concern as it can damage the water supply, could be harmful to aquatic life or cause diseases if the water is used inappropriately; therefore needs to be channeled properly for optimal use.

Due to the detection of these problems, it is necessary to use organic fertilizers (such as struvite obtained from human urine). Struvite, used as fertilizer, can be easily produced by small businesses at a low cost. In other words, it is cheaper because they can be made from simple waste. They are generally safe and have low environmental impact. Generally speaking, plant or animal materials add organic substance, which retains moisture and supports a healthysoil microbiome. Additionally, the use of struvite fertilizers is less corrosive/ not likely to hurt plants than inorganic fertilizers. Organic fertilizers may contain many micro-nutrients not found in inorganic fertilizers, and since they are released more slowly, they persist for a long time.

In this context, the recovery of nutrients, especially phosphorus and nitrogen, from human urine is important for its fertilizer value as well as for the conservation of natural resources, thus reducing water pollution and improving sanitation systems in developing countries. Therefore, it is important to compare the plant growth benefits of struvite (recycled urine products) and commercial inorganic fertilizer products.

Aim of the Study

This study aimed to recover struvite from human urine and compare its effects with inorganic fertilizers (NPK 20:10:10 and urea fertilizers) on *Cucurbita maxima* (ugbogulu/anyu) growth.

Specific Objectives of the Research

i. To recover struvite (Magnesium Ammonium Phosphate Hexahydrate) from human urine, to be used as fertilizer.
ii. To analyze the nitrogen, phosphorus and potassium content of the recovered struvite, NPK 20:10:10 and urea fertilizer.
iii. To ascertain the comparative effect of struvite and inorganic fertilizers (NPK 20:10:10 and urea) on the growth rate of *Cucurbita maxima* (ugbogulu / anyu).
iv. To compare the effect of struvite, NPK and urea fertilizer on chlorophyll A, B and total chlorophyll content of the *Cucurbita maxima* (ugbogulu / anyu).
v. To compare the effect of struvite, NPK and urea fertilizer on vitamin C composition of the leaves, of the *Cucurbita maxima* (ugbogulu / anyu).
vi. To determine the comparative effect of struvite, NPK and urea fertilizer on mineral content (Mg, K, Fe, Zn, Ca) of the *Cucurbita maxima* (ugbogulu / anyu).

Significance of the Study

This study will help to determine if the use of struvite from human urine, will enhance growth parameters / improve crop yield in plants such as *Cucurbita maxima* and find out if it can influence the quality of the vegetables produced as regards to improvement in chlorophyll content, vitamin C content, some mineral content compared with inorganic fertilizers (NPK 20:10:10 and urea fertilizer). This work will also encourage the economic viability of introducing standard sewage disposal system in Nigeria. **Justification of the Study**

In this research work; urine, was converted to a more economical productive substance through a simple methodology of struvite recovery. The removal of nutrient compounds from aqueous waste (urine), as a means of controlling land and water pollution is currently a priority. Struvite formation is an attractive approach to precipitate a valuable multi-nutrients slow release fertilizer for vegetables and plants growth.

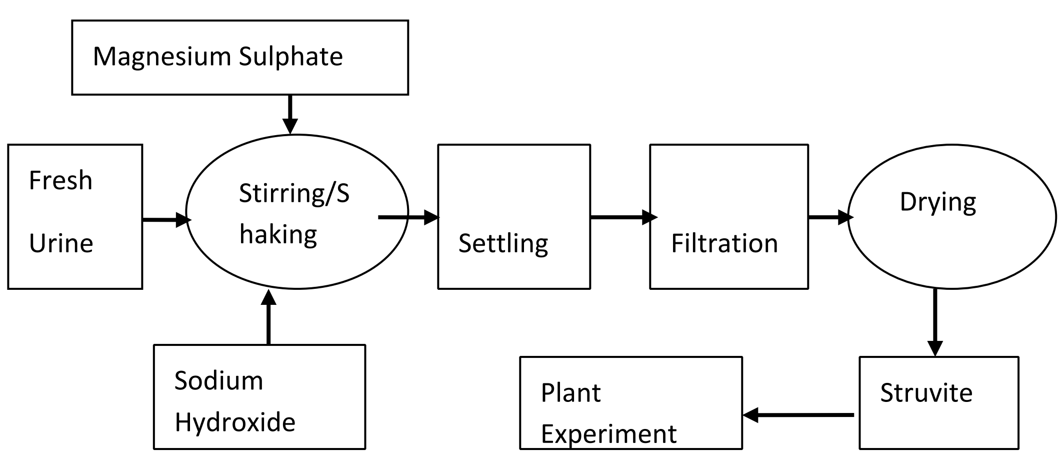
This study is of high interest as the entire methods, from struvite recovery to planting, vitamin C and mineral analysis stage was simple to carry out. Also, the raw materials involved are cheap and easily available. The goal of this project is to prove that struvite, have positive effect on plant growth (*Cucurbita maxima*); then recommend it as fertilizer with an added advantage in relation to possibly being a great business venture for either individuals or the government to venture into.

MATERIALS AND METHODS

Materials: Reagents and Equipment

Sodium hydroxide (NaOH), sulphuric acid (H_2SO_4), magnesium sulphate ($MgSO_4$), phosphoric acid (H_3PO_4), distilled water, salicylic acid (HOC_6H_4COOH), trioxonitrate (V) acid (HNO_3), hydrochloric acid (HCl), boric acid, methyl red indicator, selenium powder, zinc dust, phenolphthalein indicator, ammonium persulfate, calcium carbonate, aqueous acetone, jerry cans, filter bag, struvite reactor, pH metre, chemical balance, measuring cylinder, bucket, micro-kjeldahl digestion unit, kjeldahl digestion flasks, whatman No.4 filter paper, filter bag, flexible measuring tape, rope, homogenizer (mortar and pestle), black garbage bags, markers, data sheets, table top centrifuge, centrifuge tubes, test tube rack, 5 mL and 10 mL pipettes and bulb, spatulas, 10 mL graduated cylinders, a visible light spectrophotometer with an optically matched set of cuvettes, squeeze bottles, a freezer and stop watch.

Experimental Design



Soil sample was collected with a shovel from the farm into 16 sack bags of size 56 cm × 50 cm before watering. The experiment was performed with four treatments groups which was replicated four times. The experimental treatments were: control (no application), NPK 20:10:10, urea fertilizer and struvite from human urine. The fruit (*Cucurbita maxima)* from which the seeds were gotten was bought from Eke Awka market. 4 seeds were planted per sack bag at a depth of 2 cm. The fertilizer application was done third week after planting using ring method. Manual weeding was carried out 6 weeks after planting by hand picking.

There are three broad stages involved in this work.

STAGE I: This phase comprises the collection of urine, struvite recovery and quantitative test on the Struvite, NPK and Urea fertilizer for Nitrogen, Phosphorus and Potassium.

Urine collection and Preservation

Urine was collected and stored in jerry cans. To every litter of the collected urine 3.2grams of Magnesium sulphate was added.

Recovery of Struvite from Human Urine (Method described by Ayla *et al*., 2013)

Step by Step Procedure:

I. Collection of urine: Urine was collected in an airtight container from my house hold (a reliable source; free from any contaminant).

II. Mixing with Magnesium Source: 2.3grams of Magnesium Sulphate was mixed together with 1litre of the fresh urine (To every 10 litres, 23g of Magnesium Sulphate was added).

III. Adjusting the pH: pHof the collected urine was measured using a pH test strip. It's necessary to note that struvite formation is favourable at the pH range of 7-10. That is, to precipitate struvite; alkaline conditions are required. If the pH is too low, small amount of basic substance like sodium hydroxide (NaOH), will be added to raise the pH and if the pH is too high, small amount of acidic substance like Sulphuric acid (H_2SO_4) will be added to lower the pH}.

IV. Addition of Phosphate and shaking/ stirring the mixture: Drops of phosphoric acid was gradually added into the mixture; then poured into the vessel which was fixed unto the struvite reactor, for shaking/ stirring to agitate the reaction. This shaking lasted for 30 minutes.

V. Precipitation Reaction: The mixture was allowed to age for 48 hours. As the magnesium and phosphate ions came in contact, they react to form struvite crystals. This reaction can be stated as follows:

$$Mg^{2+} + NH_4^{+} + PO_4^{3-} + 6H_2O \rightarrow MgNH_4PO_4.6H_2O$$

VI. Sieving and Drying: The crystal struvite formed; and the mixture then carefully poured through a filter bag to separate it from the liquid; then allowed to dry completely under room temperature.

Plate 1: Struvite, recovered from human urin

Quantitative Test on the Struvite, NPK and Urea Fertilizer for Nitrogen, Phosphorus and Potassium

i. **Nitrogen (N) Determination (AOAC, 1999)**

The nitrogen content of the samples was determined using the micro kjeldahl method of AOAC (1999). The samples were dissolved with concentrated sulphuric acid, using copper sulphate and sodium sulphate as catalysts to convert organic nitrogen into ammonium ions. Alkali was added and the liberated ammonia was distilled into an excess boric acid. The distillate was titrated with hydrochloric acid.

