FACULTY OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF AGRICULTURAL MECHANIZATION AND IRRIGATION ENGINEERING.

FINAL YEAR PROJECT

EVALUATING THE INFLUENCE OF BIOGAS SLURRY ON AGRONOMIC PERFORMANCE OF TOMATOS AND SOIL FERTILITY UNDER OPEN FIELD CONDITIONS.

By

EDYANGU KOKAS

(BU/UP/2023/1063)

SUPERVISOR: MS. NABUNYA VICTO

This final year report is submitted to the Department of Agricultural Mechanization and Irrigation Engineering in partial fulfilment of the requirement for the award of the degree of Bachelor of Agricultural Mechanization and Irrigation Engineering of Busitema University.

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ABSTRACT

Tomato (Solanum lycopersicum L.) is among the most economically important horticultural crops in Uganda, contributing significantly to household income, nutrition, and food security. However, open field tomato production remains constrained by declining soil fertility and prohibitively high costs of inorganic fertilizers. This study evaluated the influence of biogas slurry (BGS) on agronomic performance of tomatoes under open field conditions at Busitema University Demonstration Farm, Busia District, Eastern Uganda. A Randomized Complete Block Design (RCBD) with four treatments biogas slurry, chemical fertilizer (NPK 17:17:17), cow dung, and an unfertilized control replicated twice was employed over 42 days. Vegetative parameters (plant height, stem diameter) and reproductive parameters (number of flowers, number of fruits per plant) were measured. Soil organic matter and organic carbon were analysed before and after treatment application using the Walkley-Black method. Data were subjected to one-way Analysis of Variance (ANOVA) in Microsoft Excel. Results indicated that while vegetative growth differences among treatments were not statistically significant ($p > 0.05$), both biogas slurry and NPK consistently outperformed cow dung and the control numerically. Reproductive parameters showed statistically significant treatment effects, with NPK recording the highest flower and fruit counts, followed closely by biogas slurry. Soil fertility analysis revealed highly significant increases in soil organic matter under organic amendment treatments, particularly cow dung and biogas slurry ($F = 129.98$, $p = 0.000193$). These findings demonstrate that biogas slurry is a viable, sustainable, and cost-effective alternative or complement to chemical fertilizers for smallholder tomato production in Uganda.

DECLARATION

I EDYANGU KOKAS declare that this work presented in the research report is mine and has never been submitted in any institution or university. I therefore take full responsibility of it and any other person mentioned here is not answerable.

Name: EDYANGU KOKAS

Reg Number: BU/UP/2023/1063

Signature :

Date: 07/06/2026

APPROVALS

This Research report is submitted to the department of Agricultural Mechanization and Irrigation Engineering with the approval from my Supervisor

Name: Ms. Nabunya Victo

Signature: 

Date: **07/06/2026**

DEDICATION:

I dedicate this report to my loving parents Mr. Ebeu Cyrus Peter and Mrs. Aganyo Grace whose prayers, affection and support are always a source of encouragement to me to reach at this destination and a humble icon for others in future. My lecturers who give me real eyes that help me to lead myself and others in the dark and the world.

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I take this opportunity to thank the Almighty God for the providence, protection and guidance he has rendered to me through my academics

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SOM………………..soil Organic matter

NPK ………………..Nitrogen, Phosphorous and Potassium

BGS ………………...Biogas slurry

CHAPTER ONE

BACKGROUND OF THE STUDY

Globally, annual production for tomatoes exceeds 180 million tonnes, making it one of the leading vegetables consumed fresh and processed into sauces, pastes, juices and canned products (*World Food and Agriculture – Statistical Yearbook 2024*, 2024a).Tomatoes play an important part in contributing significantly to food security, nutrition, and house hold incomes and agro industrial value chains across both temperate and tropical regions due to their use both as fresh vegetables and as processed products such as paste, juice, and sauces. They are rich in vitamins like vitamin C, antioxidants, and dietary fiber, making them important for human health .(Zheng et al., 2022a).

In Africa, tomato is a staple vegetable in many diets and a vital cash crop for smallholder farmers. The continent contributes about 11% of global tomato production, with Nigeria, Egypt and Morocco as the top producers (*World Food and Agriculture – Statistical Yearbook 2024*, 2024b).

However, African tomato production is still constrained by low yields compared to global averages, largely due to poor soil fertility and post-harvest handling systems resulting into high losses often exceeding 40%, undermining food security (Ddamulira et al., 2021; World Food and Agriculture - Statistical Pocketbook 2019)

In Uganda, Tomatoes are widely cultivated by smallholder farmers for both home consumption and sale in urban markets. Chemical fertilizer has been widely used to obtain the highest productivity to satisfy the need for food for a very long time, long term excessive application of chemical fertilizer causing soil degeneration has been reported in many areas resulting into soil fertility decline (Y. Sun et al., 2023) These challenges collectively undermine tomato's potential contribution to Uganda's food security and rural livelihoods. In response to soil fertility challenges, biogas slurry has emerged as a promising alternative to chemical fertilizers. Biogas slurry is the nutrient rich residue from anaerobic digestion of organic materials such as livestock manure and crop residues. It contains high concentrations of plant available nutrients including nitrogen, potassium and micronutrients as well as organic matter (Wang et al., 2023). Studies across Africa show increasing interest in utilizing biogas slurry as an affordable organic fertilizer, especially in smallholder farming systems where access to commercial fertilizers is limited (S.Yadav&Yadav, 2023)

Recent studies indicate that biogas slurry can improve plant growth, fruit yield and quality attributes such as vitamin C, lycopene and soluble solids when compared to unfertilized controls or sole chemical fertilizer application (Panuccio et al., 2021; Zheng et al., 2022b). However, much of this evidence comes from controlled greenhouse and short-term field trials, particularly in Asia and Europe. There is limited documentation on field-based research in Africa, and especially in Uganda, where tomatoes are cultivated under open field conditions exposed to fluctuating rainfall, pest and disease pressures, and diverse soils (Jin et al., 2023). Recent reviews emphasize the need for long term, open field trials that reflect real world smallholder contexts before recommending wide-scale adoption of biogas slurry in tomato production (Panuccio et al., 2021).

This study addresses that gap by evaluating the effects of biogas slurry on growth, development, yield and soil properties of tomatoes grown under open field smallholder conditions in Uganda. This research seeks to generate a well-documented evidence that bridges the gap between controlled experimental findings and smallholder realities in sub-Saharan Africa

1.2 PROBLEM STATEMENT

The declining soil fertility and high cost of chemical fertilizers represent significant constraints on tomato production in Uganda, threatening food security and rural livelihoods caused by over reliance on chemical fertilizers that degrades soil health (Y. Sun et al., 2023). Although Biogas slurry is a nutrient rich by-product of anaerobic digestion, has shown potential to improve soil fertility and crop performance in controlled studies, but its effectiveness under open field conditions in Uganda remains largely untested. The lack of field based evidence on how biogas slurry influences tomato growth and yield under real world conditions and high cost of acquiring green house facilities by small holder farmers creates a critical knowledge gap, limiting its adoption as a sustainable alternative to chemical fertilizers.

1.3 OBJECTIVE OF THE STUDY

1.3.1 MAIN OBJECTIVE

To evaluate the influence of Biogas slurry on agronomic performance of tomatoes and soil fertility under open field conditions.

1.3.2 SPECIFIC OBJECTIVES

1. To produce and characterize biogas slurry from organic wastes for field application
2. To assess the influence and effectiveness of biogas slurry, chemical fertilizer, cow dung and control experiment on growth and development of tomato plants in open field condition.
3. To assess soil fertility response to biogas slurry, chemical fertilizer, and control treatments under open field tomato production.

1.4 RESEARCH QUESTIONS

1. How can biogas slurry be produced from organic wastes like cow dung?
2. How does the application of biogas slurry compare with chemical fertilizer, cow dung and no fertilizer in influencing tomato growth parameters?
3. What are the effects of biogas slurry, chemical fertilizer, cow dung and control on soil fertility?

