

**ASSESSING THE PERFORMANCE OF BLACK SOLDIER FLY LARVAE FRASS
AS AN ORGANIC FERTILIZER ALTERNATIVE TO NPK ON TOMATO
GROWTH IN BUSITEMA UNIVERSITY.**

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BU/UP/2023/1699

**A RESEARCH PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF
BIOLOGY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
AWARD OF A BACHELOR OF SCIENCE EDUCATION DEGREE AT BUSITEMA
UNIVERSITY.**

JULY 2026

DECLARATION

I MARRIAM KISAKYE, declare that this Report titled “Assessing the Performance of Black Soldier Fly Larvae frass as an organic fertilizer alternative to NPK on tomato growth in Busitema University”, is my original work and that it has never been submitted for any award in any higher institution of learning here or anywhere else.

Signature:..... Date: 31.08.26.....

MARRIAM KISAKYE

APPROVAL

This research project has been submitted to the faculty of Science and Education, Biology Department in fulfillment of the requirement for the award of a degree of Bachelor of Science Education of Busitema University 2026 with approval of my supervisor.

Signature: H. Namusana Date: 31/08/26

Ms. HELLEN NAMUSANA

DEDICATION.

To God, who has been my help from the beginning of this research project, be the glory.

To my parents, Mr. NALUKHOB A MICHEAL and Mrs. NAKUTI JENIPHER AIDAH NALUKHOB A and siblings who have been a pillar of strength in this journey. Your love, guidance and financial support gave me a break through always.

To the students of Biology in Busitema University; the gallant intellectuals, I love you so much.

ACKNOWLEDGEMENT

My heart felt and sincere appreciation to my supervisor, Ms. Namusana Hellen for the immeasurable professional guidance and tireless efforts during this work. May God bless you.

My further appreciation flows out to Busitema University for offering me an opportunity to study; and to the entire department of Biology especially Dr. Hokello Joseph, Dr. Carol Kauma, Ms. Nantale Gauden, Dr. Ochieng Hannington, Mr. Olowo Moses, Prof. Andama Edward, Mr. Kifuko Richard, Md. Amado Mary to mention but a few.

Special thanks to Wanjala Enos, Wanzala Andrew Jacob, Bulukwa Chapeli, Icariat Emmanuel Piuze, Masinde Elvis, Masereka Jonan, Masereka Ronald, Nyabonyo Ruth, and all year three students of biology for the contribution towards this academic career.

I would also like to appreciate my elder brothers Kutosi Richard and Munyali Emmanuel for the advice and financial support; my young brothers, sisters and friends; I owe you great thanks for all you have been to me in this struggle; may the Almighty God bless you abundantly.

Above all, glory and honor back to the lord my God; for he has been faithful to the end of this study.

ABSTRACT

The increasing cost and environmental concerns associated with synthetic fertilizers have created interest in sustainable organic alternatives such as Black Soldier Fly Larvae (BSFL) frass. This study assessed the performance of BSFL frass as an organic fertilizer alternative to NPK fertilizer on tomato growth at Busitema University, Uganda. An experiment was conducted with three treatments: T1 (Control), T2 (Synthetic NPK 17-17-17), and T3 (BSFL Frass) in an open field garden. The objectives of this study were: 1. To assess the performance of BSFL frass and NPK on mean height of tomato plants with time; 2. To assess the effect of BSFL frass and NPK on sample fruit size of tomato plants after the first harvest; 3. To assess the effect of BSFL frass and NPK on sample fruit weight (biomass) of tomato plants after the first harvest. The parameters that were analyzed were plant height monitored over an eleven-week cycle, fruit size and fruit weight that were analysed after first harvest. A Randomized Complete Block Design (RCBD) with three replications was used. The data for plant height was analysed using Two-way ANOVA in IBM SPSS v.26 and revealed that BSFL frass (T3) significantly outperformed both the NPK (T2) and Control (T1) groups under natural field conditions with $F_{cal}=8.434>4.46$ for treatment and $F_{cal}=65.756>3.84$ for time in weeks at $\alpha=0.05$ significant level. Fruit size and fruit weight were assessed using percentage differences at 10% efficacy threshold. T3 achieved a 12.3% increase in overall dimensional size and a 22.1% increase in fruit biomass. On the other hand, T2 recorded a marginal increase of only 3.7% fruit size and an 8.0% weight increase, failing to meet the 10% threshold required for superior performance classification.

This study shows that BSFL frass gave superior results to NPK on plant height, fruit size and fruit weight, indicating its potential as an organic fertilizer alternative. Integrating BSFL frass into tomato production systems could reduce reliance on synthetic inputs and support environmentally friendly farming practices.

Keywords: Black Soldier Fly. Black Soldier Fly Larvae Frass. Vegetable Production. Organic Fertilizer. NPK. Sustainable Agriculture. Tomatoes.

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LIST OF ABBREVIATION

BSFL: Black Soldier Fly Larvae

BSF: Black Soldier Fly

BSFLF: Black Soldier Fly Larvae Frass

CRBD: Completely Randomized Block Design

NPK: Nitrogen, Phosphorous and Potassium

CT: Control

T1: Treatment 1

T2: Treatment 2

T3: Treatment 3

1.0 CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

In this era of global climate change and land degradation, ensuring food security for an ever-growing world population of nearly 10 billion people projected in 20–30 years is a significant issue according to the reports from research (Wardani, 2024). The global food consumption is expected to rise due to rapid population growth and urbanization (Basri et al., 2022; Gebremikael et al., 2022). Vegetable production can be adopted as a strategy for improving livelihood and easing the nutritional status of the people (Geoffrey et al., 2014).

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetable crops grown worldwide due to its nutritional and economic value. In Uganda, tomatoes contribute significantly to household income, food security, and nutrition among smallholder farmers (Gutierrez, 2018). Several technologies have been innovated to boost tomato production to support the rapid growing population that is responsible for food insecurity (Gebremikael et al., 2022). However, declining soil fertility remains a major limitation to tomato production. Farmers largely depend on inorganic fertilizers such as Nitrogen-Phosphorus-Potassium (NPK) fertilizers to improve yields. Although NPK fertilizers enhance crop growth (Penuelas et al., 2023), excessive use has been associated with soil degradation, nutrient leaching, environmental pollution (Wardani, 2024), and high production costs. Recently, organic fertilizers derived from insects, particularly Black Soldier Fly (*Hermetia illucens*) larvae frass, have gained attention as sustainable alternatives for crop growing (Salomon et al., 2025).