Procedure:

One gram (1g) of the grounded fertilizer sample was weighed and transferred into the kjeldahl digestion flask and 3g of a mixture of sodium sulphate and copper sulphate pentahydrate in the ratio 10:1 was added as catalyst. Four anti-bumping chips was added to the mixture to prevent sticking to the flask during digestion and to aid boiling. The whole content was digested with 25ml of concentrated H_2SO_4. The flask was inclined and heated gently at first until frothing ceased, before heating strongly while shaking it, at intervals, to ash down charred particles from sides of the flask. Heating continued until the mixture become clear and free from black or brown colour.

This was allowed to cool and the content in the flask made up to 100ml using distilled water. 20ml of the diluted digest was placed in the distillation flask. 20ml of 2% boric acid solution was measured into a conical flask, and few drops of methyl red indicator, added into the conical flask. The conical flask and its content were placed on the receiver, so that the end of the delivery tube dips just below the level of the acid. Few pieces of grinded zinc and anti-bumping granules was added to the distillation flask and about 40ml of 40% NaOH solution allowed to run into the flask to make the liquid in the flask alkaline. The content was highly boiled until the content of the flask bumps. At last, the distillate was titrated with 0.1N HCl to a purple coloured end point.

Calculation:

$$\text{Nitrogen(\%)} = \frac{1.4 \text{ x Titre Volume x total volume of digest}}{1000\ x\ \ weight\ of\ Sample\ x\ Aliquot\ distilled} \text{ x } 100$$

ii. **Determination of Phosphorus Content**

Phosphorus content ofthefertilizer sample was analyzed using spectrophotometry techniques, according to AOAC (2005) as follows:

a. Digestion of the Sample:

2.0g of the fertilizer samples wasmeasured into a digestion flask and 20ml of acid mixture (650ml concentrated HNO; 80ml perchloric acid; 20ml concentrated H_2SO_4) was added. The flask was heated until a clear digest obtained and distilled water was added up to the 50ml mark.

b. Laboratory Procedure:

50ml of the above sample digest was collected and 1 drop of phenolphthalein indicator added. 1ml of sulphuric acid solution and 0.4g of ammonium persulfate was added. The solution was boiled gently for 30-40minutes until total volume left was 10ml, the solution was cooled, 1 drop of phenolphthalein was added until it neutralized to light pink colour with 1N sodium hydroxide. The solution was then added up to 50ml with distilled water then tested for total phosphorus.

Total Phosphorus Content:

50 ml of the above solution was pipetted into a cleaned dry 125ml Erlenmeyer flask. One drop of phenolphthalein indicator and 8.0ml of combined reagent added and mixed thoroughly. This was made to stand for at least 10 minutes for colour development. The absorbance was measured at 880nm using a reagent blank to zero the spectrophotometer.

This was conducted thrice and the average absorbance value for the sample taken.

$$\text{Conc. of sample} = \frac{\text{Absorbance of sample x Concentration of standard (100mg/l)}}{\text{Absorbance of standard x 1}}$$

iii. **Potassium (K) Content Determination:** Potassium concentration in urine-based struvite fertilizer, NPK and urea fertilizer was determined using flame photometry according to Rehmat*et al.,* (2022). This method involves the measurement of the intensity of light emitted by potassium atoms. Samples weighing approximately 1g was measured into a 100ml digestion flask, then 10ml of 70% trioxonitrate (V) acid (HNO_3) was added followed by heating until any vigorous reaction subsided (30-45 minutes). After cooling, 8ml of 70% perchloric acid ($HClO_4$) was added to each flask and the contents were gently heated on a hot plate until the solutions became colourless or nearly so, and white fumes of $HClO_4$ were evolved making sure contents didn't dry. After cooling, approximately 30ml distilled water was poured into each flask and heated for another 10 minutes, it was cooled and filtered. The digests were then subjected to atomic absorption spectrophotometric analysis.

STAGE II: This phase involves the collection of *Cucurbita maxima* (ugbogulu / anyu) seeds, identifying them, planting them and monitoring their growth.

Collection and Identification of the Seeds

Cucurbita maxima (ugbogulu / anyu) seeds were collected from its fruit (anyu) specifically bought from Eke Awka market and identified by a taxonomist from Botany department at Nnamdi Azikiwe

University, Awka. A herbarium number **'NAUH 15[B]'** was assigned to the seeds. The seeds were dried and ready for planting.

Plate 2: The *Cucurbita* maxima fruit used for this research

Plate 3: *Cucurbita maxima* seeds identified and used for this research

Planting of Seeds (Cucurbita maxima (ugbogulu / anyu) and Treatment Groups

Four (4) experimental groups were provided. They are:

a) NPK fertilizer group (4 replicates).

b) Urea fertilizer group (4 replicates).

c) Struvite group: (4 replicates).

d) Normal control group (without any fertilizer - 4 replicates).

4 seeds were planted per bag.

Determination of the Plant Area: The average radius of the plant area was measured and recorded as 18.40cm.

Area = $\pi r^2 = 3.142 \times 18.4 = 57.8cm^2$.

Determination of the Quantity of Struvite and Other Fertilizers Applied: The moderate concentration of 1400kg/Ha according to Rumhungwe *et al*., (2016) was used. This resulted in $0.004g/cm^2$, thus $0.23g/57.8cm^2$. This was applied immediately after germination (2 weeks after planting).

Plate 4: The entire experimental groups (At four weeks).

Plate 5:: The entire experimental groups after eight weeks

Determination of *Cucurbita maxima* Growth Parameters

Growth parameters including number of leaves, leaf area, plant height and stem girth was checked at intervals.

Determination of number of leaves was done through physical counting. Plant height and stem girth was checked using rope and flexible measuring tape (cm). Leaf area (LA) was calculated as ½ W × L. As described by (Flávio and Marcos, 2003).

Where; W = leaf width

L = leaf length

STAGE III This include determination of:

a) Chlorophyll content.

b) Vitamin C content.

c) Mineral analysis: (K, Na, Ca, Mg, Zn).

Determination of Chlorophyll content (Arnon, 1949).

Chlorophyll concentration was determined according to Arnon (1949) method.

To prepare 80% aqueous acetone solution:

This was done by mixing distilled water with reagent-grade acetone in a ratio of 2:8 (v:v) (distilled water: acetone).

Procedure: The Cucurbita maxima (ugbogulu / anyu) leaves was collected based on the sampling plan of this experiment. 1.0g of the sampled leaf was cut into small pieces and homogenized in a pre-cooled mortar and pestle using 10ml of 80% (V/V) acetone. Little calcium carbonate was added after it was grinded. The prepared sample was centrifuged at 3000 revolutions per minute for 15 minutes and 80% (V/V) acetone was added and make it up to 25 ml. The clear solution was transferred to a spectrophotometer tube and the optical density was measured at 645 nm (that is, absorbance reading at wavelengths of 645 nanometres (nm) and 663 nm, against an 80% acetone blank in a Shimadzu double beam spectrophotometer (UV 240). The levels of chlorophyll 'a' and chlorophyll 'b' were determined using the equation given below:

Chlorophyll 'a' (μg/ml) = (12.7 x O.D. at 663 nm) – (2.69 x O.D. at 645 nm) Chlorophyll 'b' (μg/ml) = (22.9 x O.D. at 645 nm) - (4.08 x O.D. at 663 nm) and total chlorophyll (μg/ml) = (20.2 x O.D. at 645 nm) + (8.02 x O.D. at 663 nm). Chlorophyll content was expressed as mg chlorophyll per gram fresh weight of the leaf.

Ascorbic Acid (Vitamin C) content determination

Ascorbic acid content of the leaves sample was determined according to Klein and Perry (1982). An aliquote (20mg) of each of the samples was extracted with 10ml of 1% metaphosphoric acid. It was allowed to stand for 45 min at a temperature of 28^{o}C (Laboratory temperature) after which it was filtered through Whatman No.4 filter - paper. 1ml of the filtrate was mixed with 9ml of 50μM 2,6-dichlorophenolindophenol sodium salt hydrate and the absorbance was measured at 515nm using a UV-Vis spectrophotometer after 30min. Vitamin C content was calculated from the calibration curve of authentic L-ascorbic acid and the result expressed as mg ascorbic acid equivalent per gram (mgAE/g) of the sample.

Mineral Analysis: (Mg, K, Fe, Zn and Ca Content)

The mineral analysis of the sample was conducted using Varian AA240 Atomic Absorption Spectrophotometer based on the method of APHA 1995 (American Public Health Association)

Working principle***:*** Atomic absorption spectrometer's working principle is based on the sample being aspirated into the flame and atomized when the AAS's light beam directed through the flame into the monochromator, and onto the detector that measures the amount of light taken up by the atomized element.

Because metals have their own characteristic absorption wavelengths, using light from these materials causes no spectral or electrical interference. The energy absorbed in the flame at a characteristic wavelength is directly proportional to the concentration of elements in the sample.