1.5 JUSTIFICATION OF STUDY

The study was conducted to generate scientific evidence on the suitability of biogas slurry as a sustainable fertilizer for tomato production under open-field conditions. Evaluating its effects on tomato growth, yield, and soil fertility will provide farmers with information on whether it can serve as an effective alternative. The findings of this study will contribute to improved nutrient management, enhanced soil fertility, reduced dependence on costly inorganic fertilizers, and sustainable utilization of organic waste resources, thereby promoting environmentally friendly and economically viable agricultural production systems.

1.6 SIGNIFICANCE OF STUDY

This study is significant because it addresses declining soil fertility, poor waste management by evaluating biogas slurry a nutrient rich by product of anaerobic digestion as a sustainable alternative to chemical fertilizer for tomato production under open field conditions in Busia District. The findings generated scientific evidence on its effects on tomato growth, yield and soil fertility promoting cost effective environmentally friendly and locally available fertilizer options for smallholder farmers, by linking renewable energy and organic farming. The study supports several united Nation sustainable Development Goals, including SDG 2 (Zero hunger) through improved production, SDG 12 (Responsible consumption and production) through waste recycling, and SDG 13 (climate action) by reducing greenhouse gas emissions. This research contributes to sustainable agriculture, improved livelihoods, and environmental conservation in Uganda.

1.7 SCOPE OF STUDY

1.7.1 Conceptual scope

The study focuses on evaluating the effects of biogas slurry on the growth and development of tomatoes under open field conditions. This study is only limited to agronomic, chemical and biological effects of biogas slurry as a soil amendment.

1.7.2 Geographical scope

The research will be conducted in Busia District, Eastern Uganda, specifically at Busitema

University Demonstration farm, located within Busitema University main campus

1.7.3 Time scope

The time frame is limited to eight months

CHAPTER TWO: LITERATURE REVIEW

2.1 PRODUCTION OF BIOGAS AND BIOGAS SLURRY

2.1.1 Biogas production process

Biogas is produced through anaerobic digestion, which is a biological process that decomposes organic matter such as livestock manure, crop residues and food waste in absence of oxygen (Appels et al., 2011). The process for producing biogas occurs in four stages which are; hydrolysis, acidogenesis, and methanogenesis resulting into the generation of biogas and its by product biogas slurry (Kothari et al., 2014).

The anaerobic digestion process is influenced by feedstock composition, temperature, PH and retention time (R. Yadav et al., 2023). Digesters may be batch or continuous-flow systems, and optimal temperatures typically range between 35°C (mesophilic) and 55°C (thermophilic) (Abbasi et al., 2012).

2.1.2 Biogas slurry as a Bi-product

Biogas slurry is a nutrient rich effluent composed of partially decomposed organic matter, microbial biomass, and mineralized nutrients (Feng et al., 2024a). It exists in two phases; the solid fraction which contains stabilized organic matter and liquid fraction rich in ammonium nitrogen and soluble nutrients (Möller & Müller, 2012)

Biogas slurry contains significant of macronutrients such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), as well as micronutrients like iron (Fe), manganese (Mn), and zinc (Zn) (Mdlambuzi et al., 2021) . The ammonium nitrogen form (NH_4^+N) is immediately available to plants, while the organic nitrogen fraction contributes to long-term fertility improvement.

The PH of biogas slurry is in the range of 7.2 to 8.5, and its electrical conductivity is between 1.06 to 1.12ds/m (Nagdev et al., 2024)

(H. Sun et al., 2023) emphasized that the nutrient composition and stability of BGS determine its fertilizer potential. Proper characterization involves analyzing pH, electrical conductivity, organic carbon, C:N ratio, and heavy metals to ensure safe and efficient field use (Feng et al., 2024b). A C:N ratio between 8:1 and 15:1 indicates stable, mature slurry suitable for direct land application (Karki et al., 2021).

Additionally, microbial analysis reveals that biogas slurry contains beneficial microbes, including Bacillus spp. and Pseudomonas spp, which enhance nutrient cycling and disease suppression (Feng et al., 2024b). However, improperly treated slurry may contain pathogens or phytotoxic compounds, emphasizing the importance of composting or aging before field application (Zhang et al., 2021).

2.3 Effects of Biogas Slurry on Tomato Growth and Development

2.3.1 Effects on Vegetative Growth

Application of biogas slurry enhances tomato vegetative growth by improving nutrient availability, soil structure, and microbial activity. Partial substitution of chemical fertilizers with BGS (25–50% N) has been shown to increase plant height, leaf area index, and dry matter accumulation (Tang et al., 2022)

2.3.2 Effects on Flowering and Yield

Biogas slurry application significantly affects reproductive development and fruit yield. Moderate slurry applications increase the number of flowers, fruit set percentage, and fruit size compared to control or 100% mineral fertilizer treatments (Tang et al., 2022)

2.3.3 Effects on Fruit Quality

Biogas slurry improves tomato fruit quality by enhancing sugar accumulation, lycopene content, and firmness (Zheng et al., 2025). The balanced nutrient release supports optimal physiological functions that promote fruit coloration and taste. Conversely, immature or undiluted slurry can negatively affect fruit total soluble solids due to nitrogen excess (Okba et al., 2025)

2.4 Effects on Soil Health and Environmental Sustainability

Continuous application of biogas slurry enhances soil fertility by improving organic carbon content, cation exchange capacity, and microbial biomass (Feng et al., 2024). (Zhang et al., 2021) demonstrated that combining BGS with chemical fertilizers improves soil nutrient availability and microbial enzyme activities. Additionally, when integrated with bio char, BGS reduces nitrous oxide (N_2O) emissions and nitrate leaching, enhancing the sustainability of tomato production.

However, (Keskinen et al., 2022) caution that inadequate slurry management may lead to ammonia volatilization, odour, and potential accumulation of heavy metals. Therefore, best practices such as dilution (1:3-1:5), soil incorporation, and nutrient testing before application are recommended.

2.5 Nutrient composition of biogas slurry and its comparison with NPK chemical fertilizers

Biogas slurry contains significant amounts of plant-available macronutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), although in lower and more variable concentrations than synthetic NPK fertilizers. For example, biogas slurry typically contains approximately 1.0–2.2% N, 0.9–1.2% P, and 1.0–2.2% K depending on feedstock and digestion conditions, whereas NPK fertilizers provide higher and more concentrated and standardized nutrient levels tailored for immediate crop uptake.

Unlike NPK fertilizers, which are chemically formulated with fixed nutrient ratios, biogas slurry is a heterogeneous organic fertilizer whose nutrient content varies based on raw materials, animal feedstock, and digestion processes.

2.6 The role of water in tomato growth, nutrient uptake, flowering, and fruiting

Availability of water is a key determinant of tomato physiological development, as it directly influences cell expansion, photosynthetic activity, and biomass accumulation. Adequate irrigation supports optimal vegetative growth, while both water deficit and excess water can negatively affect plant performance. Water availability strongly affects nutrient uptake, since most mineral nutrients are absorbed by plant roots through mass flow and transpiration-driven transport. Reduced soil moisture limits nutrient mobility and uptake efficiency, while appropriate irrigation enhances the availability and transport of nitrogen, potassium, and other essential nutrients to the plant. Conversely, excessive water can lead to nutrient leaching and reduced root oxygenation, thereby impairing uptake processes.

Water also plays a significant role in flowering and fruit set, where controlled irrigation improves flower initiation and uniform fruit development. Moderate water stress has been reported to influence flowering time, while adequate moisture supports successful pollination and fruit retention. During fruiting, sufficient water supply is essential for fruit enlargement, quality development, and prevention of physiological disorders such as blossom-end rot and fruit cracking.

2.7 Research Gaps

Despite extensive research, several gaps remain in understanding the field application of biogas slurry. There is limited open field trials since most studies have been conducted in controlled greenhouse environments. Particularly under diverse soil and climate conditions (Feng et al., 2024). Variability in slurry composition; the nutrient content of BGS varies widely by feedstock and process conditions, making standardized fertilizer recommendations difficult (R. Yadav et al., 2023).

Insufficient food safety assessments; limited studies have analyzed potential pathogen or heavy metal contamination risks in biogas slurry amended vegetables (Keskinen et al., 2022). Economic analysis; few researchers have evaluated the cost-benefit or labour implications of BGS use in smallholder tomato production (Tang et al., 2022).

