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THE USE OF STRUVITE IN AGRICULTURE FOR FOOD SUSTAINABILITY AND CREATION OF CLEAN ENVIRONMENT.

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Abstract: This research was conducted as a result of the need to produce more food for the growing population, to create a clean environment by channelling urine properly and for job creation. In this study, the effects of struvite (fertilizer obtained from human urine) and inorganic fertilizers (NPK 20:10:10 and urea) were compared on the growth of *Cucurbita maxima* (ugbogulu/ anyu). Four treatment groups, which included: control (no application), NPK 20:10:10, urea fertilizer and struvite group were successfully employed. Data on plant growth parameters collected were: plant height, number of leaves, leaf area and stem girth of the plants. Chlorophyll content, vitamin C content and mineral content were also determined according to the method of Arnon, (1949), Klein & Perry, (1982) and APHA, (1995) respectively. The results showed that plants grown with struvite had a higher percentage change in plant height (91%) and the average plant height 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). The struvite group had the highest average final stem girth (2.43±0.12) when compared with other groups. 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 as a cheap source of fertilizer for promoting plant growth and making sanitation systems economically more attractive.

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

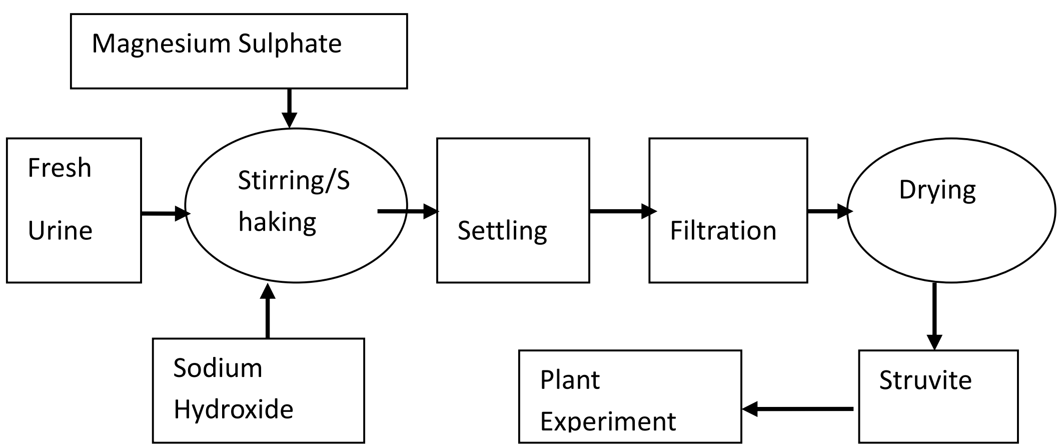
Introduction

Fertilizers are used to introduce or replenish nutrients required for plants growth and development. They are mostly classified as organic or inorganic. In recent years, the rapid increase in the population has led to large scale use of agricultural products from fertilizers; especially the synthetic / inorganic fertilizers which has a lot of drawbacks and negative consequences. For instance, inorganic fertilizers are very expensive in comparison with organic fertilizers. Most inorganic fertilizers are often produced or extracted from petroleum products and the process of production has a negative impact on the environment. Inorganic fertilizers do not increase the organic content of the soil and are easily overused, thereby damaging plants. Their use makes soil more acidic, hence needing pH adjustment. When inorganic fertilizers are used, nutrients in the soil can easily be depleted. Some literature points out the presence of heavy metals in plants grown with inorganic fertilizers. According to Lyndon (2023), artificial fertilizer application significantly impacts climate change by contributing to greenhouse gas emissions, particularly nitrous oxide (N_2O) and disrupting soil health leading to reduced carbon sequestration.

The growing population requires more use of fertilizers. Due to the problems listed above, it is necessary to design a system which will make it possible to produce fertilizer from human urine (struvite) in large scale / commercial quantity. Struvite 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.

Struvite (recycled urine products) used as fertilizer, are generally safe and have low environmental impact. Additionally, the use of struvite fertilizers is less corrosive and served as means for conservation of natural resources and reducing water pollution. Thus, it is important to compare the plant growth benefits of struvite with commercial inorganic fertilizers.