Wet digestion technique:

The method of Henryk, (2003) was adopted. Samples weighing approximately 1g was poured into a 100ml digestion flask, then 10ml of 70% trioxonitrate (V) acid (HNO_3) was added followed by heating until any vigorous reaction subsided (30-45 minutes). After cooling, 8ml of 70% per chloric acid ($HClO_4$) was added to each flask while the contents were gently heated on a hot plate until the solutions became colourless or nearly so, and white fumes of $HClO_4$ were evolved making sure contents didn't dry. After cooling, approximately 30ml of distilled water was poured to each flask and boiled for another 10 minutes, then cooled and filtered. The digests were then subjected to atomic absorption spectrophotometric analysis.

Preparation of reference solutions:

Different metal solutions in the standard concentration range were prepared. The reference solutions were prepared by diluting the single stock element solutions with water containing 1.5 mL conc. nitric acid per litre. Calibration blanks was prepared using all reagents except metal stock solution. And calibration curve for each metal was created by plotting absorbance of the standard against its concentration.

Data Analysis:

Statistical analysis of the results was done using the Analysis tool pack of Microsoft excel. Tables and bar charts were employed to show the averages of each parameter. Charts was used to show the level/actual effect of struvite, and the purchased inorganic fertilizers on the plant's growth. Data from mineral analyses (K, Na, Ca, Mg, Zn) was subjected to Anova statistical analysis to compare all the parameters between and within the treatment / plant groups (level of significance $\alpha = 0.05$. That is, values were taken to be significant at $p<0.05$). Analyses of averages was performed to find out the effects of struvite fertilizer, NPK (20:10:10) and Urea fertilizer on the grown plants {*Cucurbita maxima* (ugbogulu /anyu)}.

RESULTS

Results of the study are presented here. Growth rate of the plants (*Cucurbita maxima*) grown with struvite (organic fertilizer), those grown with inorganic fertilizer (NPK and Urea) and the normal control group were analyzed and presented, followed by the evaluated chlorophyll, vitamin C and mineral content of the plants in the four treatments groups (control, struvite, urea, NPK fertilizers),

Nitrogen, Phosphorus and Potassium Concentration in Struvite, NPK and Urea

Table 1.1: Table Showing Nitrogen, Phosphorus and Potassium Concentration in Struvite, NPK and Urea

Manure type	Nitrogen	Phosphorus	Potassium
NPK	8.00 ±0.10	3.00±0.22	3.00 ±0.04
Urea	41.00±0.31	0.50 ±0.33	1.20±0.12
Struvite	9.30±0.11	15.00± 0.06	3.70 ±0.07

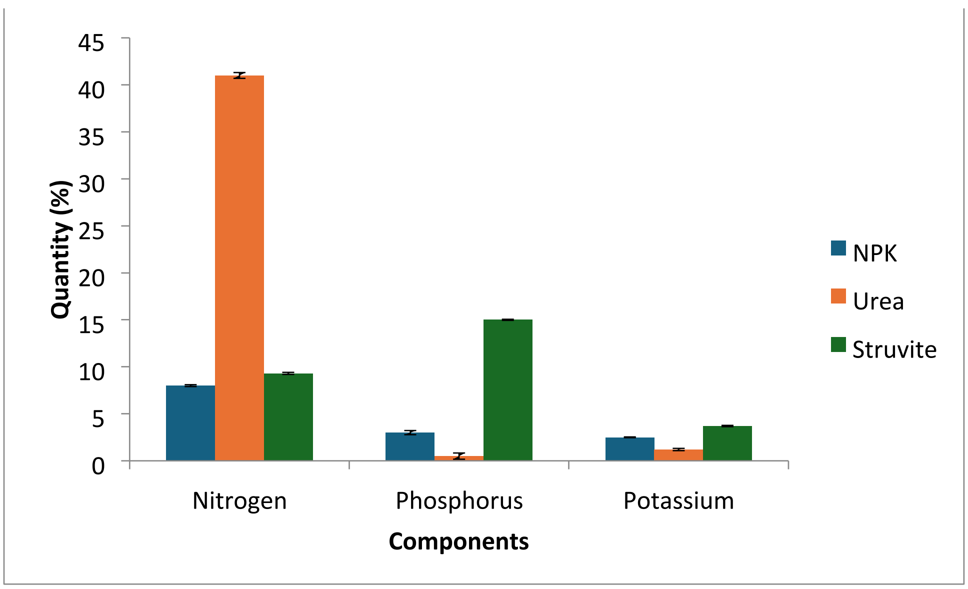


Figure 1.1: Bar chart Showing Nitrogen, Phosphorus and Potassium Concentration in Struvite, NPK and Urea

The comparison of nitrogen, potassium and phosphorus levels of the recovered struvite, urea and NPK fertilizer as shown above indicated that urea has the highest concentration of nitrogen with almost absence of phosphorus. Struvite has higher concentration of phosphorus compared with NPK fertilizer; but has the minimum concentration of potassium, which is termed more absorbable.

Effect of the Fertilizer Treatments on Plant Height

Table 1.2: Table showing average plant height (cm) during the experimental period

Weeks	Normal control	Struvite	Urea	NPK
0	13.33±1.00	12.45±1.07	15.15±1.07	12.16±1.08
1	16.47±1.45	15.54±1.28	17.72±1.11	15.69±0.93
2	17.41±1.43	17.72±1.40	19.78±1.31	17.94±0.69
3	18.91±1.18	19.02±1.54	20.87±1.33	19.66±0.82
4	19.80±1.26	19.29±1.62	21.58±1.26	20.44±0.91
5	21.10±1.31	21.60±1.93	23.44±0.53	20.27±1.66
6	22.80±1.18	23.78±1.08	24.48±0.51	20.20±2.13

Table 1.2.1: Table showing percentage change in plant height during the experimental period

	0	1	2	3	4	5	6
Normal control	0	23.57985	30.6538	41.90782	48.55305	58.30654	71.06109
Struvite	0	24.83269	42.32176	52.76167	54.90319	73.46301	90.9967
Urea	0	16.90355	30.55838	37.71574	42.43655	54.6912	61.56514
NPK	0	29.02468	47.59107	61.69213	68.15511	66.74501	66.15746

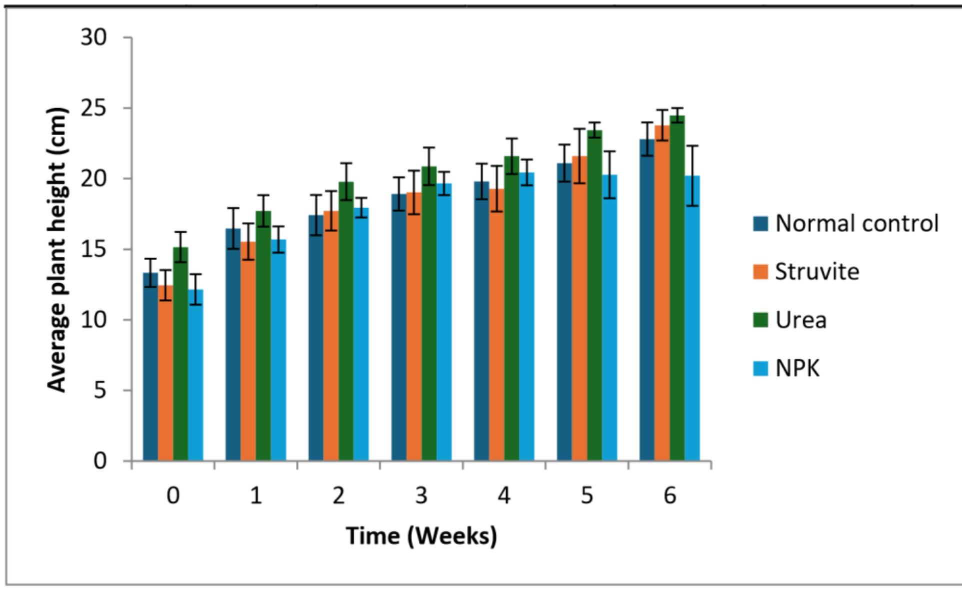


Figure 1.2: Bar chart showing average plant height (cm) during the experimental period

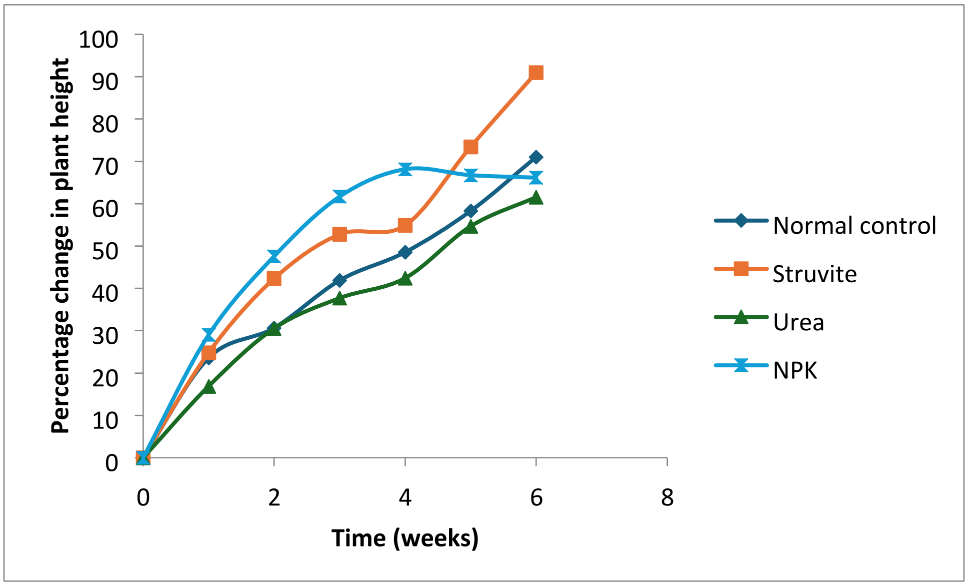


Figure 1.2.1: Scatter plot showing percentage change in plant height

From the results, there was a significant linear increase in plant height in all the groups ($p<0.05$). The struvite group had the highest percentage increase in plant height (91.00%) while the urea group had the least (61.57%); though there was no significant difference in initial and final plant heights when the groups were compared ($p>0.05$) (Refer to appendix for ANOVA table checking for significant difference in plant height). The table also showed an increase in plant height (cm) 23.78±1.08 > 21.60±1.93 > 19.29±1.62 > 19.02±1.54 > 17.72±1.40 > 15.54±1.28 > 12.45±1.07 for struvite group. This increase in plant height in the struvite group could be attributed to the high nitrogen and potassium content of the struvite since both nutrients promote plant growth and overall plant vigour.