2.8 Experimental Design Considerations

2.8.1 Randomized Complete Block Design (RCBD)

The RCBD is one of the most common experimental designs used in agricultural field experiments to control variability across heterogeneous fields (A.T. Momo et al., 2025). Each treatment is randomly assigned within each block, and every block represents a replication under similar environmental conditions.

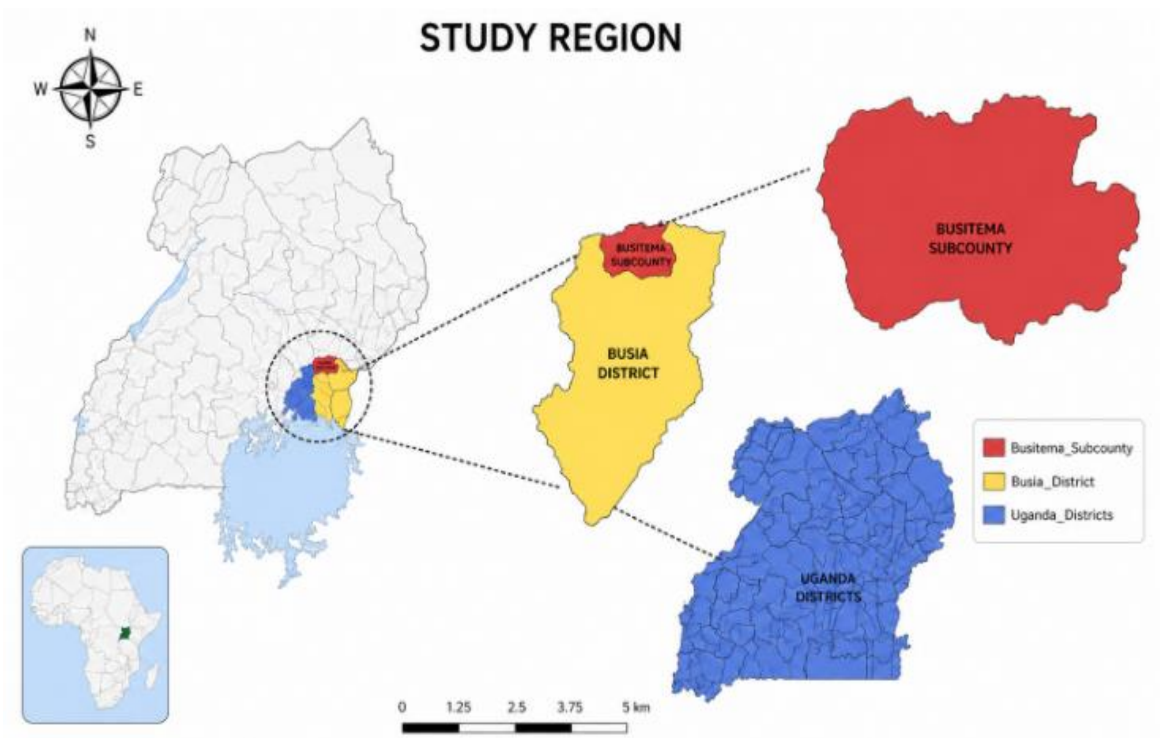
CHAPTER THREE

3.0 METHODOLOGY

This chapter basically shows the research study site location, materials and methods and procedures of experimental design and other proceeding activities.

3.1 Research site location

The project was carried out at the Busitema University research demonstration site, main campus The Area experiences a bimodal rainfall pattern with a mean annual rainfall of approximately 1514mm and average temperatures ranging from 16.2°C to 28.7°C



3.1 Conceptual framework

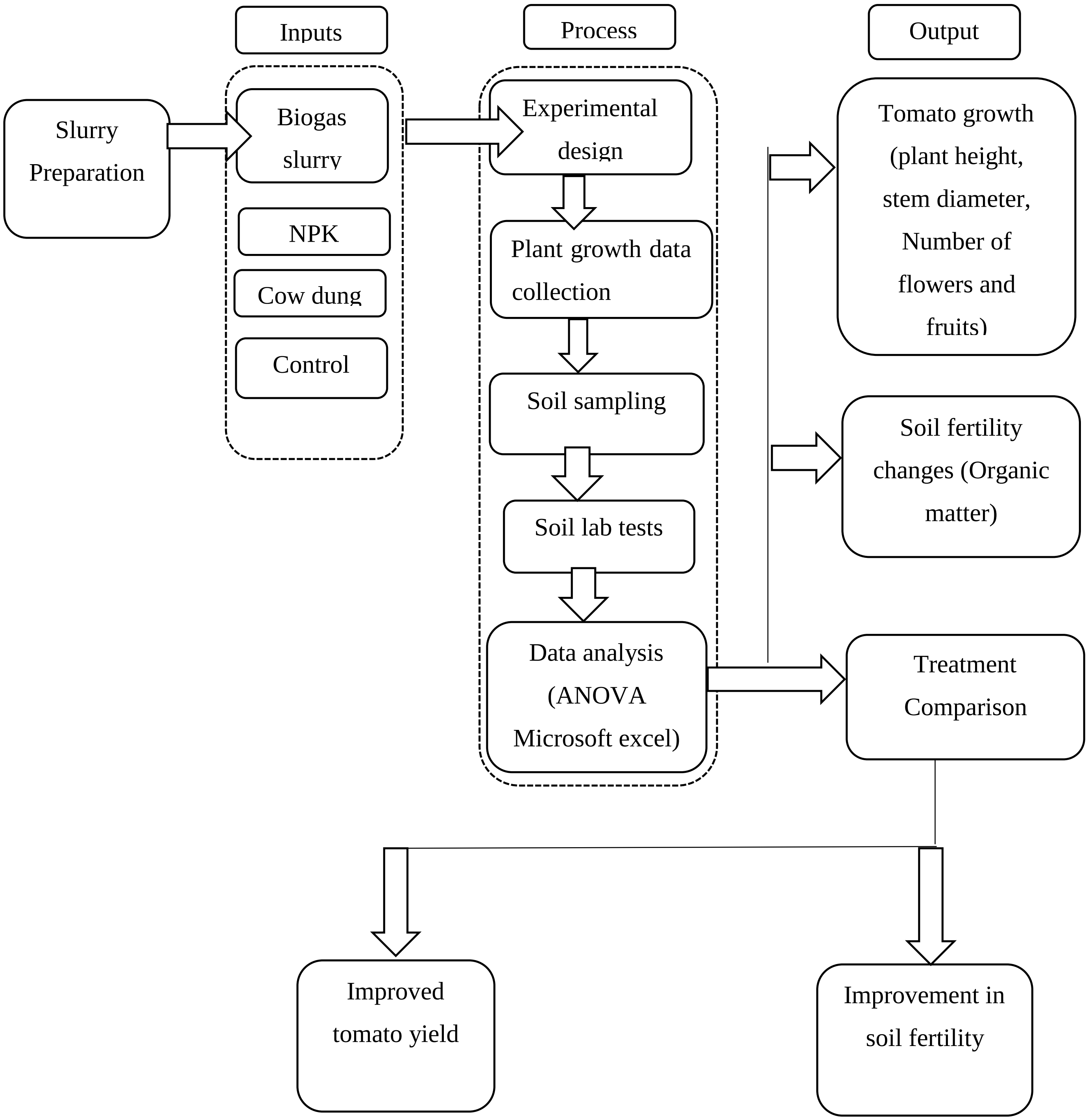


Figure 1 Showing the conceptual framework of the project

3.2 Methodology for specific objective one

3.2.1 Preparation of biogas slurry for use in evaluating its agronomic performance on tomatoes

3.2.1.1 Materials and requirements

Materials that were used during the preparation process include; Fresh cow dung (14Kg), clean water (14 litres), Digesters (2), Stirring stick.