Accordingly, the black soldier fly larvae turns tons of organic wastes into larval biomass within 2–4 weeks (Amrul et al., 2022). Additionally, the protein from BSFL has been a valuable source of dietary protein, replacing fishmeal and soybean meal in fish and poultry farming (Hossain & Bhuiyan, 2023). More still, the frass, which refers to the mixture of insect excretions, exoskeletons, and substrate residue leftover at the end of larval growth, has been used as a soil amendment and fertilizer, showing its potential in the growth and production of many different crops such as maize, Sukuma wiki among others (Tanga et al., 2022).

Despite these importances, its adoption by small scale farmers is still very low and this may be attributed to inadequate knowledge on its effectiveness majorly on tomatoes under Ugandan conditions.

1.2 PROBLEM STATEMENT.

Tomatoes are highly demanded vegetables and consumed world-wide (Collins et al., 2022; Fukase & Martin, 2020). Growing of tomatoes by small holder farmers is heavily dependent on artificial fertilizers like NPK which has contributed to declining soil quality, environmental pollution, and increased economic burden (Penuelas et al., 2023). Smallholder farmers in Uganda often struggle to afford adequate quantities of NPK fertilizers, leading to poor yields and reduced profitability. Sustainable and low-cost organic alternatives are urgently needed (Basri et al., 2022).

To prevent the risks associated with artificial fertilizers, BSFL frass from the breakdown of organic wastes by the black soldier fly larvae has been used in the growth of many crops including vegetables like Sukuma wiki. However, there is limited information on it's use on tomatoes (Tanga et al., 2022).

Although BSFL frass has shown potential as an organic fertilizer in other countries like Kenya, Ghana among others, limited information exists regarding its performance on tomato growth under the natural field conditions especially of Busitema University. Therefore, this study seeks to assess the performance of black soldier fly larvae frass as an organic fertilizer alternative to NPK.

1.3 JUSTIFICATION OF THE STUDY.

BSFL frass is a sustainable, locally available, and potentially cost-effective fertilizer source for smallholder farmers. It offers a solution to manage organic waste (Rehman et al., 2023), minimize greenhouse gas emissions (Rummel et al., 2021); Sharma et al., 2017), and reduce water pollution associated with traditional farming.

The frass contains chitin, a compound that can activate a plant's natural defense mechanisms against pests and pathogens, potentially reducing the need for chemical pesticides (Elissen et al., 2023).

Unlike mineral fertilizers that can deplete soil organic matter over time (Jaja & Barber, 2017), frass provides nutrients while also building healthier, more resilient soil for long-term productivity (Salomon et al., 2025).

While previous research exists for various crops, the specific effects on tomato performance under local conditions, still require further validation.

1.4 OBJECTIVES

1.4.1 General objectives:

To compare the performance of BSFL frass as an organic fertilizer alternative to artificial fertilizer (NPK) in promoting the growth and yield of tomato plants after the first harvest.

1.4.2 Specific objective:

1. To assess the performance of BSFL frass and NPK on mean height of tomato plants with time.
2. To assess the effect of BSFL frass and NPK on fruit size of tomato plants after the first harvest.
3. To compare the effect of BSFL frass and NPK on fruit weight (biomass) of tomato plants after the first harvest.

1.5 HYPOTHESIS.

1.5.1 Null Hypothesis.

There is no significant difference in plant height, fruit size, and fruit weight between plants treated with BSF frass and those treated with NPK fertilizer.

1.5.2 Alternative Hypothesis

BSF frass-treated plants will show significantly greater plant height, fruit size, and fruit weight compared to NPK fertilizer-treated plants.

1.6 SIGNIFICANCE OF THE STUDY.

This research study intends to contribute to the scientific knowledge of BSF as a supplement for animal feeds, poultry feeds, and BSFL frass in improving tomato growth and other vegetables (Hossain & Bhuiyan, 2023).

It will also contribute to the Sustainable Development Goals, ending hunger, achieving food security and Improving Nutrition and promoting Sustainable Agriculture.

1.7 SCOPE OF STUDY.

The study was conducted in Busitema University next to the BSF insectary.

The research covered the entire growth cycle of the tomato plant, from preparation of the nursery bed, transplanting to management.

1.7.1 Experimentation scope.

Tomato plants were used in the study.

The study compared three main treatments: a control group (no fertilizer), NPK group, and one group for BSFL frass.

The key parameters to be measured and compared were plant height, fruit size, and fruit weight.

The study focused solely on the effects of BSFL frass and NPK on plant height and yield parameters. It was limited to only tomatoes and experimental conditions that were chosen.

2.0 CHAPTER TWO: LITERATURE REVIEW

2.1 INTRODUCTION

Tomato is the second most important horticultural product cultivated worldwide (Van Andel et al., 2022). For research, tomato is considered a model organism of the Solanaceae family, and has therefore been, and is still a major crop subject of studies both in the laboratory and under field conditions (Collins et al., 2022).

Tomatoes originated in Peru of South America and name of crop came from the Aztec word "Tomato" (Timelines et al., 2018). The crop is of recent origin and first report of tomato was from Italy in 1544. Later spread was fast and the crop is grown throughout the length and breadth of world including the tropical, subtropical, and temperate regions due to their adaptability and high consumer demand (Gutierrez, 2018). Tomatoes are consumed fresh, cooked, or processed into products such as sauces, juices, ketchup, and paste.

2.2 NUTRITIONAL AND HEALTHY BENEFITS OF TOMATOES.

Tomatoes are nutrient-rich vegetables containing essential vitamins and minerals including vitamin C, vitamin A, vitamin K, potassium, magnesium, and folate (Kaboré et al., 2022). These nutrients support immunity, vision, bone development, and cardiovascular health. Tomatoes also contain dietary fiber, which improves digestion and helps prevent constipation.