Effect of the Fertilizer Treatments on Number of leaves

Table 1.3: Table showing average number of leaves

Weeks	Normal control	Struvite	Urea	NPK
0	5.14±0.34	4.78±0.32	3.85±0.27	5.00±0.00
1	4.57±0.37	3.89±0.35	4.00±0.25	4.00±0.44
2	4.43±0.20	4.11±0.31	4.31±0.33	4.29±0.42
3	5.14±0.34	4.33±0.44	4.31±0.35	4.43±0.43
4	5.71±0.47	4.33±0.78	4.50±0.32	4.71±0.78
5	6.29±0.57	6.14±0.80	4.58±0.34	5.29±0.99

6	7.29±0.61	7.50±0.96	4.67±0.43	5.57±1.41

Table 1.3.1: Table showing percentage change in average number of leaves

	0	1	2	3	4	5	6
	0		-13.8889	0	11.11111	22.22222	41.66667
Groups							
Normal	control	11.1111					
Struvite	0	- 18.6047	-13.9535	-9.30233	-9.30233	28.57143	56.97674
Urea	0	4	12	12	17	19.16667	21.33333
NPK	0	-20	-14.2857	-11.4286	-5.71429	5.714286	11.42857

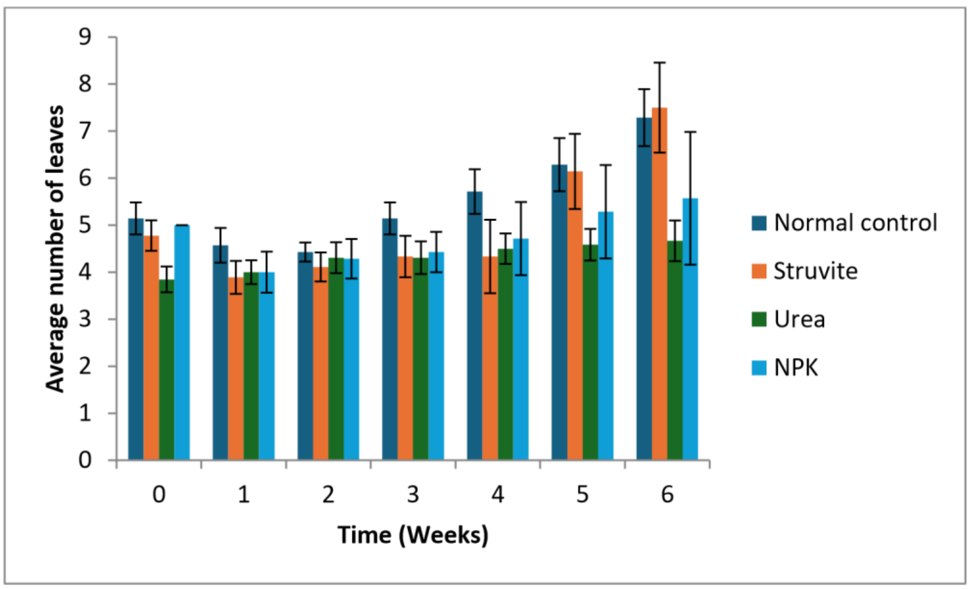


Figure 1.3: Bar chart showing average number of leaves

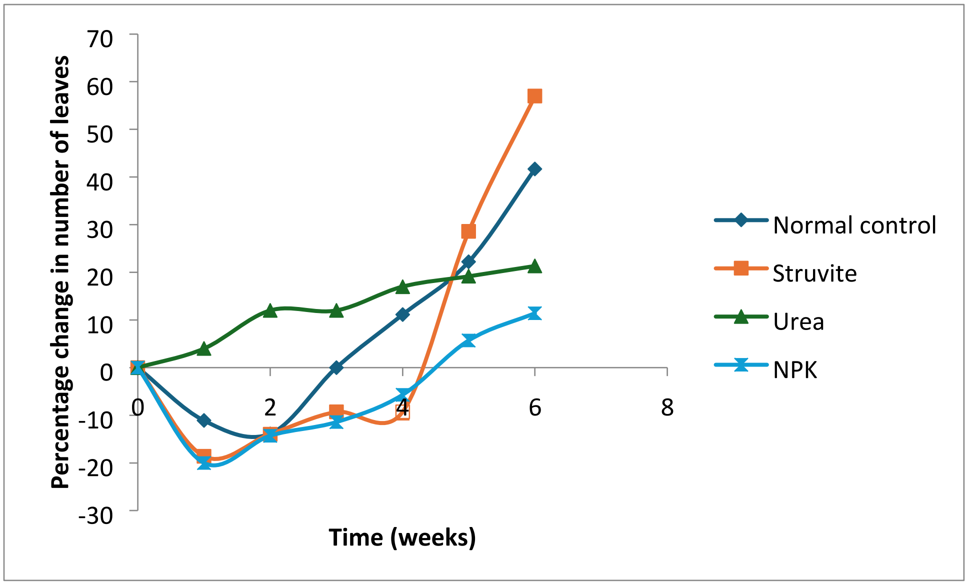


Figure 4.3.1: Scatter plot showing percentage change in number of leaves

From the results above, the struvite group had the highest percentage increase in number of leaves when compared with the rest of the groups (56.98%). There was no significant increase in number of leaves in the urea and NPK groups. This increase in number of leaves means that the struvite encouraged more leaf formation more than the other manure types.

Effect of Fertilizer Treatments on Leaf Area

Table 1.4 Table showing average final leaf area of the various groups

Groups	Final leaf area (cm^2)
Normal control	27.74±1.90
Struvite	22.89±1.56
Urea	32.68±2.70
NPK	27.90±1.74

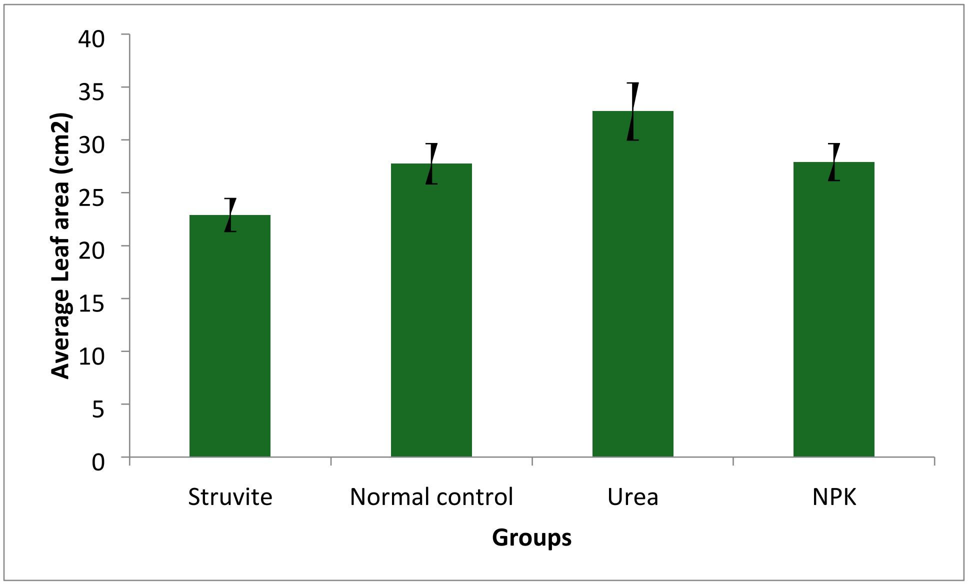


Figure 1.4: Bar chart showing average final leaf area of the various groups

The struvite group had the least final leaf area while the urea group had the largest leaf area. Excessive/abundant nitrogen/nitrate is known to promote plant height but causes reduction in leaf area. This could be the case with the struvite group.