3.2.1.2 Procedures that were taken to produce bio slurry (Jeppu et al., 2022)

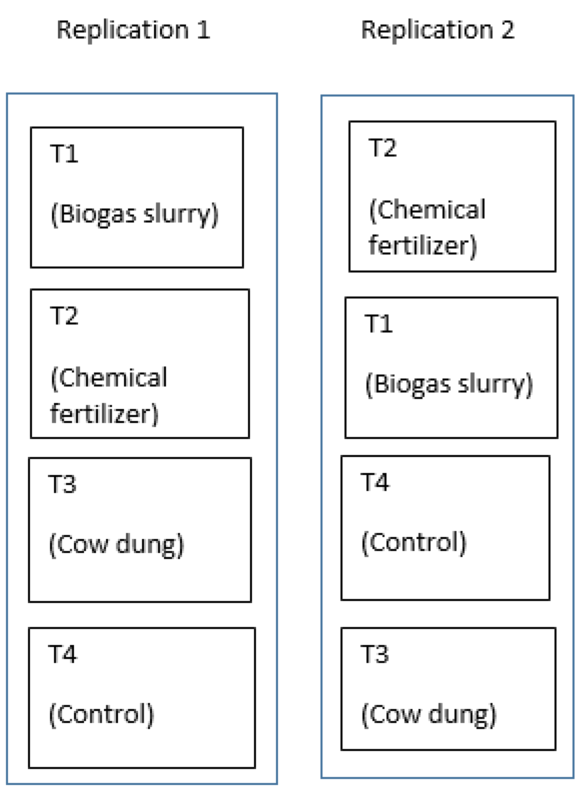
1. Fresh cow dung was collected and weighed. Seven kilograms (7kgs) of cow dung were used for each digester (2).
2. Seven litres (7L) of clean water was measured and added to the cow dung to maintain a 1:1 ratio of cow dung to water.
3. The cow dung and water were thoroughly mixed to form a homogeneous slurry.
4. The prepared mixture was poured into digesters, each containing the same mixture of 7kg cow dung plus 7 litres of water.
5. Each digester was filled to about two thirds of its capacity to allow space for gas accumulation during digestion.
6. The digesters were tightly sealed to maintain anaerobic conditions required for biogas production.
7. The digesters were placed in a warm area away from direct sunlight to maintain suitable fermentation conditions.
8. The mixture was allowed to ferment and settle for 30 days
9. During the fermentation period, the digesters were occasionally shaken gently to ensure proper mixing of contents and enhance microbial activity.
10. 28 litres of biogas slurry was obtained from the two digesters.

3.3 Methodology for specific objective 2 (assessing the influence and effectiveness of biogas slurry, chemical fertilizer, Cow dung and control experiment on growth of tomato plants in open field conditions)

3.3.1 Experimental Design

3.3.1.1 Design and layout

The experimental units were grouped into two blocks based on similar characteristics to reduce variability within each block. Within each block, all treatments were assigned to experimental units randomly. A Randomized Complete Block Design (RCBD) was employed with four treatments: (T1: Biogas slurry, T2: Chemical fertilizer (NPK), T3: Cow dung T4: Control (no fertilizer)) .Plot dimensions were made of 2m × 3 m with 0.5 m spacing between plots and 1m spacing between the blocks which was replicated two times. All plots were established within the same field to ensure uniform environmental conditions. As similarly described by studies using RCBD field layouts in fertilizer experiments(Xu et al., 2021)



3.3.3 Crop establishment and management

Tomato seedlings of a locally adapted variety (Safa F1) was raised in a nursery and transplanted after four weeks. The tomatoes were given a spacing of (75cm by 50cm), just as it was recommended by (Falodun & Emede, 2019)

3.3.3.1 Fertilizer and organic amendment application

Bio slurry; at transplanting, approximately 500 ml of diluted slurry (mixed in a 1:1 ratio with water) was applied per planting hole. Top dressing was carried out at 3 weeks after transplanting, This application approach is informed by studies showing that biogas slurry improves tomato vegetative growth and yield due to rapid nutrient mineralization and enhanced soil biological activity (Kibria et al., 2016)

Chemical fertilizer (NPK); A basal application of 10gramms of NPK was incorporated before transplanting. A second application was done as top dressing at 4 weeks after transplanting (Tesfay et al., 2019).

Cow dung; It was incorporated into the soil two week before transplanting at a rate of 1kg per planting hole as recommended by recent studies like (Gaskell et al., 2007).

Control; The control treatment received no fertilizer throughout the growing period. This treatment served as a baseline for assessing the natural fertility of the soil and for determining the net effect of biogas slurry, chemical fertilizer, and cow dung on tomato growth and yield performance under open field conditions.

Uniform agronomic practices including weeding, pest and disease control, and staking were applied across all plots.

3.3.4 Growth Data Collection

Growth parameters was measured on a weekly basis. Growth data such as plant height, stem diameter, number of flowers, and number of fruits were collected on a regular basis for 42 days, following established tomato growth monitoring procedures as described in recent studies (Arshad et al., 2024) . Data were recorded and later subjected to statistical analysis using ANOVA.

3.3.4.1 Determining the tomato plant height

The height of tomato plants were measured using a standard tape measure. Measurements were taken from the base of the stem at soil level up to the tip of the main stem.

3.3.4.2 Determining the stem diameter of the tomato plant

Stem diameter was measured using a vernier caliper to ensure precision. The caliper jaws were placed gently around the stem at a fixed position, to obtain the diameter in millimeters. Measurements were taken at a weekly basis.

3.3.4.3 Determining the number of fruits and flowers

Number of fruits and flowers per plant was determined by visual observation. Each plant was inspected carefully, and the total number of fruits was counted and recorded.

3.3.4.4 Data recording and Analysis

All measurements were recorded in a field notebook and later compiled into spreadsheets for statistical analysis.

3.3.6 Data Analysis

- All collected data were subjected to statistical analysis using Analysis of Variance (ANOVA) in Microsoft Excel.
- Treatment means was compared using appropriate post-hoc tests at a significance level of $p \leq 0.05$.
- Soil Analysis: Pre and post harvest soil samples were analyzed for organic matter to assess nutrient changes due to treatments.

- Data Analysis; Collected data was subjected to Analysis of Variance (ANOVA) using Excel.

- Results were presented in tables, graphs for clear interpretation

3.4 Methodology for specific objective 3 (To assess soil fertility response to biogas slurry, chemical fertilizer, and control treatments under open field tomato production.)

3.1.2 Soil sampling and preparation

Soil samples were collected from the experimental site using appropriate sampling techniques to ensure representativeness. Multiple cores were taken across the field and composited

The samples were then prepared as follows;

- Soil samples were air dried in a well-ventilated area to prevent chemical and biological alterations
- Dried samples were gently crashed using a motor and pestle to break aggregates
- The soil was sieved through a 2mm mesh to remove stones, roots and debris.
- A representative sub sample was obtained through coning and quartering

3.1.3 Materials and Reagents used for soil tests

Soil organic carbon was determined using the Walkley–Black wet oxidation method involving potassium dichromate and concentrated sulfuric acid digestion followed by ferrous ammonium sulfate titration. Soil samples were air-dried, crushed, and sieved through a 2 mm mesh before analysis, as described in tropical soil fertility studies (Laoufi et al., 2025)

The following materials and reagents used included;

- Air dried and sieved samples
- 1N potassium dichromate ($K_2Cr_2O_7$) solution
- Concentrated sulfuric acid (H_2SO_4)
- 0.5N ferrous ammonium sulfate (FAS)

- Diphenylamine indicator
- Distilled water
- 500ml conical flasks
- Burette, pipettes, and measuring cylinders
- Analytical balance

3.1.4 Experimental procedure

The procedure for determining soil organic matter followed standard laboratory steps consistent with the soil analysis manual;

1. A soil sample was accurately weighed into a 500ml conical flask
2. 1N potassium dichromate solution was added to the flask
3. 20ml of concentrated sulfuric acid was rapidly added, and the mixture was swirled gently to ensure thorough mixing.
4. The flask was allowed to stand for 30 minutes to allow complete oxidation of organic carbon
5. After the reaction period, the mixture was diluted with approximately 200ml of distilled water
6. A few drops of diphenylamine indicator were added to the solution
7. The excess dichromate was titrated with 0.5N ferrous ammonium sulfate until the color changed to coffee brown marking the end point
8. A blank determination was conducted using the same procedure without soil to account for reagent impurities.

