
**FACULTY OF AGRICULTURE AND ANIMAL SCIENCES
DEPARTMENT OF CROP PRODUCTION AND MANAGEMENT**

**EFFECT OF BLACK SOLDIER FLY LARVAE FRASS ON GROWTH AND
YIELD OF BAMBARA NUT**

BY

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DATE: OCTOBER 2025

DECLARATION

I, Aliku Moses, affirm that the information in this research report is fully comprehended by me, and I participated in the experiment carried out to evaluate the effect of black soldier fly frass on Bambara groundnut.

Signature: *Aliku Moses* Date: 5/11/2025

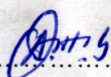
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APPROVAL

This research work done by Aliku Moses from proposal writing, field implementation and report writing has been under my close supervision. I therefore approve it for submission to the crop department science Busitema University

SIGN.....



DATE.....

5/10/25

ACADEMIC SUPERVISOR

Dr. ANDIKU CHARLES

DEDICATION

I wish to dedicate this work to my brothers and sisters, who provided significant financial support to help me complete my work. Another dedication goes to academicians of the new generation who would want to promote the growth of orphan crops in Uganda

ACKNOWLEDGEMENT

Firstly, I want to offer my thanks to God for the abundant grace, the blessing of existence, and the well-being He has granted me with all along. A grate acknowledgment of Busitema University faculty of crop and animal sciences for building students capacities through research study. My grate honor goes also to entire department of crop science together with their leadership under Dr. Amayo Robert the head of department and research coordinator madam Mss. Buteme Ruth for the intellectuality that projects the name of the department. I want to acknowledge my academic supervisor Dr. Andiku Charles who tremendously dedicated his valuable time amidst tight schedules to guide me in this research study. My colleague students matter a lot in my memories with team spirit, encouragement and experiences shared. St. Andrews church of Uganda Arapai and Rev. Obony Godfrey thank you very much for the word of god

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TABLE OF CONTENT

DECLARATION	i
APPROVAL.....	ii
DEDICATION	iii
ACKNOWLEDGEMENT	iv
TABLE OF CONTENT	v
LIST OF ABBREVIATIONS.....	vii
LIST OF TABLES AND FIGURE	viii
ABSTRACT	ix
CHAPTER ONE: INTRODUCTION.....	10
1.1 Back ground of the study	10
1.2 Statement of problem	12
1.4.1 General Objectives	13
1.4.2 Specific Objectives.....	13
1.4.3 Hypothesis.....	13
1.6 Scope of the study	14
CHAPTER TWO: INTRODUCTION.	15
2. 0. LITERATURE REVIEW.....	15
2.1. Overview of Bambara nut.....	15
2.2 Importance of bambara nut	16
2.4 Uses of bio organic fertilizers	16
2.5. Effect of frass on growth and yield parameters.....	17
2.6 Growth parameters:	18
2.7 Relationship between yield and growth parameters	18
CHAPTER THREE: INTRODUCTION	20
3.0 MATERIALS AND METHOD	20
3.1 Description of the study area.....	20
3.2.1 Bambara nut variety	21
3.2.2. Black soldier fly (<i>Hermetia illucens</i>) larvae frass fertilizer.	21
3.3 Description of design and experimental lay out.....	21
3.4 Data collection.....	22

3.6 Statistical Analysis.....	23
CHAPTER FIVE.....	27
DISCUSSION OF RESULTS.....	27
CHAPTER SIX: CONCLUSION AND RECOMMENDATION	28
REFERENCES	a
APPENDICES	e

LIST OF ABBREVIATIONS

BSFF	Black soldier fly frass
SSA	Sub Saharan Africa
NaSARRI	National Semiarid Resources Research Institutes
RCBD	Randomizes Combine Block Design
ANOVA	Analysis of Variance
FYM	Farm Yard Manure