Effect of the Fertilizer Treatments on Stem Girth

Table 1.5: Table showing average final stem girth

Groups	Stem girth (cm)
Normal control	2.23±0.10
Struvite	2.43±0.12
Urea	2.18±0.19
NPK	2.23±0.16

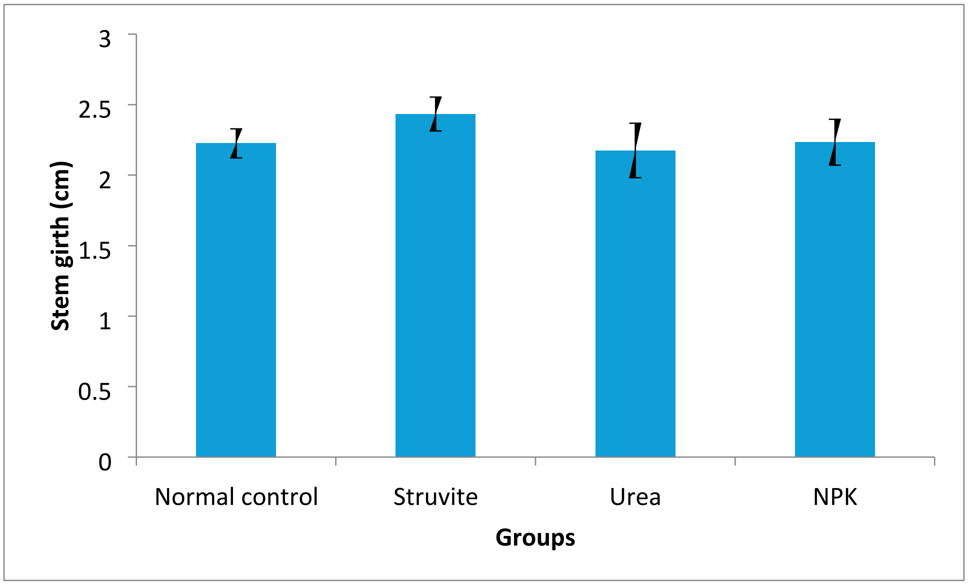


Figure 1.5: Bar chart showing average final stem girth

From the results, the struvite group had the largest average stem girth when compared to the rest of the groups, though this wasn't significantly different from the rest of the groups ($p>0.05$). This could also be attributed to its nutrient composition that supports more of plant growth and leaf formation.

Effect of the Fertilizer Treatments on Chlorophyll Content

Table 1.6: Table showing average chlorophyll composition of the various treatment groups

Groups	Chlorophyll A (mg/g)	Chlorophyll B (mg/g)	Total chlorophyll (mg/g)
Normal control	0.81±0.06	0.37±0.15	66.59±5.13
Struvite	0.84±0.13	2.21±0.79	69.15±10.65
Urea	1.07±0.11	1.40±0.12	87.74±9.02
NPK	0.93±0.12	1.19±0.17	76.18±9.85

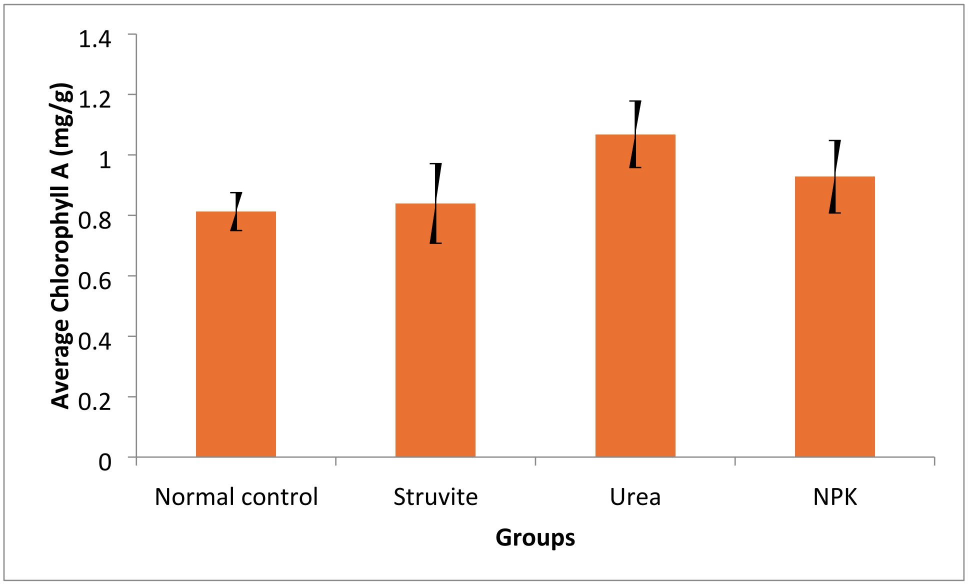


Figure 1.6.1: Bar chart showing average chlorophyll A composition

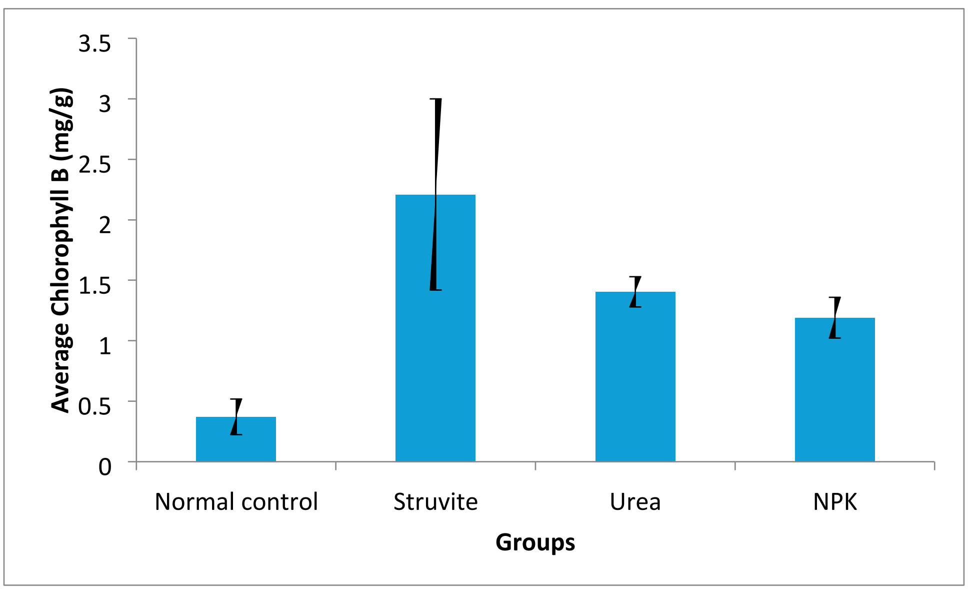


Figure 1.6.2: Bar chart showing average chlorophyll B composition

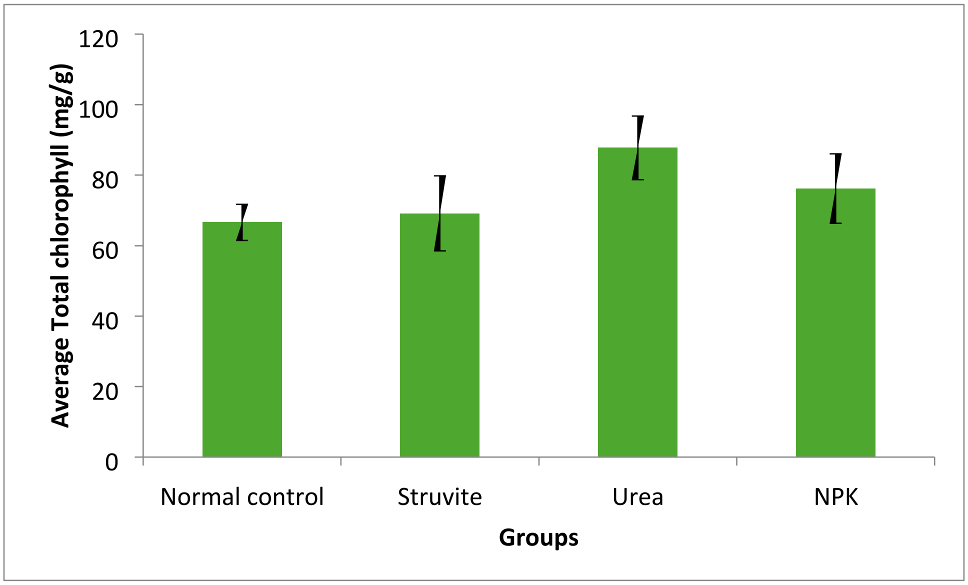


Figure 1.6.3: Bar chart showing average total chlorophyll

The normal control group had the least chlorophyll A, B and total chlorophyll levels, thus the importance of additional nutrients to the soil to enhance light harvest. The struvite group had a higher chlorophyll B concentration. This means that the use of struvite manure can directly increase photosynthetic capacity since chlorophyll b is the major captor of light energy transferring it to chlorophyll a, the primary pigment involved in the conversion of light energy into chemical energy. The urea and NPK though had higher total chlorophyll levels; these weren't significantly different from that of the rest of the groups ($p>0.05$). (Refer to appendix for ANOVA comparing chlorophyll levels).