3.1.5 Calculation of organic matter

The organic matter content was determined from the difference between the blank and sample titration values.

$$\%OC = \frac{T \times 0.3 \times 0.2}{weighted\ sample}$$

Equation 1Determining organic carbon content

$$\%OM = \%OC \times 1.7241$$

Equation 2 Determining organic matter content

3.4.5 Data presentation

Results are presented in tables and graphs showing the soil fertility status before and after application of treatments.

CHAPTER FOUR

4.0 DISCUSSION AND RESULTS

4.1 Results for specific objective 1: (To prepare biogas slurry for use in evaluating its agronomic performance on tomatoes)

4.1.1 Results of biogas slurry preparation

The preparation of biogas slurry was successfully achieved through anaerobic digestion of cow dung mixed with water in a ratio of 1:1 (7Kg cow dung to 7L of water) over a period of 30 days

4.1.2 Physical characteristics of biogas slurry

The physical characteristics of the biogas slurry changed noticeably during the anaerobic digestion process. Observations on color, odor, texture, physical state, gas production, foaming, and settling behavior indicated successful decomposition and stabilization of the organic materials. The slurry changed from a greenish-brown color to dark brown, suggesting progressive breakdown of organic matter. A reduction in foul smell was also observed, indicating a decrease in unstable organic compounds due to microbial digestion. The slurry became smooth and homogeneous, showing effective decomposition and mixing of the substrate materials.

Continuous gas bubble production was observed during digestion, confirming active microbial activity and biogas formation. No foaming was observed throughout the process, suggesting stable digestion conditions without excessive fermentation disturbances. In addition, the slurry did not rapidly separate into layers, indicating good stability and uniform distribution of suspended particles, which is desirable for agricultural application.

Table 1 showing the physical the physical characteristics of biogas slurry

Parameter	**Observation**	**interpretation**
Color	Greenish brown to dark brown	The darkening of color indicates decomposition and stabilization of organic materials during anaerobic digestion.
Odor	Reduced foul smell	Reduction in foul odor suggests successful digestion and reduction of unstable organic compounds.
Texture	Smooth and homogeneous	Indicates effective breakdown and uniform mixing of substrate materials
Physical state	Liquid to semi liquid	Shows that the slurry attained a consistency suitable for handling and application
Gas production	Continuous gas bubble production observed, which started after 5 to 7 days	Confirms active microbial activity and successful biogas generation
Settling behaviour	No rapid separation into layers	Suggests good slurry stability and uniform distribution of suspended particles

4.1.4 Discussion

- The results indicate that anaerobic digestion was effective in producing biogas slurry. The early production of gas within 5 to 7 days confirmed active microbial activity, which is essential for the breakdown of organic matter under anaerobic conditions.
- The observed color change from Greenish brown to dark brown signifies progressive decomposition of organic materials into more stable compounds
- The use of 1:1 ratio of cow dung to water provided adequate moisture content necessary for microbial activity. Proper moisture levels enhance the efficiency of anaerobic digestion by facilitating microbial metabolism and nutrient dissolution.
- Filling the digesters to two-thirds of their capacity proved effective in allowing space for gas accumulation, thereby preventing excessive pressure buildup.
- Maintaining airtight conditions ensured an oxygen free environment, which is critical for survival and activity of anaerobic microorganisms.
- The placement of digesters in a warm environment contributed to faster digestion, as temperature plays a significant role in microbial activity. Occasionally shaking of the digesters improved the mixing contents, enhancing contact between microorganisms and substrate.
- The 30 days retention period was sufficient to achieve a well digested slurry, which was evidenced by the uniform texture and absence of large particles. This indicates that the organic matter was adequately decomposed.

4.1.2 Results for specific objective 2 (To evaluate the growth response of tomato plants in open field conditions as influenced by biogas slurry, chemical fertilizer and on fertilizer on independent plots)

4.1.2.1 Summary of treatment means

4.1.2.1.1 Plant Height (cm)

Table 2showing mean plant height (cm) and standard deviation across the treatments

Treatment	Replication 1	Replication 2	Mean	Standard deviation
Biogas Slurry	54.70	55.20	54.95	0.25
NPK	55.30	56.05	55.68	0.375
Cow Dung	50.55	56.30	53.43	2.875
Control	48.30	52.25	50.28	1.975

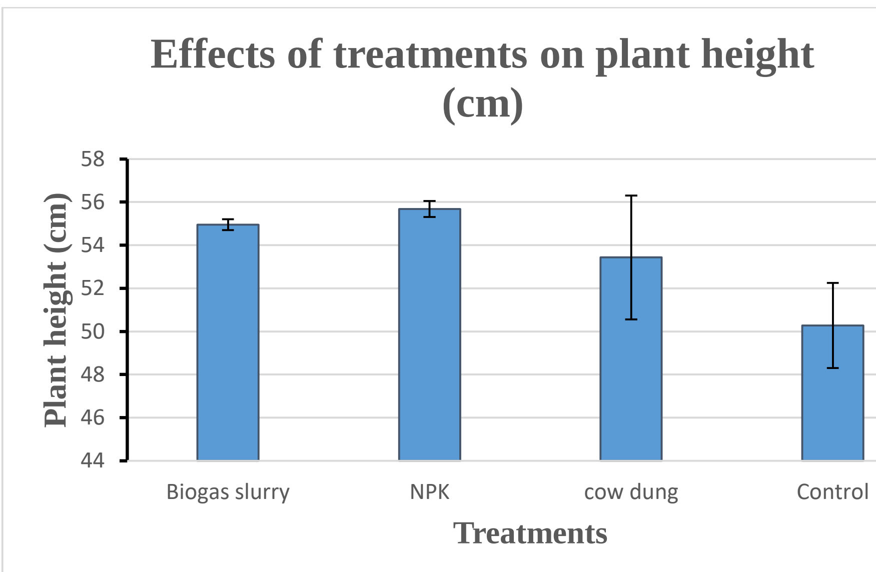


Figure 2 a graph showing mean plant height

4.1.2.1.2 Stem diameter (cm)

Table 3 showing mean stem diameter (cm) and standard deviation across the treatments

Treatment	Replication 1	Replication 2	Mean	Standard deviation
Biogas Slurry	1.05	1.05	1.05	0.000
NPK	1.13	1.07	1.10	0.042
Cow Dung	0.97	1.05	1.01	0.057
Control	1.00	0.95	0.98	0.035

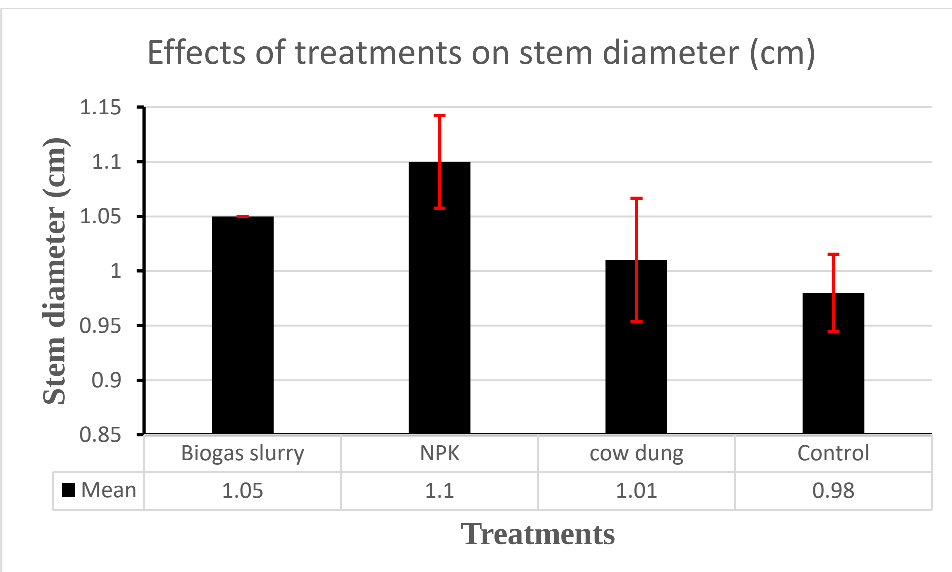


Figure 3showing mean stem diameter across the treatments

4.1.2.1.3 Number of flowers

Table 4showing mean number of flowers and standard deviation across the treatments