LIST OF TABLES AND FIGURE

Table1 shows experimental lay out.....	22
Table 2. Effect of treatments on the yield and growth Parameters of Bambara Nut ...	25
Table 3 shows the work plan	e
Table 4 shows the Budget.....	e
Figure 1 showing harvesting of Bambara nuts	f

ABSTRACT

The Bambara groundnut (*Vigna subterranea* L.) is a resilient crop that can withstand dry conditions and offers valuable nutrients. indigenous African legume, yet its production in Bambara nut production in Uganda is hampered by inadequate soil quality and a lack of agricultural research. This research examined the impact of black soldier fly frass (BSFF) fertilizer on the growth and yield of Bambara nuts in Eastern Uganda. The study was carried out at the Arapai Campus of Busitema University. (Soroti District), and NaSARRI (Serere District) Employing a fully randomized block arrangement, we will examine five different interventions: 5 kg, 10 kg, and 15 kg BSFF, 1 kg NPK fertilizer, and a control, each replicated three times. Measured growth parameters consisted Height of the plant, leaf area, and leaf area index, whereas yield parameters comprised biomass, pod count and weight, harvest index, and weight of 100 seeds. Findings indicated extremely significant variations ($p < 0.001$) across treatments. The 15 kg BSFF (T3) and NPK (T5) treatments yielded the highest values for most measures, whereas the control (T4) showed the lowest. Correlation analysis showed substantial positive connections between growth and yield traits, indicating that vegetative vigor had a direct impact on productivity. The results indicate that BSFF, an eco-friendly and nutrient-dense organic fertilizer, can offer a sustainable substitute for synthetic fertilizers by enhancing the growth, yield, and soil fertility of Bambara nuts. It is thus advisable to apply 5–10 t ha⁻¹ of BSFF to improve sustainable Bambara nut cultivation in Uganda.

CHAPTER ONE: INTRODUCTION

1.1 Back ground of the study

Bambara nut (*Vigna subterranea* (L) is a grain legume of papillionaceae family seed originates from Africa. Bambara nut was found by Dalziel in its genuinely wild state in 1901, in the North Yola province of Nigeria. He reported that Ledermann also found the wild plant the same year, near Garoua in northern Cameroon. Dalziel's finding was confirmed by Hepper in 1957 in that Bambara nut is now known to extend from Jos Plateau and Yola in Nigeria, to Garoua in Cameroon, and probably beyond. The world's global production of bambara nut is 330 thousand tons and it is commonly grown in sub-Saharan Africa (SSA)(Falola et al., 2022).

In West Africa, Burkina Faso, Niger and Cameroon are the leading producers with annual production of about 42,514t, 21,416t and 20,705t respectively. Although it is also partly grown in Asia(Thailand, Indonesia, and Malaysi)(Khan et al., 2021). In Africa, bambara nut is the most neglected and orphan crop among legumes like green gram, beans soybean chick pea, cow pea(*Vigna unguiculata*) and ground nut(*Arachis hypogaea*) (Valombola et al., 2019). Meanwhile in Uganda, there is limited research and documented information available on bambara nut and has a low yield of 0.2 t ha- (IKiryowa et al.2022). However there are some few districts in Northern (Gulu, Kole, Lira, Ouke ,Oyam ,Pader Agago) and Eastern (Soroti, Kumi, Tororo, Amuria, Kapeleby) Uganda where the crop is also grown(Omondi et al., 2023)

This crop is primarily cultivated for its underground seeds, which are a valuable food source. These seeds can be consumed at various stages of maturity: fresh, partially ripe, or as a pulse when fully mature and dried. They can also be milled into flour for future use (Ibrahim et al., 2018). The dried seeds serve as a crucial food reserve during periods of scarcity due to their excellent storage properties Rachmayani, 2015).