Effect of the Fertilizer Treatments on Vitamin C Concentration of the Leaves

Table 1.7: Table showing average vitamin C concentration of the sample leaves

Groups	Vitamin C (mg/g)
Normal control	408.75±4.59
Struvite	440.50±10.21
Urea	408.00±0.25
NPK	417.50±3.03

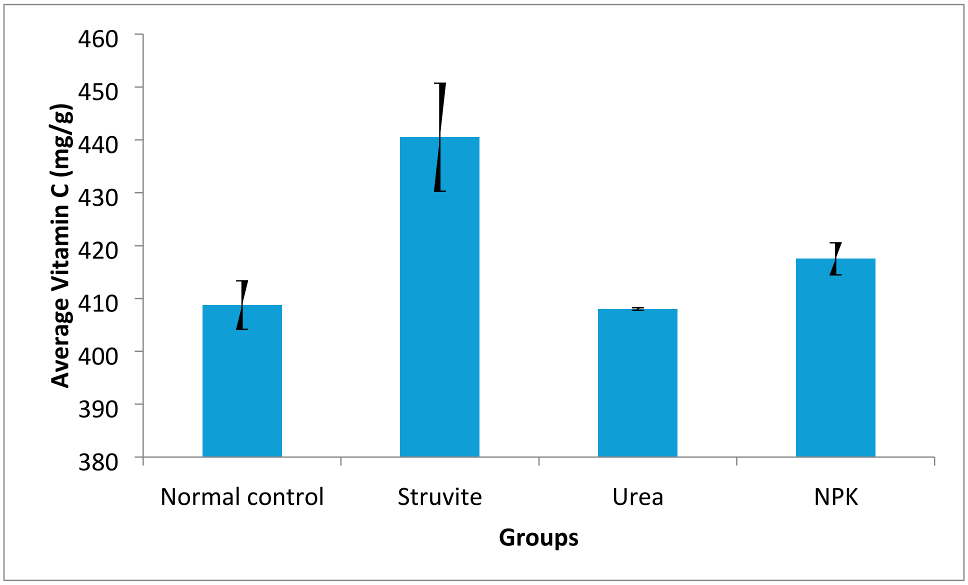


Figure 1.7: Bar chart showing average vitamin C concentration

Based on the results, the struvite group had the highest vitamin C concentration while the urea group had the least. The difference in vitamin C was significant ($p<0.05$) when the struvite group was compared with most of the groups. Vitamin C concentration in plants is also affected by phosphorus and nitrogen content of the soil, thus the concentration in the struvite group. This also means that the nutrients in struvite are more absorbable.

Effect of the Fertilizer Treatment on Minerals Content

Table 1.8: Table showing average mineral composition of the various plant samples

Groups	Mg (ppm)	K (ppm)	Fe (ppm)	Zn (ppm)	Ca (ppm)
Normal control	3.65±0.30	2.63±0.10	2.79±0.34	0.20±0.03	1.71±0.09
Struvite	2.44±0.61	5.43±2.08	1.85±0.08	0.20±0.03	2.05±0.05
Urea	3.21±0.41	2.86±0.63	1.39±0.46	0.23±0.16	1.11±0.04
NPK	3.58±0.65	2.79±0.45	1.48±0.17	0.22±0.08	1.95±0.08

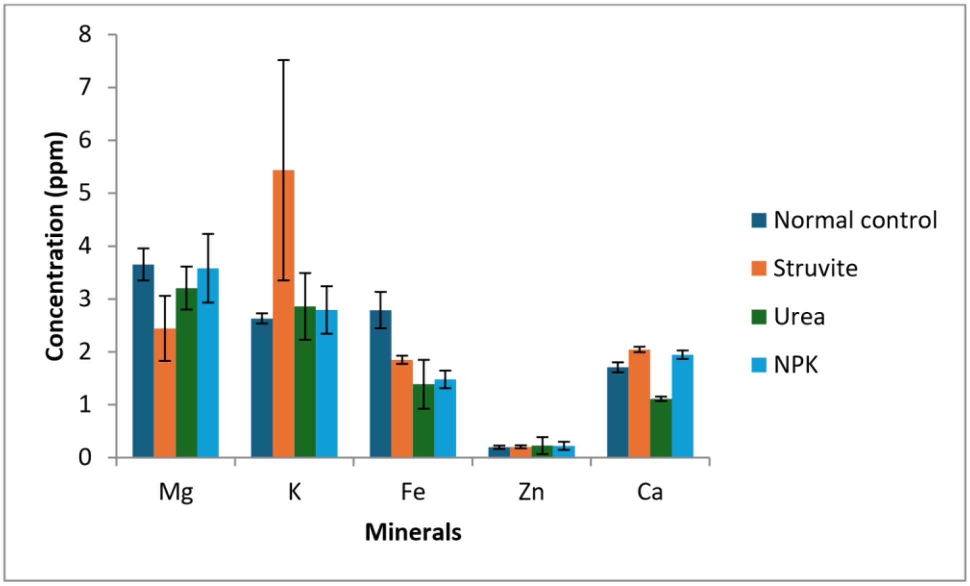


Figure 1.8: Bar chart showing mineral composition of the various plant samples

Table4.8 shows the mean results of mineral content of the various plant samples in each treatment group, there was a wide range of increase in potassium for those grown with struvite. The chart actually compared Mg, K, Fe, Zn and Ca concentration of the various plant samples. It showed there was greater concentration of potassium in plants grown with struvite. The variation of the parameters K, Mg and Zn in the fertilizer samples were not significant ($p>0.05$). However, a post hoc test was performed for Fe and Ca to check where their significance lies. (Refer to appendix for POST HOC analysis of Fe and Ca).

DISCUSSION

This study compared the effect of struvite precipitated from human urine with inorganic fertilizers on *Cucurbita maxima*. Analysis of the dry struvite recovered showed that it had averagely 9.30% of N, 15.00% P and 3.70% K contents. This research revealed the positive effects of struvite produced from urine on growth of *Cucurbita maxima* plants and finally showed to be an effective and valuable source of fertilizer. Starting from the first phase of this work, to the third stage of this research (determination of chlorophyll content, vitamin C and some mineral content of plants in the various treatment groups), it was found that struvite gave a better plant growth when compared with other treatments.

Considering the effect of fertilizer treatments on plant growth parameters, the plants (*Cucurbita maxima*) in all four treatments (including the control) grew averagely well probably because the soil used is loamy soil which is more favourable for plants growth. However, for assessment of the rate of growth, the differences among treatments in stem girth, plant height, numbers of leaves and leaf area were compared. The variation in plant height, number of leaves, leaf area and stem girth of *Cucurbita maxima* for the different treatments were shown in Figure 1.2, 1.3, 1.4 and 1.5 respectively.

i. Plant height

From the results, checking the ANOVA table where p-value (0.1755) which is greater than the significant value of 0.05 level of significance clearly showed that there was no significant difference in initial and final plant heights when the groups were compared ($p>0.05$). Also, there's no significant difference in the final plant heights. However, a T– test was performed to compare the initial and final plant heights in the various groups; which showed, there was linear increase in the plant height for the four treatment groups. That is, there's great significance difference between the initial and final plant heights considering the p(test) two-tail which are all less than 0.05 (with the normal control, struvite, urea and NPK being 1.43E-05, 0.000248, 8.51E-09 and 0.00895 respectively. The average plant height for all treatments increased with time (check Table 1.2).The highest average values of *Cucurbita maxima* heights were observed at 6 weeks of checking (week 9^{th} after planting), with urea group being the highest (24.48 ±0.5) followed by struvite group (23.78±1.08). Although, urea fertilizer has considerably high nitrogen content when analyzed; the result showed that urea group had the least percentage increase in plant height (61.57%) in comparison with struvite group (91%). This could be aligned with the findings according to Lei *et al*., (2023) which stated that struvite is a slow release fertilizer and it's nutrients readily absorbable by plants. Considering the percentage increase in plant height (From the scatter plot), it is easily noticed that initially the plants grown with struvite grew slowly from three (3) to five (5) weeks after planting in comparison with the normal control, NPK and urea group; but there was tremendous increase after five (5) weeks indicating that struvite is a slow release fertilizer and it's effect is more prolonged, other than the NPK and urea group whose impact is earlier noticeable. Also, excess nitrogen as seen in urea fertilizer could have detrimental effect on the plant. Plant growth rates are influenced by elements of phosphorus (P), nitrogen (N) and potassium (K). N element is a constituent of chlorophyll, responsible for division and enlargement of cells in the apical meristem. The activity of the apical meristem affects shoot growth, leading to increase the height of plant. **ii Number of leaves**

Cucurbita maxima planted with struvite had averagely more numbers of leaves than other fertilizer types (urea and NPK). From the ANOVA comparing the initial number of leaves in the various groups, there was significant difference among the groups and a post hoc analysis was conducted. Referring to the T-test comparing paired two samples for mean, it was discovered that there was no significant increase in the number of leaves for urea and NPK groups {with p(T<=t) two tail values of 0.180340 and 0.699696 respectively}. Looking at the scatter plot for percentage change in number of leaves, it's clear that at some point in time during the experimental period some leaves got wilted (fell off) probably based on lack of water. This could be attributed to the season (dry season) in which this research work was conducted and thus, the plants were watered as required. The leaf number is dependent on several environmental factors including nutrient levels in the soil. Therefore, low number of leaves in NPK and Urea might be due to senescence, which is also caused by the low nutrient status of the soil (Gungula *et al*., 2005).