Treatment	Replication 1	Replication 2	Mean	Standard deviation
Biogas Slurry	9.20	9.30	9.25	0.050
NPK	11.60	10.20	10.90	0.700
Cow Dung	8.20	8.51	8.36	0.155
Control	7.80	7.30	7.55	0.250

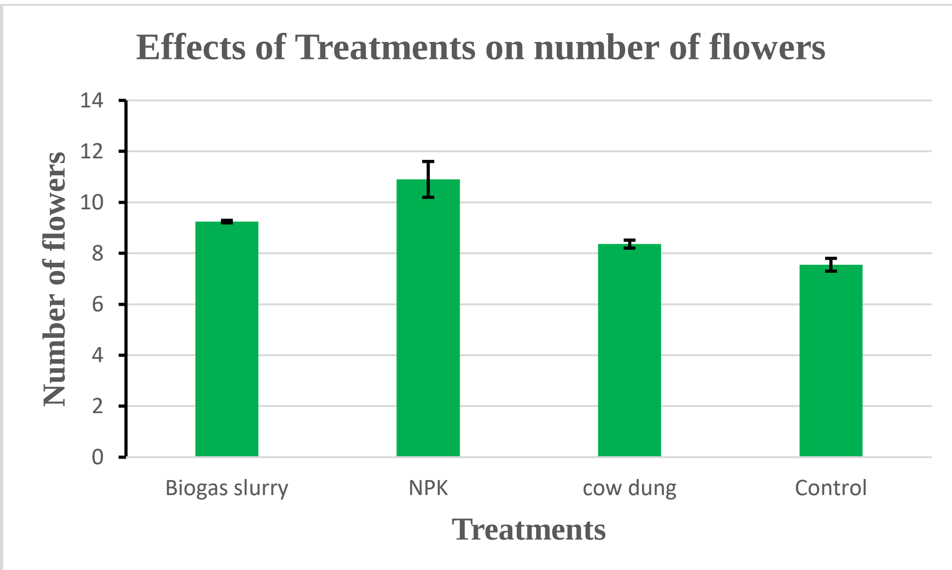


Figure 4 showing mean number of flowers per treatment

4.1.2.1.4 Number of fruits

Table 5 showing mean number of flowers and standard deviation across the treatments

Treatment	Replication 1	Replication 2	Mean	Standard deviation
Biogas Slurry	9.20	9.30	9.25	0.050
NPK	11.60	10.20	10.90	0.700
Cow Dung	8.20	8.51	8.36	0.155

Control	7.80	7.30	7.55	0.250

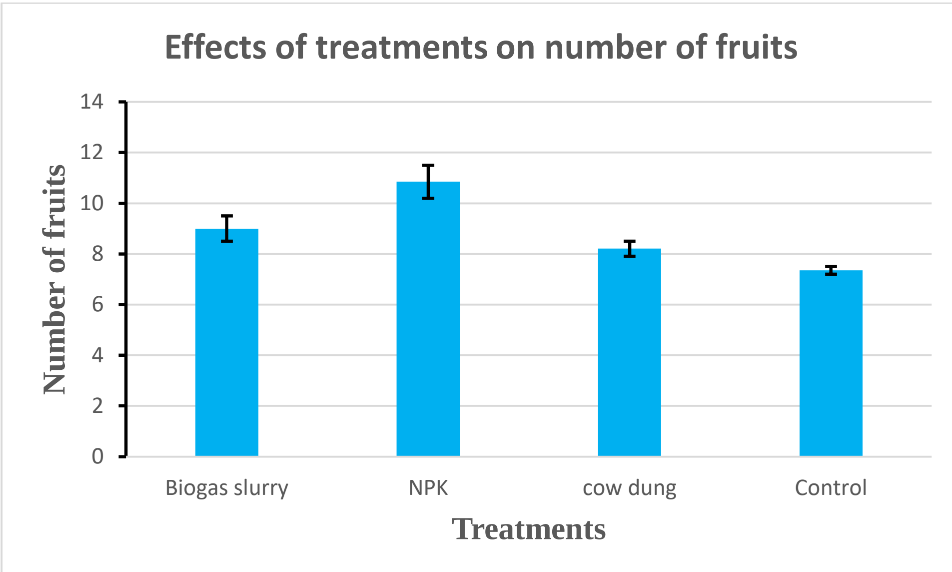


Figure 5 showing mean number of fruits per treatment

4.1.2.2 ANOVA RESULTS

4.1.2.2.1 Effect of Treatments on plant height

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BIOGAS SLURRY	2	109.9	54.95	0.125
NPK	2	112.1	56.05	1.125
COW DUNG	2	106.85	53.425	16.53125
CONTROL	2	100.5	50.25	7.605

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*

Between Groups	38.11844	3	12.70615	2.002052	0.256101	6.591382
Within Groups	25.38625	4	6.346563			
Total	63.50469	7				

Interpretation

The ANOVA results indicate that although there are observable differences in mean plant height among the treatments, these differences are not statistically significant. For instance, NPK recorded the highest average plant height (56.05), followed by bio slurry (54.95), cow dung (53.43), and the control (50.25), suggesting a trend where treated plants tend to grow taller than untreated ones. However, the calculated F-value (2.00) is much lower than the critical F-value (6.59), and the p-value (0.256) is greater than the conventional significance level of 0.05. This means that the variation in plant height is more likely due to random variation like light and temperature which directly influences photosynthetic activity in tomatoes, thereby affecting the growth parameter like stem diameter (Song et al., 2022), rather than the effect of the treatments themselves. Therefore, based on this analysis, the treatments did not have a statistically significant effect on plant height, even though some treatments showed slightly higher average growth.

4.1.2.2.2 Effects of treatments on stem diameter

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BIOGAS SLURRY	2	2.1	1.05	0
NPK	2	2.2	1.1	0.0018
COW DUNG	2	2.02	1.01	0.0032
CONTROL	2	1.95	0.975	0.00125

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.017338	3	0.005779	3.698667	0.119367	6.591382
Within Groups	0.00625	4	0.001563			
Total	0.023588	7				

Interpretation

The ANOVA results for stem diameter show slight differences among treatments, with NPK having the highest average stem diameter (1.10), followed by biogas slurry (1.05), cow dung (1.01), and the control (0.98), suggesting that treated plants tended to have marginally thicker stems than the untreated ones. However, these differences are not statistically significant, as the calculated F-value (3.70) is lower than the critical F-value (6.59), and the p-value (0.119) is greater than the 0.05 significance level. This indicates that the observed variation in stem diameter is likely due to random variation like light and temperature which directly influences photosynthetic activity in tomatoes, thereby affecting the growth parameter like stem diameter (Song et al., 2022) rather than a true effect of the treatments. Therefore, despite the slight numerical advantage seen in some treatments, there is no strong statistical evidence that the treatments significantly influenced stem diameter.

4.1.2.2.3 Effects of treatments on Number of flowers

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BIOGAS SLURRY	2	18.5	9.25	0.005
NPK	2	21.8	10.9	0.98
COW DUNG	2	18.2	9.1	0.02
CONTROL	2	15.3	7.65	0.045

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	10.605	3	3.535	13.46667	0.014753	6.591382
Within Groups	1.05	4	0.2625			
Total	11.655	7				

Interpretation

The ANOVA results indicate that the treatments had a statistically significant effect on the number of flowers produced. NPK recorded the highest mean number of flowers (10.9), followed by biogas slurry (9.25), cow dung (9.1), and the control (7.65), showing a clear improvement in flowering with treatment application compared to the untreated plants. This difference is supported by the F-value (13.47), which is greater than the critical F-value (6.59), and the p-value (0.0148), which is below the 0.05 significance level. This means that the variation observed in the number of flowers is unlikely to be due to chance alone, but rather reflects a real effect of the treatments. Therefore, the treatments, particularly NPK, significantly enhanced flower production compared to the control.