Work Design



Sixteen (16) sack bags of loamy soil was collected. The experiment was performed with four treatments groups which was replicated four times. The experimental treatments were: control (no fertilizer application), NPK 20:10:10 (indicating the ratio of nitrogen to phosphorus to potassium) urea fertilizer and struvite (from human urine). 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 were three broad stages of this work.

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

Urine collection and Struvite Recovery: This was done according to the method described by Ayla *et al*., (2013). Urine was collected and stored in jerry cans.

To every litter of the collected urine 3.2grams of Magnesium sulphate was added.

Step by Step Procedure:

I. Collection of urine: Urine was collected in an airtight container

II. Mixing with Magnesium Source: 2.3grams of Magnesium Sulphate was mixed together with 1litre of the fresh urine.

III. Adjusting the pH: pH of the collected urine was measured using a pH meter. {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 reacted 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: Plate showing Struvite, recovered from human urine

Image source: Self photograph

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

1. Nitrogen (N) Determination

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 and Calculated as: Nitrogen (%) =

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

2. Determination of Phosphorus Content

Phosphorus content of the fertilizer sample was analyzed using spectrophotometry techniques, according to AOAC (2005) and was calculated as:

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

3. 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).

Stage II: This phase involved the collection of *Cucurbita maxima* (ugbogulu / anyu) seeds, its identification, planting and growth monitoring.

Collection and Identification of Seeds

Plate 2: Plate showing the Cucurbita maxima fruit used for this research

Image source: Self photograph

Cucurbita maxima (ugbogulu / anyu) seeds were collected from its fruit (anyu) and identified by a taxonomists. The seeds were dried and ready for planting.

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

Image source: Self photograph

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.

Image source: Self photograph

Determination of *Cucurbita maxima* Growth Parameters

Growth parameters including number of leaves, leaf area, plant height and stem girth were checked at intervals. Determination of number of leaves was done through physical counting. Plant height and stem girth were checked using rope and flexible measuring tape (cm). Leaf area (LA) was calculated as ½ W × L; as described by Flávio & Marcos, (2003).

Where;
W = leaf width
L = leaf length

Stage III This included determination of:

a) Chlorophyll content.
b) Vitamin C content.
c) Mineral content.

Determination of Chlorophyll content

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

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 & Perry (1982) and 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.

Data Analysis:

Bar charts were used to show the differences in each growth parameter and tables for chlorophyll, vitamin and mineral determination. Statistical analysis of the results was done using the Analysis tool pack of Microsoft excel. Data obtained was subjected to Anova statistical analysis to compare the parameters between and within the treatment / plant groups (level of significance $\alpha = 0.05$). That is, values were taken to be significant at $p<0.05$).

Results

a. 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 in figure 1, indicated that urea has the highest concentration of nitrogen with almost absence of phosphorus. Struvite has higher concentration of phosphorus compared with NPK and urea fertilizer; but has the minimum concentration of potassium, which is termed more absorbable.