iii. Leaf Area

ANOVA, checking for significant difference in the final leaf area showed that there was significant difference in the final leaf area among the treatment groups and a post hoc analysis was conducted to find out which pair of the groups are significant using the t test. There is great significant difference in mean 22.89466 for struvite group, compared with that of 32.68043 for urea group; with the p(T<=t) two- tail value as 0.00183. That is, urea group had the largest final leaf area (32.68±2.70) in comparison with struvite group which had the least final leaf area (22.88±1.56). Struvite has high absorbable nitrogen content which tends to enhance plant height but might cause reduction in leaf area as supported by Henrique *et al.,* (2022); which clearly stated that under no weed control, N application increased weed biomass by58%, which resulted in reductions of 57% in leaf area index. **iv. Stem girth**

Cucurbita maxima planted with struvite were not significantly different (p<0.05) in stem girth (width) when compared with normal control, urea and NPK. However struvite gave the highest average stem girth of 2.43±0.12cm, compared with those of normal control, urea and NPK groups, which are 2.23±0.10, 2.18±0.19 and 2.23±0.16 respectively. Struvite is said to have more absorbable Nitrogen (N) and according to Omar *et al*., (2019), the application of N fertilizers resulted in thicker stems as compared to control plants. This finding agrees with the report that stem circumference for struvite treated plant had the highest value.

v Chlorophyll

The use of fertilizer had significant effect on accumulation of total chlorophyll content. The interaction between these treatments showed significant effect on it. There was no significant difference on total chlorophyll content and chlorophyll A content among the treatment groups. Total average chlorophyll content indicated that normal control has the least value; while the highest average total chlorophyll content was generated by those planted with urea fertilizer. However, analysis of chlorophyll B composition showed that there was significant difference among the groups as also revealed by a post hoc analysis. Magnesium is known to be an essential element of chlorophyll, which is responsible for the green coloration of plant, this probably indicated why the group planted with urea fertilizer (analysed here, to have reasonably high magnesium content), which also had a total chlorophyll (mg/g) 87.74±9.02; being the highest when compared with other treatments. Supporting that chlorophyll content increased with the application of organic fertilizer, total chlorophyll content increased by increasing dosage of inorganic fertilizer that was supplemented with organic fertilizer and manure responsible for chlorophyll biosynthesis which significantly improved the nutrient absorption, so that chlorophyll biosynthesis was optimized (Wang, 2010). A high amount of chlorophyll is needed to maintain photosynthetic pigments, and synthesize the enzymes that take part leading to increased yield and growth of plants (Wang, 2010). Chlorophyll biosynthesis are influenced by light, carbohydrate, temperature, genetic and nitrogen availability. N element contributes to high growth and production of plant leaves. Availability of N is sufficient to increase chlorophyll biosynthesis, leaf organ formation and assimilation. Plant growth and yield are directly proportional to its nutrient supply and various fertilizer types have specific effect on the growth of plants. Also, an increase in photosynthetic pigment content shows a significant increase in plant growth parameters. These are consistent with those as reported by Mohamed *et al.*, (2023). According to Wang, (2010), organic fertilizer increases the chlorophyll level of the leaves of grown wheat and different degrees / rates changes the transpiration rate of the leaves.

i. Vitamin C

The struvite group had the highest vitamin C concentration (440.50±10.21), while the urea group had the lowest vitamin C concentration (408.00±0.25). Difference in vitamin C concentration between the struvite group and the normal group was significant ($p < 0.05$). It is known that vitamin C concentrations in plants are affected by soil phosphorus and nitrogen levels. The nutrients in struvite (organic fertilizer) are absorbed more easily, and according to Cintya *et al.,* (2018), the effect of organic fertilizer increases the nitrate, nitrite and vitamin C concentration of plants. Nitrogenous fertilizers generally stimulate plant growth. It is said that application of 20 ml/L liquid organic fertilizer can increase crop yield by 83% and vitamin C release by 66%; according to Mozafar, (1996). Excessive use of nitrogenous fertilizers is known to increase NO_3 content and decrease vitamin C content in fruits and vegetables, and this may also be the case with the those grown with urea fertilizer. (See Figure 1.7, which shows the average vitamin C concentration of leaf samples). Poonam and Lalit (2020) also researched and confirmed this. Nitrogenous fertilizers, especially at high concentrations, appear to reduce the concentration of vitamin C in many fruits and vegetables, such as potatoes, tomatoes and citrus fruits, which have been the main source of vitamin C in the diet for many societies. Using these fertilizers will have a negative effect, since excessive nitrogenous fertilizers leads to an increase in the concentration of NO_3 in the plant food, while also reducing the concentration of ascorbic acid, a known inhibitor of the nitrite-forming carcinogen. Vitamin C and various carotenoids have antioxidant properties and have been reported to lower the risk of heart disease and some types of cancer. This study showed that vitamin C increases with organic fertilizers (struvite) and decrease with inorganic fertilizers.

ii. Minerals

Struvite fertilizer treatment caused increase in the potassium and calcium contents of *Cucurbita maxima* leaves. However, other fertilizer treatments led to significant reduction ($P < 0.05$) in the calcium content of *Cucurbita maxima* leaves. Although fertilizer treatment generally caused increased concentration of zinc, such increase was not significant. Increase in potassium (K), Iron (Fe) and Calcium (Ca) for those fertilized with struvite (organic fertilizer), may be attributed to an increase in the activity of microbes, which tends to increase the uptake and availability of nutrients, as described by Alzain, (2023).Improving soil physical activity and microbial activity is facilitated by using additional nutrients from organic materials. Organic fertilizers increase the mineral content of plants compared to non-organic fertilizers and also improves the utilization of macro and micronutrients compared to inorganic fertilizers (Alzain, 2023).

The growth and productivity of plants are noticeable in sufficiency of nutrients. Results of this work showed that various fertilizer types have different effects on plant growth. Organic fertilizers can improve soil chemical and physical properties, enhance the absorption of nutrients by the plant, increase the nutrient content, and promote the growth and development of seeds (Xiao, 2018); which means there is a high relationship between fertilizer type used and the growth rate of a plant. The use of NPK fertilizers may cause negative effects on soil health, chemical, physical and biological properties of the soil. The negative effects of chemical fertilizers, combined with increasing costs, led to increased interest in organic fertilizers usage as a nutrient source. Organic fertilizers gradually create a good growing environment, while inorganic fertilizers provide nutrients instantly. Organic fertilizers increase the metabolic rate in plants, increase the energy of metabolites from the roots to the leaves, and can increase the mineral content of the plant. It improves the physical condition of the soil and lowers the pH, enhancing the soil nutrients availability for cultivation and promoting plants growth (Alzamel, 2022).

CONCLUSION

Urine is a known waste, but it contains nutrients that are essential in agriculture yet problematic in excess, in aquatic environments. Unlike most inorganic fertilizers, which require limited resources, urine is available from many sources. Separating and processing urine can recover nitrogen, phosphorus and potassium as useful products, thus reducing environmental impact and helping to meet the needs of the fertilizer industry. The separation and treatment of urine is an appreciable process for fertilizer production. Urine contains different plant nutrients like nitrogen (N), phosphorus (P), sulphur (S), potassium (K), chloride (Cl^-), and magnesium (Mg^{2+}). In agriculture, N, P, and K (also referred to as NPK) are key nutrients and are needed for plant nutrition and optimum growth. The production of NPK fertilizers involves mining (from the ground), transporting, and processing of location-specific raw materials, which requires water, energy, and other finite resources.

The treatment of urine has been proposed as an alternative approach to fertilizer production as struvite (explained in the first chapter of this work). Struvite ($MgNH_4PO_4 \cdot 6H_2O$) precipitation has gained attention because it is an effective source as fertilizer. By addition of a magnesium source 95% of Phosphorus may be obtained in the form of an odourless, easily transportable slow release fertilizer.

Fertile soil is important for crop production, as it help increase crop yields. Struviteis known to enhance soil organic matters. Soil organic matters improve soil structure and increased the availability of nutrients. Organic matter also contributes to crop growth and yield directly by supplying nutrients and indirectly by modifying soil physical properties such as stability of aggregates and porosity that can improve the root growth and stimulate plant growth. Generally, the application of struvite fertilizer showed significant effect on the height, leaf production, stem girth and vitamin C concentration of *Cucurbita maxima*. The plants responded well with the application of struvite manure. Thus, its application is adequate for maximum performance and growth of plants.