4.1.2.2.4 Effects of treatments on the number of fruits

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
BIOGAS SLURRY	2	18	9	0.5
NPK	2	22.7	11.35	2.645
COW DUNG	2	18	9	0.08
CONTROL	2	14.7	7.35	0.045

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	16.245	3	5.415	6.623853	0.049606	6.591382
Within Groups	3.27	4	0.8175			
Total	19.515	7				

Interpretation

The ANOVA results show that the treatments had a statistically significant effect on the number of fruits produced, although the significance is marginal. NPK recorded the highest mean number of fruits (11.35), while bio slurry and cow dung both had moderate and equal averages (9), and the control had the lowest (7.35), indicating that treatment application generally improved fruit production compared to no treatment. This conclusion is supported by the F-value (6.62), which is slightly higher than the critical F-value (6.59), and the p-value (0.0496), which is just below the 0.05 significance level. This suggests that the observed differences in fruit numbers are unlikely to be due to chance alone, but the closeness of the values indicates the effect is relatively weak. Therefore, the treatments, particularly NPK, had a significant but modest influence on fruit production.

4.1.2.2 Discussion of Results

The results indicate that vegetative growth parameters showed no statistically significant differences among treatments ($p > 0.05$), although bio slurry and NPK consistently recorded higher mean values than cow dung and the control. This suggests that while nutrient application improved growth numerically, the effects were not strong enough to produce significant variation at early growth stages. This finding is consistent with recent research showing that bio slurry often produces gradual improvements in vegetative growth due to its slow mineralization and dependency on soil microbial activity for nutrient release(Möller & Müller, 2012) .

In contrast, reproductive growth parameters showed statistically significant differences among treatments, with NPK and bio slurry performing best. Flower production ($p = 0.0148$) and fruit production ($p = 0.0496$) indicate that nutrient application significantly influenced yield formation. This is strongly supported by recent agronomic studies showing that phosphorus- and nitrogen-rich inputs including bio slurry enhance flowering and fruit set by improving energy transfer, reproductive branching, and assimilate allocation during critical growth stages(Franceschi et al., 2023). Furthermore,(Nkoa, 2014)found that biogas slurry application significantly increased yield components in horticultural crops due to improved nutrient synchrony during reproductive development.

The relatively close performance of bio slurry to NPK in both flowers and fruits demonstrates its strong potential as a partial substitute for inorganic fertilizers. Recent meta-analyses confirm that anaerobic digestate can achieve comparable yields to mineral fertilizers when properly applied, particularly in terms of reproductive yield parameters, (Nkoa, 2014). For example,(Senbayram et al., 2022) reported no significant yield differences between digestate-treated and mineral-fertilized crops in several field experiments, provided nutrient supply is well matched to crop demand.

Overall, the findings strongly support the objective of promoting bio slurry as a sustainable fertilizer. While NPK remains more immediately effective in maximizing yield components, bio slurry demonstrates statistically and agronomically meaningful performance in flowering and fruiting. Therefore, bio slurry can be recommended as a viable alternative or complementary fertilizer, especially in sustainable and low-cost agricultural systems.

4.1.3 Results of specific objective 3 (To assess soil fertility response to biogas slurry, chemical fertilizer, and control treatments under open field tomato production.)

4.1.3.1 Initial soil characteristics

The initial soil sample collected before treatment application had low fertility status, with organic matter and organic carbon indicating poor soil organic condition suitable for comparison after treatment application

Parameter	Initial soil value
Organic carbon (%)	1.42
Organic matter (%)	2.53

Table 6 Showing the initial composition of organic carbon and organic matter in the soil before treatment application

4.1.3.2 Effect of treatments on soil organic carbon and organic matter

Table 7 Showing the effect of treatments on soil organic carbon and organic matter content

Treatment	Soil sample	Organic carbon	Organic matter

BIO SLURRY	A1	2.054	3.541
BIO SLURRY	A2	2.042	3.521
COW DUNG	B1	2.324	4.007
COW DUNG	B2	2.372	4.090
NPK	C1	1.942	3.348
NPK	C2	1.831	3.157
CONTROL	D1	1.479	2.550
CONTROL	D2	1.431	2.467

4.1.3.3 Change in soil organic carbon and organic matter from initial soil

Table 8 Showing change in soil organic carbon and organic matter from the initial after application of treatments

Treatment	Change in organic carbon (%)	Change in organic matter (%)
BIO SLURRY (1)	0.634	1.191
BIO SLURRY (2)	0.622	1.171
COW DUNG (1)	0.904	1.657
COW DUNG (2)	0.952	1.740

NPK (1)	0.522	0.998
NPK (2)	0.411	0.807
CONTROL (1)	0.059	0.2000
CONTROL (2)	0.011	0.117

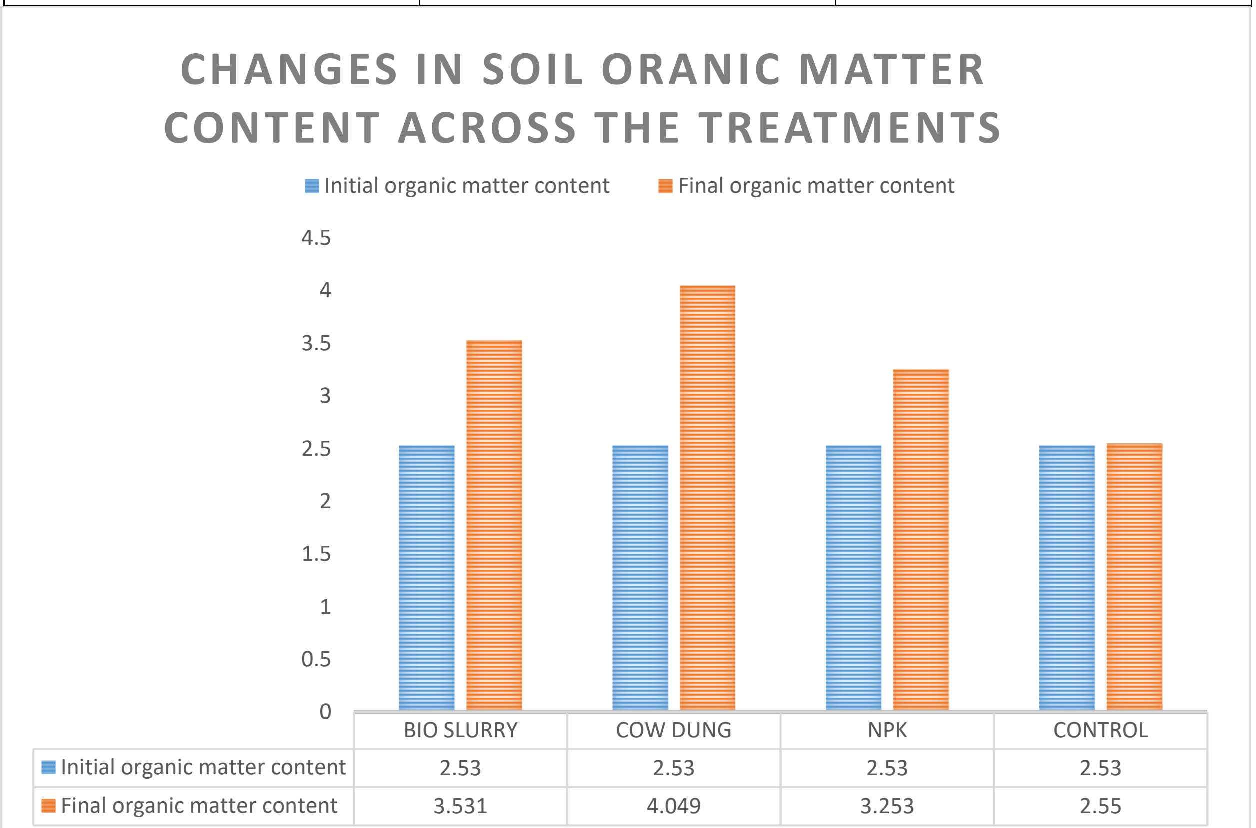


Figure 6 Showing changes in soil organic matter content

4.1.3.2 Anova for change in soil Organic matter across the treatments

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
BIO SLURRY	2	1.256	0.628	7.2E-05