Furthermore, the seeds boast a nutritional profile that makes the crop a well-rounded food. They contain a moderate amount of oil (5-6%), a significant amount of carbohydrates (40-60%), and a substantial amount of protein (16-25%). This composition can help address dietary shortcomings. The high soluble fiber content is

also linked to a decreased risk of certain cancers and heart ailments (Adu-Dapaah et al., 2016). In addition to its nutritional benefits, this crop is drought-resistant and can produce reasonable yields (500 – 800 kg per hectare) even in nutrient-poor soils and regions with limited rainfall. In spite of the above advantages, in Uganda Bambara nut yield remains as low as 0.2 t ha⁻¹ (Kiryowa et al., 2022) and is among the neglected orphanage legume crops like tepary beans (*Phaseolus acutifolius*), marama bean (*Tylosema esculentum*), horse gram (*Macrotyloma uniflorum*), grass pea (*Lathyrus sativus*), and adzuki bean (*Vigna angularis*) among others, with a low production scale of 0.2 to 3 hectares of land in SSA (Gerard et al., 2022). These low production scale associated with low yields of bambara nut are attributed to various contributing factors of low soil fertility and semi-arid climatic condition of SSA and yet the crop has a yield potential of 500kg/ha to 800kg/ha. Among these factors, low soil fertility has been a key issue leading to low yield of bambara nut. And due to this, soil fertility management have been advocated for improvement of yield of crops which include use of chemicals and organic manure of which chemical fertilizer as agrochemicals are very harmful to human health due to their residual effect on food crops being consumed by humans (Boudabbous et al., 2023). This led to choice of organic fertilizers (cow dung, chicken droppings, kitchen refuse, and black soldier fly frass) as the next option to address the problem of low soil fertility and recent study demonstrated frass of black soldier fly (*Hermetia illucens* L) had high total N (3%) and K (4%) contents (Amorim et al., 2024), (Kamdi et al., 2014),

Black soldier fly larva frass is a bio resource composed of excrement, undigested food and insect exoskeletons that can be used in agriculture for many purposes like improve plant growth, increase production and improve soil and this therefore prompts the research study to assess the growth and yield parameter of bambara nut under frass fertilizer treatment (Ibrahim et al., 2018). The yield of bambara nut 500 to 800kg/ha in farm fields can be raised to 4000kg/ha under research conditions. (Verdc, 1995).

BSFF is as effective as mineral NPK fertilizer in growth trials with barley where nutrient content of leaves was similar between the two fertilizer treatments which propose that frass can substitute mineral NPK fertilizer partially or completely,

without compromising biomass output besides, the presence of frass increases the diversity as well as metabolic activity of soil microbiota(Nyanzira et al., 2023).

MATERIALS

1.2 Statement of problem

Bambara nut is an underutilized orphan legume in Africa, including Uganda, despite being a crucial traditional crop important for food security and nutrition for subsistence farmers in sub-Saharan Africa. Many of these semi-arid tropics are marked by erratic weather patterns, extended dry periods, variable rainfall, and poor soil fertility (Basu et al., 2007). Additionally, the primary factors contributing to the reduction in bambara nut production and productivity in developing nations, particularly in SSA, are poor soil fertility coupled with a lack of enhanced agronomic management techniques For both independent producers and larger agricultural operations. (Gerrano et al., 2021). And still FYM vermi composting and other organic source including BSFF fertilizer have been used in other other crops like mung bean , maize among others, BSFF has not been tested on Bambara nut in Uganda has very limited documented information among researchers and the farming community, arguably restricting its production and use (Obura et al., 2022). This study investigated how black soldier fly residue affects the growth of bambara nuts. Growth measurements are important because they greatly determine the crop's ultimate harvest and its yield characteristics in Eastern Uganda.

1.3 Justification

Use of organic nutrient sources is a strategy to produce healthy food, improve soil fertility, and reduce climate impact(Poveda, 2021).