Studies have demonstrated that agronomic practices, fertilizer application, and postharvest management can influence the nutritional quality of tomatoes (Chavez et al., 2023). Improved cultivation methods enhance vitamin and antioxidant content in tomato fruits. These nutrients support immunity, vision, bone development, and cardiovascular health. Tomatoes also contain dietary fiber, which improves digestion and helps prevent constipation.

Regular consumption of tomatoes contributes to disease prevention and overall well-being. Lycopene and other antioxidants in tomatoes have been associated with reduced risks of cardiovascular diseases by lowering oxidative damage and improving blood vessel function (Timelines et al., 2018).

Tomatoes may also reduce the risk of certain cancers, particularly prostate, stomach, and lung cancers. Their bioactive compounds help inhibit cancer cell growth and reduce DNA damage.

Recent studies further suggest that tomato-rich diets positively influence gut microbial diversity and digestive health.

2.3 AGRICULTURAL IMPORTANCE OF TOMATOES.

Tomatoes play a major role in food and nutritional security. They can be cultivated under open-field, greenhouse, and soilless systems, making them adaptable to different environmental conditions (Timelines et al., 2018).

Modern research has focused on improving tomato fruit quality, disease resistance, nutrient management, and productivity through biotechnology and sustainable farming approaches (Kumar & Lata, 2025).

Tomatoes are also used in crop rotation systems and sustainable agriculture because of their economic returns and consumer demand.

2.4 ECONOMIC IMPORTANCE OF TOMATOES.

Tomatoes are economically important because they generate income for farmers, traders, transporters, and food processors. Tomato farming contributes significantly to rural livelihoods and employment creation worldwide (Ddamulira et al., 2021). Processing industries use tomatoes in the production of sauces, ketchup, canned products, and juices, thereby supporting agro-industrial development.

Tomatoes are also valuable export commodities in many countries due to their high global demand. Their short growth cycle allows farmers to obtain income within a relatively short period compared to many other crops.

Tomatoes are widely grown and used in Eastern Africa. During the peak season most farmers sell their tomatoes at throw-away prices and substantial quantities go to waste because they are highly perishable. To avoid this, farmers can process tomatoes into various products for storage and use at home or as value-added products for income generation.

2.3 ENVIRONMENTAL CONDITIONS FOR TOMATO GROWTH.

Tomatoes can grow in any climatic condition but thrive mostly in warm weather, with optimal daytime temperatures between 20°C and 27°C. Temperatures above 30°C can adversely affect fruit setting, while temperatures below 10°C slow down growth and can cause

flower drop. The plants need at least six to eight hours of direct sunlight each day to produce healthy fruit (Ddamulira et al., 2021).

The ideal soil should be deep, well-drained, fertile, and rich in organic matter. Sandy or loamy soils are often preferred, but tomatoes can grow in a wide variety of soils as long as drainage is good.

Tomatoes are heavy feeders and require ample nitrogen, phosphorus, and potassium for optimal growth and high yields (Ddamulira et al., 2021). A consistent and adequate water supply is critical, especially during the flowering and fruiting stages. However, the soil should not become waterlogged, as this can cause root rot. Favorable conditions will increase production. Tomatoes take 2-3 months to mature.

2.4 BSFL FRASS IN TOMATO GROWING.

Black Soldier Fly Larvae (BSFL) frass is the byproduct of the bioconversion of organic waste, consisting of larval excreta, exoskeleton sheds (chitin), and unconsumed substrate (Chavez et al., 2023b). In tomato production, frass is increasingly recognized as a high-value organic soil amendment. Vegetables treated with frass are seen to show increased plant height and increased fruit production (Antoniadis et al., 2023). The fertilizing potential of BSF frass stems from its unique composition, though its exact nutrient profile varies based on the larvae's feedstock C

BSF frass is consistently rich in macronutrients (nitrogen, phosphorus, and potassium) and beneficial micronutrients, with concentrations often higher than traditional composts. For example, total nitrogen can double commercial composts (Elissen et al., 2023; Wardani, 2024).

2.5 NPK IN TOMATO GROWING

Synthetic NPK (Nitrogen, Phosphorus, and Potassium) fertilizers are the conventional standard in commercial vegetable production due to their high solubility and precise nutrient delivery. NPK fertilizers allow farmers to apply specific ratios tailored to the tomato's life cycle e.g., high Nitrogen for leafy greens or high Phosphorus for root development. Because the nutrients are in inorganic forms, they are immediately available for plant uptake, leading to rapid growth bursts and predictable harvest cycles (Fonge et al., 2016). While effective for yield, heavy reliance on NPK in vegetable growing can lead to soil acidification, salt buildup, and a "boom-bust" nutrient cycle that lacks the long-term soil conditioning provided by organic matter (Tanga et al., 2022).

2.6 MECHANISMS THROUGH WHICH BSFL FRASS ENHANCES TOMATO GROWTH.

The efficacy of frass in tomato cultivation extends beyond simple nitrogen delivery. It functions through a combination of chemical, biological, and elicitor-based pathways. While NPK offers a rapid initial boost to plant growth due to its soluble nutrients, BSF frass demonstrates a more sustained effect (Aronsson, 2024). Studies show that crops fertilized with BSF frass can initially lag behind NPK-treated crops but later surpass them in biomass and yield (Salomon et al., 2025). The majority of nitrogen in BSF frass is in organic form, requiring mineralization by soil microbes before it becomes available to plants. This differs from NPK fertilizer, which provides immediately available nutrients (Beesigamukama et al., 2020). The slower, more sustained release of nutrients from frass can benefit long-term soil fertility and reduce nutrient leaching, particularly for long-cycle or repeatedly harvested crops (Wardani, 2024; Basri et al., 2022).

Several studies indicate that BSF frass can achieve comparable and even superior yields to NPK, especially when applied at optimized rates or in combination with NPK. For example, studies on maize in Kenya demonstrated that BSF frass applied alone or with NPK could significantly increase grain yields compared to sole NPK (Tanga et al., 2022). Another study in Madagascar found that optimal doses of BSFF increased seedling growth more significantly than NPK fertilizer (Solofondranohatra et al., 2025).