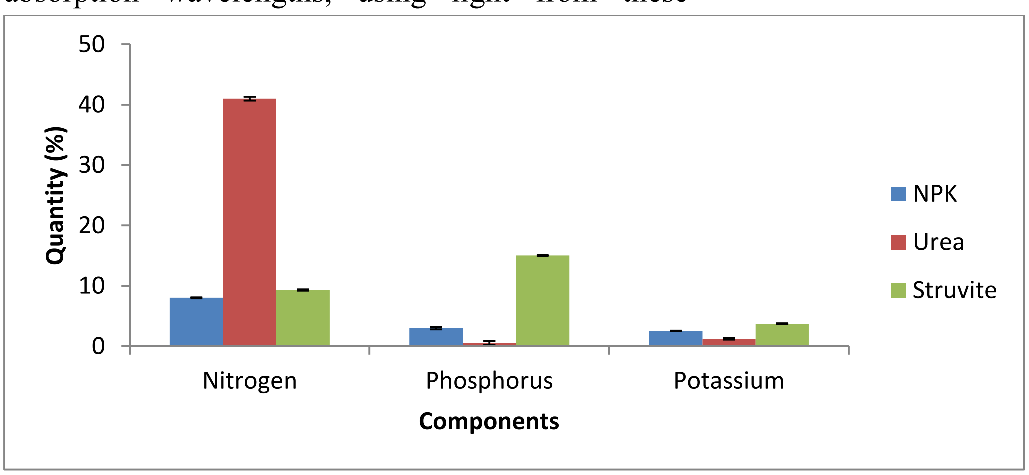


Figure 1: Bar chart Showing Nitrogen, Phosphorus and Potassium Concentration in Struvite, NPK and Urea

b. Effect of the Fertilizer Treatments on Plant Height

From figure 2a and 2b, the plants all increased in height per time. Although, urea fertilizer has considerably high nitrogen content when analyzed; the struvite group had the highest percentage increase in plant height (91.00%) while the urea group had the least (61.57%); This aligned with the findings according to Lei *et al*., (2023) which has it that struvite is a slow release fertilizer and it's nutrients readily absorbable by plants. However, there was no significant difference in initial and final plant heights when the groups were compared ($p>0.05$). 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 its effect is more prolonged, other than the NPK and urea group whose impact is earlier noticeable.

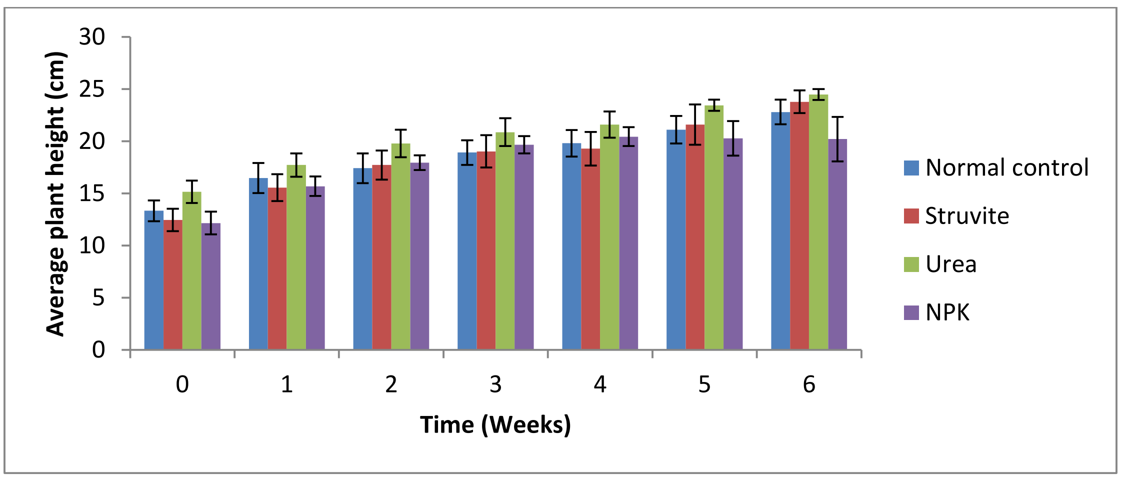


Figure 2a: Bar chart showing average plant height (cm) during the experimental period