COW DUNG	2	1.856	0.928	0.001152
NPK	2	0.933	0.4665	0.00616
CONTROL	2	0.07	0.035	0.001152

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.832177	3	0.277392	129.9795	0.000193	6.591382
Within Groups	0.008537	4	0.002134			
Total	0.840714	7				

Interpretation

The ANOVA results indicate that there is a highly significant difference in the change in soil organic matter among the different treatments. This is evidenced by the very high F-value (F = 129.98), which is far greater than the critical value (F crit = 6.59), and a very small p-value (p = 0.000193), which is well below the 0.05 significance level. This means that the observed differences in organic matter improvement are not due to random variation but are a direct effect of the treatments applied. Among the treatments, biogas slurry and cow dung recorded the highest increases in soil organic matter, indicating strong contributions to soil organic build-up through the addition and decomposition of organic residues. NPK showed a moderate improvement, likely due to indirect effects such as crop residue contribution rather than organic input from the fertilizer itself, while the control showed the least change, reflecting minimal natural improvement under cropping without amendments. Overall, the results clearly demonstrate that organic amendments, particularly biogas slurry and cow dung, significantly enhance soil organic matter compared to inorganic fertilizer and no treatment, highlighting their superiority in improving soil fertility status.

4.1.3.3 Discussion of results

The significant differences in soil organic matter among treatments agree with established soil fertility research. The higher SOM increases under bio slurry and cow dung are due to their direct carbon inputs and stimulation of microbial activity, which promote humification and soil organic build-up. This is consistent with findings by (Möller & Müller, 2012), who reported that anaerobic digestates improve soil organic carbon due to their partially stabilized organic matter, and with studies showing that livestock manure enhances SOM through continuous addition of decomposable organic substrates.

The slightly higher SOM under cow dung compared to biogas slurry reflects evidence that raw manure often contributes more particulate organic matter in the short term, while biogas slurry provides more stabilized carbon that supports longer-term soil improvement.

The low SOM increase under NPK aligns with long term fertilization studies (Ladha et al., 2011) , which show that inorganic fertilizers do not significantly increase soil organic matter. The control treatment showed minimal change, reflecting natural SOM decline under continuous cultivation without amendments.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

This study evaluated the influence of biogas slurry on the agronomic performance of tomatoes under open field conditions, with comparisons made against chemical fertilizer (NPK), cow dung, and a control with no fertilizer. The findings provide important insights into plant growth, yield performance, and soil fertility improvement.

The results indicate that biogas slurry has a positive effect on tomato growth and development, although its influence varies across different parameters. For vegetative growth characteristics such as plant height and stem diameter, the differences among treatments were not statistically significant ($p > 0.05$). However, numerical trends consistently showed better performance in fertilized treatments (NPK and biogas slurry) compared to cow dung and the control, suggesting that nutrient application enhances early plant development.

In contrast, reproductive parameters including number of flowers and number of fruits showed statistically significant differences among treatments ($p < 0.05$). NPK recorded the highest performance, followed closely by biogas slurry, while cow dung performed moderately and the control recorded the lowest values. This indicates that both biogas slurry and inorganic fertilizer positively influence yield formation, with NPK showing slightly higher immediate effectiveness, while biogas slurry demonstrates comparable potential under field conditions.

Soil fertility analysis revealed significant improvements in soil organic matter and organic carbon, especially under biogas slurry and cow dung treatments. Organic amendments contributed substantially to soil quality enhancement compared to inorganic fertilizer and the control, which showed minimal improvement. This confirms that biogas slurry plays a strong role in improving long-term soil health through organic matter accumulation and nutrient recycling.

Overall, the study concludes that biogas slurry is an effective organic fertilizer that improves tomato yield components and significantly enhances soil fertility. Although chemical fertilizer

(NPK) showed slightly higher performance in some yield parameters, biogas slurry demonstrated strong potential as a sustainable, low-cost, and environmentally friendly alternative suitable for smallholder farmers in Uganda.

5.2 RECOMMENDATION

- Small holder farmers should be encouraged to adopt biogas slurry as a primary or supplementary fertilizer to improve soil health.
- Agricultural stake holders and government agencies should integrate biogas technology and slurry utilization into national organic farming programs.
- Future research should investigate different application rates and long term effects of BGS on a wider variety of crops and soil types.
- Utilizing organic waste for biogas and slurry production should be promoted as a dual solution for energy needs and agricultural productivity.

Appendix

Table 9 Showing raw data got from measurement of the crop growth parameters

Date	Replication	Treatment	Plant Height (cm)	Stem Diameter (cm)	Number of Flowers	Number of Fruits
24-Jan-2026	1	Bio Slurry	28	0.8	-	-
24-Jan-2026	1	NPK	27	0.8	-	-
24-Jan-2026	1	Cow Dung	31	0.6	-	-
24-Jan-2026	1	Control	30	0.8	-	-
24-Jan-2026	2	Bio Slurry	28	0.7	6	0
24-Jan-2026	2	NPK	29	0.9	0	0
24-Jan-2026	2	Cow Dung	31	0.7	4	0
24-Jan-2026	2	Control	25	0.7	0	0
31-Jan-2026	1	Bio Slurry	38	0.8	21	1
31-Jan-2026	1	NPK	49	1.0	22	3
31-Jan-2026	1	Cow Dung	40	0.7	20	2
31-Jan-2026	1	Control	46	0.8	13	5
31-Jan-2026	2	Bio Slurry	41	0.7	18	1
31-Jan-2026	2	NPK	47	0.7	22	-
31-Jan-2026	2	Cow Dung	50	0.8	23	3
31-Jan-2026	2	Control	44	0.7	17	-
07-Feb-2026	1	Bio Slurry	44	0.9	26	17
07-Feb-2026	1	NPK	50	0.9	40	23
07-Feb-2026	1	Cow Dung	45	0.8	18	12
07-Feb-2026	1	Control	50	0.9	37	25
07-Feb-2026	2	Bio Slurry	48	0.9	21	15
07-Feb-2026	2	NPK	54	1.0	39	22

Date	Replication	Treatment	Plant Height (cm)	Stem Diameter (cm)	Number of Flowers	Number of Fruits
07-Feb-2026	2	Cow Dung	50	1.0	36	29
07-Feb-2026	2	Control	47	0.8	26	8
14-Feb-2026	1	Bio Slurry	58	1.1	41	44
14-Feb-2026	1	NPK	56	1.2	69	65
14-Feb-2026	1	Cow Dung	53	0.9	40	37
14-Feb-2026	1	Control	54	1.1	42	40
14-Feb-2026	2	Bio Slurry	56	1.2	55	42
14-Feb-2026	2	NPK	60	1.1	53	45
14-Feb-2026	2	Cow Dung	58	1.0	45	45
14-Feb-2026	2	Control	58	1.0	53	42
21-Feb-2026	1	Bio Slurry	66	1.2	85	103
21-Feb-2026	1	NPK	69	1.3	126	120
21-Feb-2026	1	Cow Dung	65	1.2	80	79
21-Feb-2026	1	Control	66	1.2	86	103
21-Feb-2026	2	Bio Slurry	73	1.1	80	88
21-Feb-2026	2	NPK	70	1.2	98	91
21-Feb-2026	2	Cow Dung	71	1.3	66	76
21-Feb-2026	2	Control	69	1.0	77	72
28-Feb-2026	1	Bio Slurry	78	1.5	90	122
28-Feb-2026	1	NPK	78	1.6	144	163
28-Feb-2026	1	Cow Dung	69	1.4	100	113
28-Feb-2026	1	Control	69	1.2	90	142
28-Feb-2026	2	Bio Slurry	82	1.7	97	113
28-Feb-2026	2	NPK	81	1.5	102	151

Date	Replication	Treatment	Plant Height (cm)	Stem Diameter (cm)	Number of Flowers	Number of Fruits
28-Feb-2026	2	Cow Dung	81	1.5	109	102
28-Feb-2026	2	Control	74	1.5	96	112

Figure 7 Preparation of bio slurry

Figure 8 Showing tomato nursery bed


BLI


BLI

4.4 Reference

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