The slower release mechanism of BSF frass often results in higher nitrogen use efficiency compared to soluble NPK fertilizers, where nutrients can be easily lost through leaching (Beesigamukama et al., 2020). However, this has an advantage of crops with long life cycle (Beesigamukama et al., 2021) and a disadvantage to crops with a short life cycle.

Another significant consideration for BSF frass is its potential for phytotoxicity, particularly at high application rates. High concentrations of frass can inhibit germination and early plant growth due to nutrient overload, high salt content, or ammonia toxicity. Composting or using lower, calibrated doses can mitigate this risk (Salomon et al., 2025).

BSF frass typically has a slightly alkaline pH, a high organic matter and carbon content, and a good water-holding capacity. These properties contrast with NPK fertilizers, which provide nutrients but do little to improve soil structure or water retention (Basri et al., 2022).

2.7 MECHANISMS THROUGH WHICH NPK ENHANCES TOMATO GROWTH

NPK enhances tomato growth through direct physiological pathways by providing the essential building blocks for plant tissue in readily absorbable ionic forms. Nitrogen is a core component of the chlorophyll molecule. In tomatoes, NPK provides nitrate and ammonium which drive rapid vegetative expansion and leaf area index, maximizing the plant's photosynthetic capacity (Wang et al., 2024). Tomatoes have high energy demands during flowering. NPK provides soluble phosphates essential for ATP production and DNA synthesis, which ensures robust root systems and successful pollination

Additionally, tomato fruit quality (sugar content and firmness) is heavily dependent on Potassium. NPK facilitates the transport of sugars from leaves to the fruit and regulates stomatal conductance, helping the plant manage water stress effectively.

2.8 EFFECT OF BSFL FRASS AND NPK ON TOMATO PLANT HEIGHT.

Research conducted under greenhouse and field conditions reported that tomatoes treated with BSFL frass showed significant increases in plant height compared to NPK treated plants (Beesigamukama et al., 2021).

2.9 EFFECT OF BSFL FRASS AND NPK ON TOMATO FRUIT SIZE.

Studies have shown that BSFL frass improves plant biomass and nutrient uptake in tomatoes. Salomon et al., 2025 observed increased tomato biomass with increasing frass application rates, although excessively high rates caused ammonium toxicity. Similarly, Zaato, Amponsah, Kyei-baffour, et al., 2025; reported that tomato fruit size and quality under BSFL frass treatments were comparable to NPK treated tomato plants.

NPK fertilizer remains widely used because of its rapid nutrient release and immediate crop response. Nitrogen promotes vegetative growth, phosphorus supports root and flower development, while potassium enhances fruit formation and quality. However, excessive use of NPK may reduce soil organic matter and negatively affect long-term soil productivity.

2.10 EFFECT OF BSFL FRASS AND NPK ON TOMATO FRUIT BIOMASS.

Studies comparing BSFL frass and NPK fertilizers indicate that BSFL frass can produce comparable tomato growth and yield performance. (Awad et al., 2024) found that tomato fruit yield, plant biomass, and fruit quality under BSFL frass treatments were statistically comparable to conventional peat-based controls.

3.0 CHAPTER THREE: MATERIALS AND METHODOLOGY.

3.1 STUDY AREA

The experiment was conducted on a sandy loamy soil at the teaching and research farm of Busitema University, Faculty of Science and Education with the geographical coordinates 0°45'38" North, 34°1'18" East elevation 1082m in Nagongera Sub County, West Budama North constituency Tororo District in Eastern Uganda.

3.2.1 Land preparation

Land adjacent to the insectary unit was cleared using a hand hoe in December 2025 (Plate 1).

Plate 1: Digging of the land



3.2.2 Sourcing of tomato seeds.

Tomato seeds of Tengeru type were bought from agro-dealers in Nagongera TC.

3.2.3 Viability test.

Viability test is a very important aspect and paramount before planting of seeds. 20 tomato seeds were randomly picked from a packet of 100g. They were then placed on a moist cotton wool then put on a box. All the 20 seeds germinated by day 4 representing 100% seed viability. This indicated that the seeds were viable for germination.

3.2.4 Nursery bed preparation.

Out of the prepared land, an area of 15cm high by 80cm wide was curved out to make a nursery bed (Plate 2A).

All weeds, stones, and plant debris were removed to prevent competition for nutrients and reduced the risk of pests and diseases. Thereafter, the soil was then disinfected by burning grass on the raised nursery bed to prevent soil borne diseases.

Shallow drills of about 1 cm deep and 10cm apart were made where the seeds were sown thinly along the rows to prevent overcrowding and promote good airflow. The seeds were then covered with a thin layer of soil then mulched with grass to retain moisture and protect the seeds from being displaced by heavy rain or watering.

A temporary shelter was built around the bed to reduce direct sunlight (Plate 2B).

Watering of the seeds planted on the nursery bed was done every morning and evening for 30days. However, watering was done to keep the soil moist but not soggy because overhead watering, can spread fungal diseases like early blight.

The bed was carefully monitored to prevent weeds (Plate 2C), overcrowding through thinning and scouting for pests like whiteflies and leaf miners and diseases like tomato blight. Other activities like hardening off were practiced 8 days before transplanting to prepare the seedlings for main field conditions (Plate 2D). After 30 days, the seedlings were transplanted to the prepared garden 9X4 feet.

Plate 2: A Raising a nursery bed B: Raising a temporary shelter C: Weeding seedling on a nursery bed D: Hardening seedling.



3.2.5 Sourcing and preparation of BSFL frass.

Frass was got from the insectary unit at Busitema University, Nagongera campus. Frass was then pounded, soaked and fermented for 1 week to allow cooling before application. 5kgs of frass was soaked by adding 10 litres of water.

3.3.0 Experimental layout.

A Completely Randomized Block Design (CRBD) was used for the study because it is ideal for agricultural field trials. Three replicates and three fertilizer treatments were used i.e. Control, NPK and Frass (Table 1).

Table 1: The fertilizer treatments used for the experiment.

TREATMENT	DESCRIPTION
T ₁	CONTROL
T ₂	NPK
T ₃	BSFL FRASS

These treatments were replicated three times to ensure statistical reliability. Each field plot contained the same number of plants to ensure consistency.