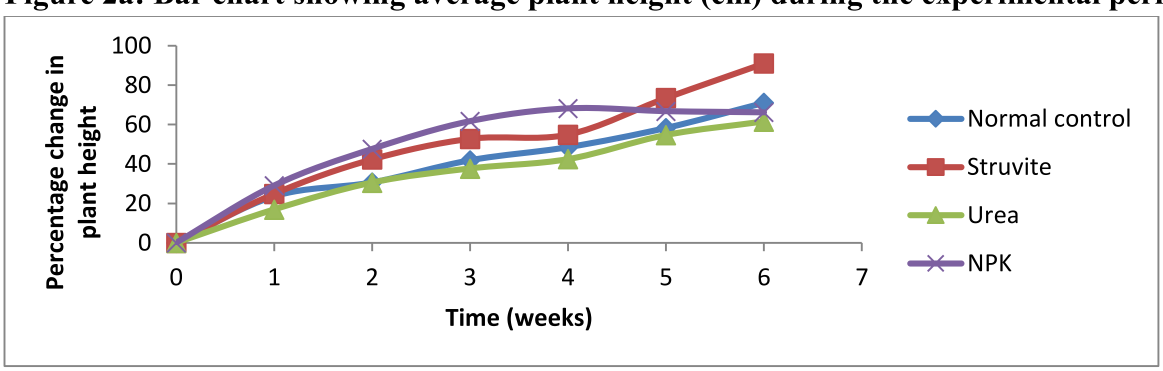


Figure 2b: Scatter plot showing percentage change in plant height

c. Effect of the Fertilizer Treatments on Number of leaves

Struvite group had the highest percentage increase in number of leaves when compared with the rest of the groups, though there was no significant difference in increase in number of leaves when compared with urea and NPK groups. Increase in number of leaves means that the struvite encouraged more leaf formation. The leaf number may be dependent on environmental factors including nutrient levels in the soil. Therefore, lower 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)..

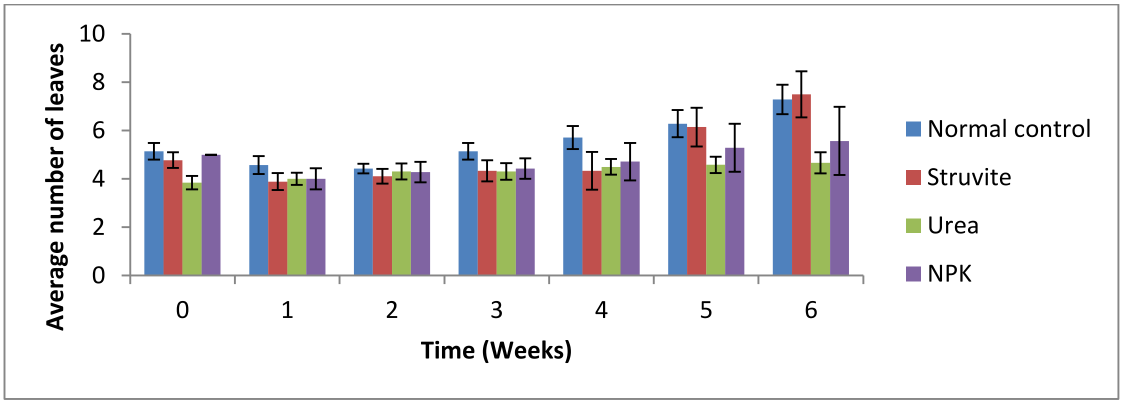


Figure 3: Bar chart showing average number of leaves

d. Effect of the Fertilizer Treatments on Leaf Area

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. 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.,* (2023); which clearly stated that under no weed control, N application increased weed biomass by 58%, which resulted in reductions of 57% in leaf area index.

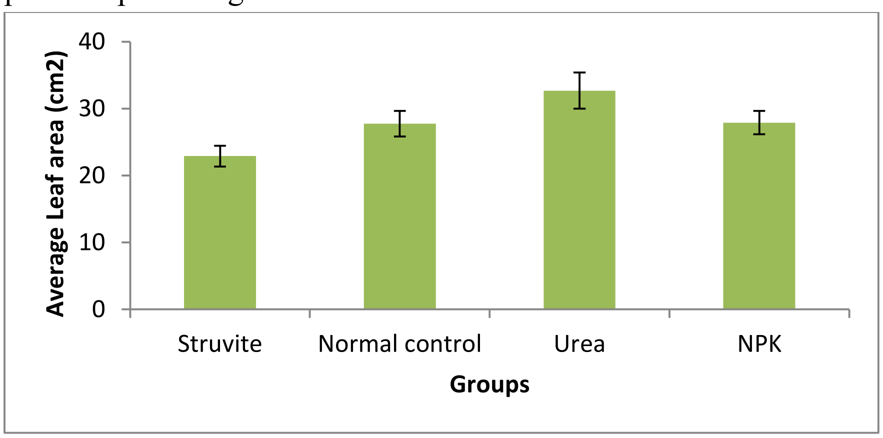


Figure 4: Bar chart showing average final leaf area of the various groups

e. Effect of the Fertilizer Treatments on Stem Girth

From figure 5, 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. 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 agree with the report that stem circumference for struvite treated plant had the highest value.