RECOMMENDATIONS

Based on the findings from this research on comparative effects of struvite and inorganic fertilizers on growth parameters of *Cucurbita maxima* (Ugbogulu/ anyu), the following recommendations were made:

i. Struvite is a slow-release valuable fertilizer that can be used in agriculture. Therefore, the commercial production of struvite should be encouraged as a great alternative for inorganic fertilizer especially now that urine, itself is been considered as fertilizer. It’s usage in agriculture should be employed on a larger scale to increase plant yield, hence improving food security.

ii. This research recommends that community sensitization should be undertaken to equip all households with knowledge and skills on human urine usage to break ignorance, social norms and taboos. We should also carry-out capacity building to the identified community members for continuous promotion of values and uses of human urine among the households, establish demonstration gardens in both urban and rural areas to offer learning and usability of human urine fertilizer.

iii. Precipitation of struvite from urine has indirectly improve environmental sanitation, as people are encouraged to use the toilet properly. Since urine separating systems are being used in Sweden (Höglund, 2001), it is also recommended that such source separating toilet be used here in Nigeria; however, regulatory guidelines may be employed as endorsement on how to use source separated urine in agriculture in order to minimize the risks for transmission of diseases and improvement in the sanitation systems of our country. Below are pictures showing source separating toilets:

Figure 1.9: source separating toilets:

iv. Also considering the negative economic implication in sourcing inorganic fertilizer and the adverse effect on the environment, struvite fertilizer along side other organic fertilizers obtained from other sources are recommended for crop production. Struvite, as fertilizer is highly recommended as there is potentially a threat to the future supply and cost of phosphate inorganic fertilizer which has increased tremendously.

v. It is well known that chemicals and most inorganic fertilizers used in agriculture leads to increased environmental pollution and some diseases. This challenge can be handled by the use of organic fertilizer, just as struvite fertilizers which are also desired to be effective and most importantly reliable.

vi. This current work has shown that struvite can potentially be used in soils and can be comparable to commercial fertilizers. However, more research should be conducted so as to understand fully the effect of struvite through field experiments with a variety of crops, so as to understand fully the potential, limitations and any possible drawbacks from using struvite.The study also encouraged that fertilizer applications should be provided based on plant need and suggest that more experiment should be done on higher rates and lower rates of struvite fertilizer usage by the crop.

REFERENCES

Alzain, M. N., Loutfy, N. and Aboelkassem, A. (2023). Effects of different kinds of fertilizers on the vegetative growth, antioxidativedefensesystem and mineral properties of sunflower plants. *Sustainability*,**15**(13):10 - 72.

Alzamel, N.M., Eman-Taha, M.M.E., Bakr, A.A. and Loutfy, N. (2022). Effect of organic and inorganic fertilizers on soil properties, growth yield, and physiochemical properties of sunflower seeds and oils. *Sustainability,* **14**:12 – 28.

American Public Health Association (APHA) (1995). Standard methods for the examination of food, water and waste water (19th edition). Byrd press, Springfield, Washington.

Arnon, D. I. (1949). Copper Enzymes in Isolated Chloroplasts. Polyphenol oxidase in *Beta vulgaris. Plant Physiology,***24**: 1-15.

Association of Official Analytical Chemist (AOAC). (1999). Association of Analytical Chemistry. Methods for Proximate Analysis. Pp 2318-2391.

Association of Official Analytical Chemist (AOAC). (2005). Official methods of analysis (18th edition), Washington D.C. *Journal of Nutrition*, **18**: 1147-1161.

Ayla, U., Sinan, D., Emine, S., Figen, E. and Zeliha, K. (2013). Optimization of struvitefertilizer formation from baker's yeastwastewater: Growth and nutrition of maize and tomato plants. *Environmental Science and Pollution Research* **21**(5): 3264-3274 ISSN 0944-1344.

Bhuiyan, M. I. H., Mavinic, D. S. and Koch, F. A. (2008). Phosphorus recovery from wastewater through struviteformation in fluidized bed reactors: A sustainable approach. *Water Sci Technol.*,**57**(2):175-81. doi: 10.2166/wst.2008.002.

Bouropoulos,N. and Koutsoukos, P. (2000). Spontaneous precipitation of struvite from aqueous solutions. *Journal of Crystal Growth,***213.**

Cintya, H., Silalahi, J., Putra, E. D. L. and Siburian, R. (2018). The influence of fertilizer on nitrate, nitrite and vitamin C contents in vegetables. *Orient J. Chem.*, **34**(5). http://www.orientjchem.org/?p=49887

Etter, B. (2009). Process optimization of low-cost struviterecovery. M. Sc. thesis EPFL, Lausanne, Switzerland.http://www.eawag.ch/organisation/abteilungen/sandec/publikationen/stun (09/30/2009).

Gantenbein, B. and Khadja, R. (2009). Struviterecovery from urine at community scale in Nepal (STUN) – Final project report phase 1, Kathmandu, Nepal..

Gungula, D.T., Togun, A.O. and Kling, J.G. (2005). The influence of N rates on Maize Leaf Number and Senescence in Nigeria. *World Journal of Agricultural Sciences*, **1**(1): 01-05.

Henrique, R. R., Francielli, O., João, O. A. and Pedro, J. C. (2023). Broadcast nitrogen application can negatively affect maize leaf area index and grain yield components under weed competition. *Farming System*, **1**(3): ISSN 2949 9119,https://www.sciencedirect.com/science/article/pii/S2949911923000497.

Henryk, M., (2003). Wet digestion methods: Article in Comprehensive Analytical Chemistry. DO:101016/S0166526X (03)410064https://wwwresearchgatenet/publication/241067291.

Höglund, C. (2001). Evaluation of microbial health risks associated with the reuse of Sourceseparated human urine, a doctoral thesis, Royal Institute of Technology (KTH) Department of Biotechnology and Applied Microbiology Swedish Institute for Infectious Disease Control (SMI), Department of Water and Environmental Microbiology, Stockholm.

Joanne, R. T., Martin, H. E., Kimberley, D. S., Francis Z. and Henry, F. W. (2021). Response of organic grain and forage crops to struvite application in an alkaline soil. *Agronomy Journal*, **114**(1):795-810.

Klein, B.P. and Perry, A.K. (1982). Ascorbic acid and Vitamin A activity in selected vegetables from different geographical areas of the United Sates. *Journal of Food Science*, **47**: 941-945.

Lei, W., Chengsong, Y., Bing, G., Xiaojun, W., Yaying, L., Kai, D., Hu, L., Kexin, R., Shaohua, C., Wei, W. and Xin, Y. (2023). Applying struvite as a N-fertilizer to mitigate N_2O emissions in agriculture: Feasibility and mechanism. *Journal of Environmental Management*,**330**: 117 – 143.

Maurer, M., Pronk, W. and Larsen, T. A. (2006). Treatment processes for source-separated urine. *Water Research*, **40**(17): 3151–3166.

Mohamed, A.S., Mohamed, M.H.M., Halawa, S.S. and Saleh, S.A. (2023). Partial exchange of mineral N fertilizer for common bean plants by organic N fertilizer in the presence of salicylic acid as foliar application. Published in GesundePflanz. *2023* and *Agricultural and Food Sciences*doi:10.1007/s10343-023-00834-3Corpus ID: 256855779.

Mozafar, A. (1996). Decreasing the NO_3 and increasing the vitamin C contents in spinach by a nitrogen deprivation method. *Plant Foods Hum.Nutr.,* **49**(2):155-162.

Oloyede, F.M., Obisesan, I.O., Agbaje, G.O. and Obuotor, E.M. (2012). Effect of NPK Fertilizer on Chemical Composition of Pumpkin (Cucurbita pepo Linn.) Seeds. *The Scientific World Journal,* Article ID 808196.

Omar, M., Stanislav, M. and Aquiles, D. (2019). Effect of nitrogen and potassium on plant height and stem diameter of *Jatropha curcas L.* in Colombian tropical dry forest. *AgronomíaColombiana*, **37**(3): 203-212.

Orluchukwu, J. A. and Amadi, C. (2022). Effect of organic and inorganic fertilizers on the growth and yield of cucumber (*Cucumissativa L.)* In South-South Nigeria. International *Journal of Agricultural Policy and Research*,**10**(2): 31-37.

Ostara Nutrient Recovery Technologies Inc. (2010): Creating Value from Waste. Ostara, Vancouver BC, Canada. http://www.ostara.com/commercial-installations (07/07/2010).

Poonam, B. and Lalit, B. (2020). Effects of different fertilizers on yield and vitamin C content of cauliflower (*Brassica oleracea* var. Botrytis)‒A Review. *Asian Journal of Agricultural and Horticultural Research,* **6**(4):37-46

Rahaman, M.S., Ellis, N. and Mavinic, D.S. (2008). Effects of various process parameters on struviteprecipitation kinetics and subsequent determination of rate constants. *Water Sci. Tech.,***57**(5):647-654.

Wang, J.L. (2010). The effect on long-term fertilization to chlorophyll content of winter wheat (*Triticumaestivum*) and summer corn (*Zea mays*). *Chin. Agric. Sci. Bull*., **26**, 182–184.

Xiao, Q., Wang, Q.Q., Wu, L., Cai, A.D., Wang, C.J., Zhang, W.J. and Xu, M.G. (2018) Fertilization impacts on soil microbial communities and enzyme activities across China’s croplands: A meta-analysis. *Plant Nutr. Fertil. Sci.,***24**: 1598–1609.