A garden measuring 9X4 feet was divided into 9 blocks (Jacob, 2021). These blocks were raised 15cm high by 30cm wide to prevent flow and mixing of nutrients among the plots especially during watering and spraying. A small space of about 10m was left and maintained between each plot to separate plots and give walkways during planting, and data collection and other agronomic practices (Plate 3).

Plate 3: Measuring blocks



3.3.1 Planting of seedlings.

After transplanting, the seedlings were placed in the nine blocks on 5th Jan, 2026 and watered, staked and left to adapt to environmental conditions of the area. Staking was done as soon as tomatoes were transplanted into the ground. Installing stakes early prevents root damage that can occur if you try to put them in later. Staking tomatoes is a crucial gardening technique for holding plants upright, preventing fruit rot, and reducing disease by improving air circulation. (Plate 4).

Plates 4: Planting and staking of the seedlings.



3.3.2 Treatment of the blocks with NPK and BSFL frass.

NPK and BSFL frass were applied in 6 blocks. BSFL frass was applied a week before the transplanting time and watered daily to make cool it. NPK was applied on the same day during transplanting. All plots received the same amount of fertilizer per treatment.

Tomatoes take a life span of 90 days from the time of transplanting to harvesting. Additional application of NPK and frass was done after every 3 weeks. Therefore, these fertilizers were applied 4 times for the whole life process.

Frass has high amounts of uric acid and direct application can lead to scorching and death of plants. Therefore, grounded frass was soaked and fermented for 1 weeks to allow cooling before application. To every plot of frass treatment, 2 handfuls of frass weighing 500g were applied using basal application. A small whole was dug around the tomato plants where 2 handfuls of frass was placed and the covered with a thin layer of soil (Plate 5).

Plate 5: Application of BSFL frass.



NPK was applied using a bottle top on the same day after transplanting and then after every three weeks to boost the growth of the crops. The fertilizer was applied by ring placement into drills 5 cm deep and 7.5 cm away from the plant and covered with soil. A total of 1kg of NPK in the ratio of 17:17:17 was used.

3.3.3 Agroeconomic practices

3.3.3.1 Watering.

Watering was done in the morning and evening persistently for the first 2 weeks until the seedlings were fully established then after reduced as the days went by. This was done manually using a watering can (Plate 6).

Plate 6: Watering



3.3.3.2 Mulching

The seedlings were mulched with peelings of banana stems to reserve moisture for the seedlings for seven days. These banana stem peelings are curved and these made them suitable to provide adequate shelter to protect the newly transplanted seedlings from stress. After seven days, the banana stem peelings were removed and the plots were covered with dry grass. This grass was left till the harvesting of the fruits (Plate 7).

Plate 7: Mulching



3.3.3.3 Weeding

Weeding was done to remove unwanted plants and grass around the plots. This practice kept the plots clean and reduced the risks to pest and disease outbreak. Weeds were eliminated manually using a hand hoe and pulling from the 3rd week after transplanting. Each weeding operation was completed on the very day for all plots for avoid bias. Four weeding operations were carried out at a three weeks interval (Plate 8).

Plate 8: Weeding



3.3.3.4 Pruning

Pruning was done to remove suckers (new stems growing in the Y-shape between the main stem and a leaf branch) to concentrate energy on fruit production. This was done weekly using hands.

3.3.3.5 Spraying

The materials that were used to mulch the blocks were sprayed with “Rocket” and “Surgent”. This was done because these materials were susceptible to harboring termites. Rocket and surgent are among the recommended insecticides used to kill termites and other insect that would be harbored in mulches and then in turn eat the plant stems.

The plants were sprayed against pests and diseases after every one week.” Dudu Acelemectine” is a broad-spectrum insecticide that was used to spray against insects such as leaf miners that had started to attack the plant leaves. “Blight Force” that was packaged in 120g is a curative fungicide that was used to spray and cure tomato blight. 5mL of Dudu Acelemectine and one a half spoons of Blight force were mixed with 5L of water and sprayed against all blocks without bias (Plate9).

Plate 9: Spraying.



3.4. Data collection.

3.4.1 Sampling procedures

A simple systematic random sampling technique was used. This meant that each individual plant had an equal probability of being selected and the data collected was used to determine the mean plant height, fruit size and fruit weight. This was done by giving plants numbers and writing the letters corresponding to the plants on the papers. The papers were then folded, mixed together and then put down. Three of the papers were picked one by one randomly, and opened and those were the plants to be evaluated and used for the whole experiment.

3.4.2 Measurement of Plant Height.

The height of the three sampled plants from each plot was measured using a thread and the thread was transferred to the ruler for accurate records. This was done two weeks after transplanting and was consistency after every two weeks for a period of 10 weeks. Measurement was done from the soil surface to the highest point of the plant stem. The average measurement of plant height was recorded in the nearest cm and recorded and kept for further analysis (Plate 10).

Plate 10: Measuring of plant Height



3.4.4 Measurement of Fruit Size.

In the 11th week, three mature fruits were harvested from the three sampled plants from each plot and taken to the lab where fruit sizes were measured longitudinally and transversely. Each fruit was sliced into two equal parts using a knife and measured using a ruler and their averages were recorded to the nearest cm.

3.4.5. Measurement of Fruit Weight.

The mature fruits of the three randomly selected plants from each plot were harvested and weighed using an analytical scale (Plate 11). The total weight per treatment was recorded to calculate average fruit weight and yield for the three fertilizer treatments.