Beans grown using BSFFF showed impacts on traits for example plants were the most towering, featuring the widest leaves and the greatest chlorophyll concentration with more flowers, pods, and seeds compared to NPK treatments. (Chepkorir et al., 2024)

Frass fertilizer, produced from the Utilizing insect larvae that feed on decaying matter to process organic waste offers a method to improve soil quality and increase bush bean production. Insect larval excrement, used as fertilizer, is rich in nutrients and beneficial microorganisms. However, there is limited research on how well this fertilizer performs on leguminous crops like bush beans. BSF frass is superior to NPK in enhancing the vegetative growth and pod biomass of green bean plants because of

its high levels of organic carbon that further aids rapid frass decomposition and mineralization (Ony et al., 2024)

BSFF as bio fertilizer is a useful technology to support developing organic farming and it has been found to perform as well Frass, an insect-derived waste product, has been shown to potentially substitute some or all mineral NPK fertilizers in barley growth studies without negatively impacting biomass production. Research also suggests that using frass can increase the variety and activity of soil microorganisms (Nyanzira et al., 2023). Bambara groundnut remains a relatively neglected crop, with insufficient research on its cultivation requirements, indicating a need for more investigation (Umeugokwe et al., 2021). Research indicates that employing processed black soldier fly larvae waste as a natural fertilizer can improve the development of different types of plants, such as French beans, tomatoes, and kales (Boudabbous et al., 2023)

1.4.0 OBJECTIVES

1.4.1 General Objectives

To improve the long-term viability of black soldier fly residue as a soil fertilizer and increase crop yields.

1.4.2 Specific Objectives

1. To evaluate the effect of black soldier fly residue fertilizer on the growth and yield traits of bambara groundnut using a more conventional approach.
2. To investigate the connection between production and development characteristics of bambara groundnut using black soldier fly residue as fertilizer, expressed in a more formal way, utilizing common synonyms.

1.4.3 Hypothesis

1. Frass fertilizer from black soldier flies boosts the yield growth metrics of Bambara nuts
2. There is a relationship between how well bambara nuts grow and how much they produce when they are fertilized with black soldier fly waste.

1.5 Significance of the study

This study explored the potential of black soldier fly frass as a natural fertilizer. If effective, using this organic material could decrease the need for artificial fertilizers

and gradually improve soil quality. The study contributed to the growing body of knowledge on insect-based fertilizers, encouraging innovation in alternative nutrient sources and bio-based farming practices.

Findings from the research informed agricultural extension officers and policy makers to promote recommend and promote use of black soldier fly frass for organic farming and sustainable agriculture.

1.6 Scope of the study

This research investigated two key aspects: first, how black soldier fly frass fertilizer affects various growth measurements (plant height, number of leaves, leaf area, leaf area index, number of branches) and yield characteristics (biomass, fresh pod weight per plant, number of pods per plant, number of branches, harvest index, and weight of one hundred seeds) in bambara groundnut. Second, it examined the relationship between yield and the growth characteristics of bambara groundnut when using black soldier fly frass fertilizer.

CHAPTER TWO: INTRODUCTION.

2. 0. LITERATURE REVIEW.