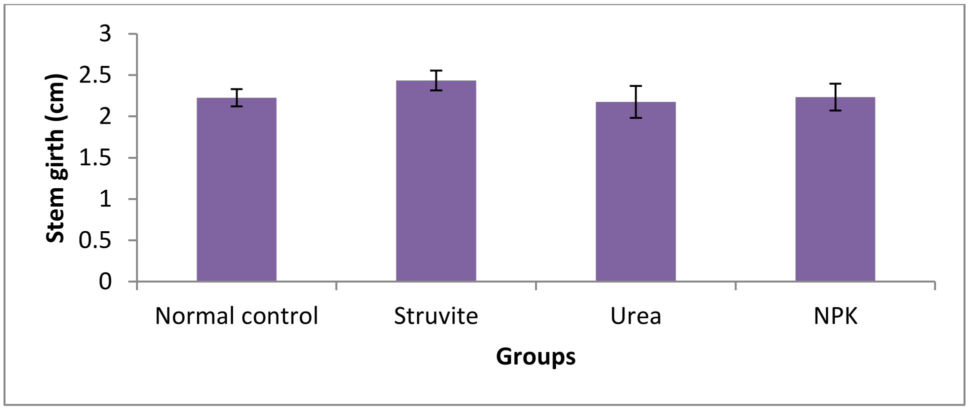


Figure 5: Bar chart indicating the effect of fertilizer treatments on stem girth

f. Effect of the Fertilizer Treatments on Chlorophyll Content

Table 1: 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

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 ($p>0.05$). 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.

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

Table 2: 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

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 the groups. Vitamin C concentration in plants is said to be 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, and according to Cintya *et al.,* (2018), the effect of organic fertilizer increases the nitrate, nitrite and vitamin C concentration of plants.

h. Effect of the Fertilizer Treatment on Minerals Content

Table 3: 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

Table 3 showed the mean results of mineral content of the various plant samples in each treatment group. The table 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 ($p>0.05$). 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). 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).

Conclusion.

This research revealed the positive effects of struvite precipitated from human urine on the growth of *Cucurbita maxima* plants, which showed to be an effective and valuable source of fertilizer, as it 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. However, for assessment of the rate of growth, the differences among treatments in terms of plant height, numbers of leaves, leaf area and stem girth, were compared as shown in Figure 2a & b, 3, 4 and 5 respectively. The application of struvite fertilizer showed significant effect on the height, leaf production, stem girth and vitamin C concentration of the *Cucurbita maxima* plants.

Struvite application helps in reducing negative environmental impact and is adequate for maximum performance and growth of plants. It is also worthy to note that the use of struvite as an organic fertilizer (trapped with magnesium source), enhances soil health and fertility, reducing the need for synthetic fertilizer whose excess nitrogen can volatilised as gases, contributing to pollution and acid rain.

Recommendations

The following recommendations were made:

i. Struvite production should be done on a larger scale and used as fertilizer to improve plant yield.

ii. This research recommends that community sensitization should be undertaken to equip all households with knowledge and skills on the use of human urine as a fertilizer, to break ignorance, social norms and taboos by learning the usability of human urine fertilizer.

iii. The study also suggested that more experiment should be done on higher rates and lower rates of struvite fertilizer application on different crops and its applications should be provided according to the plant need, hence improving food security.

iv. It is also recommended that future studies should be conducted to understand more effect of struvite e.g on soil nutrient dynamics, so as to understand fully the potential, limitations and any possible drawbacks from using struvite.

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