Plate 11: Measuring of Plant Weight



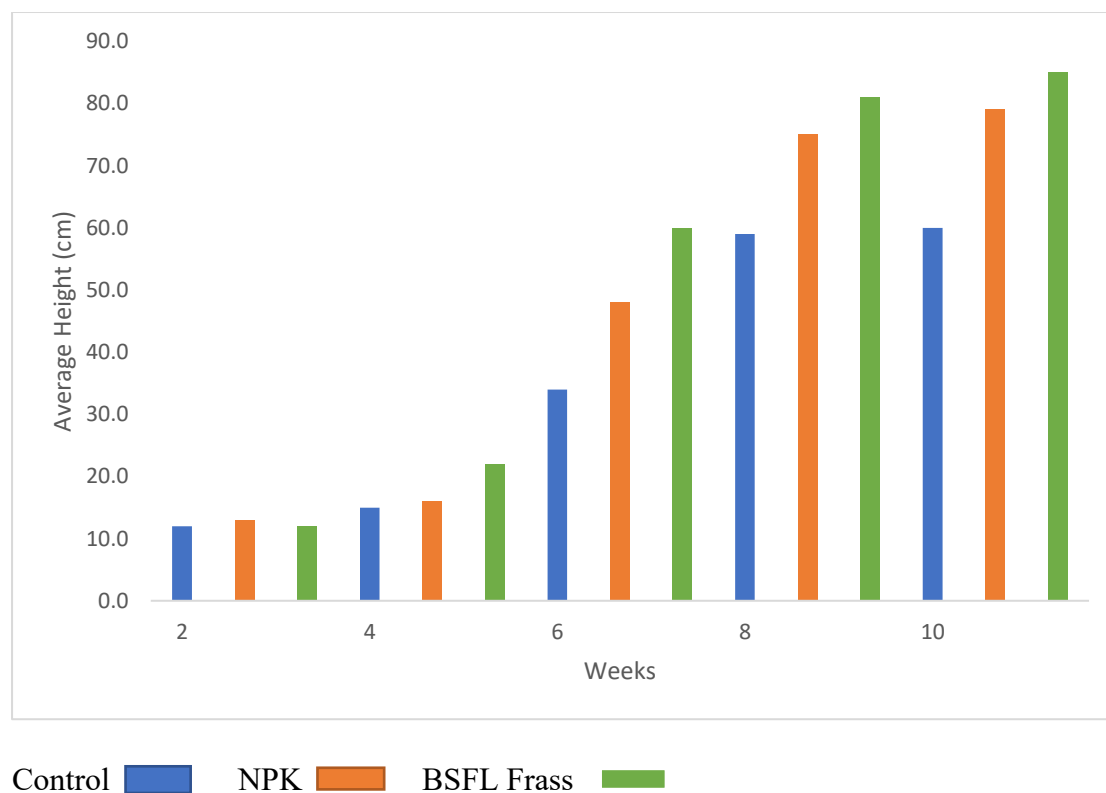
4.0 CHAPTER FOUR: RESULTS

4.1 DATA PRESENTATION

4.1.1 Plant Height.

Two weeks after transplanting, the average tomato plant height for T₁ (Control) was 12.0cm, T₂ (NPK) was 13.0cm, and T₃ (BSFL frass) was 12.0cm. These results show that the BSFL frass-treated plants lag behind in growth compared to NPK. The nutrients in BSFL frass take a long time to be mineralized, while in NPK, nutrients are readily available. However, in week 4, T₃ shows a greater increase in tomato plant height as compared to T₁ and T₂. The increase was consistent to the end of the experiment. The slower release mechanism of BSF frass often results in higher nitrogen use efficiency compared to soluble NPK fertilizers, where nutrients can be easily lost through leaching. The highest mean average plant height was recorded in T₃, (BSFL frass) 85cm and the lowest was 60cm recorded from T₁ (Control) experiment. (Figure:1)

Figure 1: Change in average tomato plant height subjected to different fertilizer treatment measured in weeks



4.1.2 Fruit size

The Results from this study showed that the average fruit dimension (longitudinally and transversely) were recorded in T₁ (BSFL frass) having 9.0cm and 15.5cm respectively as highest and 7.9cm and 14.0cm respectively for T₁ (Control) showing the least increase (Table 3).

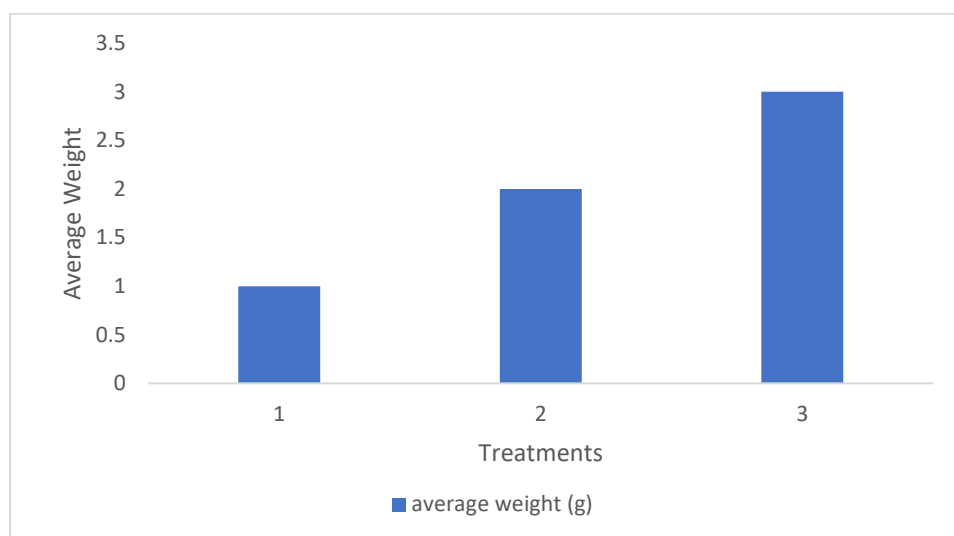
Table 2: Average fruit size (Longitudinally and Transversely).

Treatment	Longitudinal size (cm)
T1	7.9
T2	8.2
T3	9.0

4.1.3 Fruit weight

The significant was seen after recording the average fruit weight in grams with 73.0g for T3 as compared to 64.6g for T2 and 59.8g for T1. The extremely high weight of fruits for tomato plants treated with BSFL frass was accounted to the mechanism of frass on tomato plants. The slow release of nutrients prevents leaching and allows nutrients to be used sustainably thus buildup of biomass that resulted into increased fruit weight. Increase in fruit weight was also due to large fruit size. The impact of the various fertilizer treatments on fruit biomass is presented in fig.2.

Figure 2: Average Fruit Weight of Tomato Plants subjected to different Treatments.



4.2 DATA ANALYSIS

Analysis of plant height was done in IBM statistics version 26. Data for both categorical and continuous variables was entered and cleaned. Using a general, linear model, a univariate analysis was run against the dependent variable (plant height) a fixed factor (time and weeks) and the random factors (T_1 -Control, T_2 - NPK and T_3 – BSFL frass) respectively. The F-test statistics was performed where the calculated F- value were compared with the Tabulated F-value at 0.05% significant levels and the degrees of freedom ((R-1), (R-1) (C-1)). Fruit dimensions and weight were analyzed using descriptive statistics, comparing mean averages across treatments to quantify performance. By calculating the percentage differences in yield and size, the study established the relative efficacy at 10% threshold of BSFL frass versus NPK and the control group at the point of first harvest.

4.2.1 Plant Height

To assess the effect of time (in weeks) and the fertilizer treatment (T_1 – T_3) on the average plant height, results of a Two-way ANOVA revealed a significant difference between the means of the plant height. The mean of squares and F tabulated values for the categorical variables have been presented in Table below.

Table 3: The effect of two categorical variables (Time in weeks and Fertilizer treatment against plant height using Two-way ANOVA

Tests of Between-Subjects Effects						
Source		Type III Sum of Squares	Df	Mean Square	F	Sig.
Intercept	Hypothesis	30016.067	1	30016.067	91.494	.011
	Error	656.133	2	328.067 ^a		
Weeks	Hypothesis	10231.600	4	2557.900	65.756	.000
	Error	311.200	8	38.900 ^b		
Treatments	Hypothesis	656.133	2	328.067	8.434	.011
	Error	311.200	8	38.900 ^b		
Weeks * Treatments	Hypothesis	311.200	8	38.900	.	.
	Error	.000	0	. ^c		

^a mean of squares for the Treatment (T_1 - T_3); ^b Mean of squares for the Time in weeks: df- degrees of freedom; F is calculated F value

The $F_{tab}=3.84$ with (4,8) degrees of freedom at $\alpha=0.05$ significant level. Since $F_{cal} 65.756 > 3.84$ for weeks, reject the null hypothesis and accept the alternative hypothesis. Therefore, time in weeks had a significant effect on the plant height.

The $F_{tab}=4.46$ with (4,8) freedom degrees of at $\alpha=0.05$ significant levels. Since $F_{cal}=8.434 > 4.46$ for the treatments, reject null hypothesis (H_0) and accept the alternative hypothesis.

Therefore, the different fertilizer treatments had significant effect on the plant height.

4.2.2 Fruit size

From table 3, BSFL Frass shows superior results which are attributed to a slow-release supply of macronutrients alongside essential micronutrients like Calcium, which are vital for fruit expansion. Additionally, the chitin found in insect frass triggers plant growth hormones and

boosts the soil's beneficial microbial activity, leading to improved water retention and more efficient sugar transport to the developing fruits.

Fruit size data presented in Table 3 was also analysed using percentage differences to determine the practical efficacy of the fertilizers based on a 10% Efficacy Threshold.

Table 4: Percentage Differences for Fruit Size.

Treatment	Sample Size (n)	Longitudinal (cm)	Transverse (cm)	% Increase over T1
T1	27	7.9	14.0	0.0%
T2	27	8.2	14.5	3.7%
T3	27	9.0	15.5	12.3%

T3 achieved an overall size increase of 12.3%, effectively surpassing the 10% threshold ($12.3\% > 10\%$). T2 recorded a marginal increase of only 3.7%, failing to meet the requirement for superior performance ($3.7\% < 10\%$). Therefore, the alternative hypothesis that there is a significant difference on fruit size between treatments is accepted.

4.2.3 Fruit Weight

From fig. 2, BSFL frass had a tremendous effect on the weight of the fruits because it is rich in both primary and secondary nutrients that boosted the biomass.

Fruit weight data presented in Fig.2 was analysed using percentage differences to determine the practical efficacy of the fertilizers based on a 10% Efficacy Threshold and the results are presented in table 5 below.

Table 5: Percentage Differences for Fruit Weight.

Treatment	Sample Size (n)	Average Weight (g)	% Increase over T1
T1 (Control)	27	59.8	0.0%
T2 (NPK)	27	64.6	8.0%
T3 (BSFL Frass)	27	73.0	22.1%

Treatment 3 (BSFL Frass) achieved the highest mean weight of 73.0g, 22.1% increase over the control. This performance significantly exceeds the 10% efficacy threshold ($22.1\% > 10\%$). In contrast, Treatment 2 (NPK) recorded a marginal ($8.0\% < 10\%$), failing to meet the criteria for superior performance. Therefore, the alternative hypothesis that BSFL frass has a significant effect on fruit weight is accepted.

5.0 CHAPTER FIVE: DISCUSSION OF RESULTS

5.1.0 Introduction:

The growth parameters of tomato plants were greatly improved by application of BSFL Frass as an organic fertilizer alternative to NPK. This is because the slower release mechanism of BSF frass often results in higher nitrogen use efficiency compared to soluble NPK fertilizers, where nutrients can be easily lost through leaching. Also, the slower, the more sustained release of nutrients from frass can benefit long-term soil fertility and reduce nutrient leaching, particularly for long-cycle or repeatedly harvested crops. The nutrients in BSFL frass take a long time to be mineralized, while in NPK, nutrients are readily available. There is plenty of evidence in the literature that confirm BSFL frass is a beneficial amendment for yield in tomato crops.

5.1.1 The effect of BSFL frass on Plant Height.

The findings of this study are in agreement with (Solofondranohatra et al., 2025) who carried out a study and found out that BSFL frass increased seedling growth and plant height. The findings are also in agreement with (Tanga et al., 2022) who grow maize and observed increased plant height. The findings are also in agreement with (Beesigamukama et al., 2021), who carried a study on three key vegetables using BSFL Frass and realized increased plant height. The Two-way ANOVA confirmed that time (weeks) had the most significant impact on plant height. From the results, a notable divergence occurred at Week 6, where T3 (60 cm) began to significantly outpace T2 (48 cm) and T1 (34 cm). This suggests that the microbial mineralization of the organic frass peaked during this period, overlapping with the tomato plant's highest demand for nitrogen during stem elongation. The control group (T1) plateaued at 60 cm between Week 8 and Week 10. This indicates that the soil nutrients were exhausted, leading to stunted vertical growth compared to the treated groups. The rejection of the null hypothesis for both variables supports the reliability of using BSFL frass as a viable alternative to NPK. The significant interaction between treatment and time suggests that the effectiveness of BSFL frass is not just about the amount of nutrients, but the timing of their availability. These findings suggest that for tomato cultivation, BSFL frass is not merely a sustainable alternative but a performance-enhancing amendment.

5.1.2 Effect of BSFL frass in Fruit Size.

The assessment of reproductive performance through fruit dimensions confirms that Black Soldier Fly Larvae (BSFL) frass (T3) significantly enhances fruit development compared to both NPK (T2) and the control (T1). While T2 showed only a marginal 3.7% increase over the

control, T3 achieved a 12.3% improvement, making it the only treatment to surpass the 10% efficacy threshold for superior performance. This suggests that the nutrient composition of BSFL frass likely a combination of essential macro-elements, micronutrients, and organic matter is more effective than synthetic NPK in supporting the physiological demands of fruit expansion in tomatoes. These findings are in agreement with (Zaato et al., 2025) who grew tomatoes in and found out that Black soldier fly frass significantly improves tomato yield. The significant increase in both longitudinal (9.0 cm) and transverse (15.5 cm) sizes in T3 indicates that organic insect-based fertilizers provide a more balanced nutrient release, which may optimize cell division and elongation during the fruiting stage. These results justify the rejection of the null hypothesis and highlight BSFL frass as a more sustainable alternative for improving crop yield and physical fruit quality in tomato production.

5.1.3 The Effect of BSFL Frass on Fruit Weight.

Findings from this study indicate that T3 achieved a mean fruit weight of 73.0g, representing a remarkable 22.1% increase over the control. This result is nearly double the 10% efficacy threshold set for the study, providing strong evidence for the superiority of insect-based organic amendments. The higher biomass in T3 suggests that BSFL frass improved the plant's photosynthetic efficiency or the transport of carbohydrates to the reproductive organs more effectively than NPK. While T2 did increase fruit weight to 64.6g, its 8.0% improvement failed to meet the 10% threshold for superior performance. Synthetic T2 provides a high concentration of macronutrients, but it often lacks the micronutrients such as Boron, Calcium, and Magnesium and organic carbon present in BSFL frass. The findings of this study are therefore in agreement with (Awad et al., 2024) who evaluated the effect of BSFL frass as an organic fertilizer alternative on fruit quality of open field grown tomatoes. The acceptance of the alternative hypothesis that BSFL frass has a significant effect on fruit weight is supported by the wide margin between T3 and T2. Furthermore, the 22.1% weight increase is more pronounced than the 12.3% size increase. This suggests that BSFL frass doesn't just make the fruits bigger in dimension, but significantly denser and more nutrient-packed, which is a high value trait for consumers and the processing industry. The findings of this study are also in agreement with (Salomon et al., 2025) who tested the Potential of black soldier fly larvae frass (BSFL) as a novel fertilizer: impacts on tomato growth, nutrient uptake, and mycorrhizal formation and found out that Biomass production increased rapidly with higher frass application rates.

5.2 CONCLUSION

This study assessed the performance of BSFL frass as an organic fertilizer alternative to NPK and the results showed that tomato plants treated with BSFL frass had increased plant height compared to NPK- treated plants. The increased plant height contributed to better vegetative growth and canopy development, which in turn supported the development of larger fruits.

Consequently, plants treated with BSFL frass also produced fruits with greater size and significantly higher fruit weight. These findings indicate that BSFL frass enhanced overall growth and yield by improving plant stature, which directly influenced fruit development making it a viable and sustainable alternative to synthetic NPK fertilizer.

RECOMMENDATIONS

Farmers should incorporate BSFL frass into tomato production systems to improve plant growth sustainably. However, Further research has to be conducted on the quantity of BSFL frass needed per standing crop from transplanting up to the time of harvesting. There is also need to carry out a study on the postharvest quality of fruits focusing on vitamin C, total soluble solids, and firmness. It was observed that some of the frass treated plants had double fruits (appendix 4) therefore, a further study has to be conducted to confirm this observation.

5.4 LIMITATIONS OF THE STUDY.

The study had many limitations which led to the delay in conducting the experiment.

The study was planned to start in 2025 but after establishing the first seeds on the nursery bed and mulching, the grass that was used harbored termites that ate all the seeds. This interrupted seed germination.

The sun was also too much despite watering of the plants twice in a day that is morning and evening that resulted into drying of the first seedling after transplanting on 15th December 2025.

Additionally, the sun was responsible for burning of the plants treated with NPK where plants on one of the replicates were all lost.

The study was also limited by monkeys as animal pests that picked the first fruits before even ripening from at least every replicate.

Despite of the fact that the plants were sprayed with insecticides and fungicides, they were attacked by incurable bacterial blight that resulted into withering and dying of tomatoes.

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APPENDICES

Appendix 1: Average plant height (cm) of Tomatoes under the different fertilizer treatments measured in weeks

Treatment	Plant height in weeks				
	Week two	Week four	Week six	Week eight	Week ten
T1	12	15	34	60	60
T2	13	16	48	75	79
T3	12	22	60	81	85

Appendix 2: Average number of branches, flowers and fruits.

week	6			7			8			9			10		
treatment	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
no. of branches	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
no. of flowers	4	5	8	10	15	14	14	16	21	12	18	22	12	23	24
no. of fruits	1	3	4	6	8	11	13	15	20	12	26	29	15	28	33

Appendix 3: Average fruit weight.

Treatment	Average weight (g)
T1	59.8
T2	64.6
T3	73.0

Appendix 4: BSFL Frass stimulated double fruiting among the three frass treated plots.



Appendix 5: Insect pest on Tomato Plants.



Appendix 6: Tomato fruits at week 8



Appendix 7: Tomato fruits at week 10



Appendix 8: Harvesting of Tomato fruits at week 11.



Appendix 9: Harvested Tomato Fruits.