2.1. Overview of Bambara nut

Bambara nut (*Vigna subterranea* (L)), a leguminous grain of the papilionaceae family, is native to Africa and primarily cultivated in Sub-Saharan Africa (SSA), particularly West Africa, though It is also cultivated in Asian countries, particularly Thailand, Indonesia, and Malaysia (Khan et al., 2021). Dalziel first found the wild Bambara nut in 1901 in the North Yola province of Nigeria, and noted that Ledermann also recognized the wild plant around the same time near Garoua in northern Cameroon. Hepper verified Dalziel's discovery in 1957, potentially expanding further. Bambara nut is a yearly legume that features herbaceous, intermediate, pinnately trifoliate leaves and a robust nodulated taproot with abundant geotropic lateral roots; it has sprawling, branching stems with nodes at ground level, where clustered leaves emerge at the soil surfaceThe plant's leaves are composed of three leaflets arranged along a central stalk, have a smooth surface, and are attached to the stem by an erect leaf stalk that is enlarged at its point of attachment (Olanrewaju et al., 2021). Its roots feature numerous nodules that facilitate nitrogen fixation. The seed pods are round, wrinkled, and longer than 1.27 cm; each pod holds one or two seeds which exhibit variability in form and color (smooth, circular, or oblong, and various shades of white, tan, reddish-brown, reddish, yellowish, spotted, and dark), and are quite firm when mature. desiccated.(Mahama, 2023). Bambara nut varieties namely Black variety (kernel is usually between small to medium size), Red variety (kernel is usually large size), Cream/black eye variety (kernel is usually large size), Cream/brown variety (large moderate size), Cream/no eye variety (very small pod and kernel), Speckled/flecked/spotted variety (purple color predominates but the kernel is small) and Brown variety (variation is ranging from light to dark brown, and the kernel has a medium size to) (Adejuyitan et al., n.d.) . Bambara pods have 1-2 seeds of round or literally flattened shape with smooth hard seed coat and self-pollinated cleistogamous flowers which needs temperature range of 30-40⁰c at flowing time, flowering occurs after 40-60 days of planting, pod maturity after 30 days of pollination and has 90-170 days growth cycle (Quintieri et al., 2023) The seeds provide a full diet, comprising 63% carbohydrates, 19% proteins, and 6.5% fats (Adebola & Esson, 2017). The

average yield in SSA is also relatively low at where typical production is around 0.4 tons per hectare, yields of 4 to 6 tons per hectare are possible with improved practices (Gerard et al., 2022). Bambara groundnut grows well at elevations up to 1600 meters, with best results at specific daytime temperatures between 20 and 28 degrees Celsius. The time needed for the plant to mature ranges from 110 to 150 days, influenced by factors like climate and the specific variety. While adaptable to various well-drained soils, it performs best in light, sandy loams with a slightly acidic pH (5.0-6.5). Interestingly, this crop can also grow well in nutrient-poor soil (Basu et al., 2007).

2.2 Importance of bambara nut

This nutritious bean, often called a "complete food," boasts a well-proportioned combination of macronutrients: roughly 64% carbohydrates, 24% protein, 7% fat, and 6% fiber. It is also a good source of minerals (Tenkodogo et al., 2023). In Congo, the seeds are roasted and crushed to extract oil for cooking (Kiryowa et al., 2022). This crop thrives even in depleted soils (yielding 500-800 kg per hectare) and areas with limited rainfall because it can withstand dry conditions better than crops like groundnuts and beans. Furthermore, it enriches the soil by fixing atmospheric nitrogen (Mayes et al., 2019). Bambara nut plays a vital role... in low input agricultural systems due to its capacity to convert atmospheric nitrogen into soil, facilitated by Bradyrhizobium bacteria (Nafula et al., 2021). Bambara groundnuts currently averages between 650 and 850 kg/ha, with yields up to 4.1 t/ha reported by Collinson and seed yield of 2.6 t/ha (Akpalu et al., 2012)

2.4 Uses of bio organic fertilizers

These are organic component derived from decomposition of agricultural waste, animal manure (chicken, cattle dung, small ruminants and insect frass) or vermicompost used for soil amendments (Syed et al., 2021). Organic manure include; farmyard manure (a blend of cow dung, urine, and straw), green manure (plants such as legumes cultivated to be mixed into the soil), compost (Decomposed organic materials from kitchen and other farm wastes), vermin composite (Compost produced with the help of earthworms), frass (excrements and undigested food from insects) and oil cakes (residue left after oil extraction from seeds). Premium organic fertilizers like insect frass fertilizer, produced through the Chepkorir et al. (2024) found that using saprophytic insect larvae to process organic waste can improve soil quality and

increase bush bean production. This is because insect excrement, used as fertilizer, is rich in nutrients and helpful microorganisms.

2.4.1 Frass fertilizer

Black soldier fly larvae residue, a blend of waste, unused nourishment, and insect exoskeletons, represents a natural asset. Applied in farming, it can improve plant development, increase yields, and improve soil quality (González-Lara et al., 2024). Chemical examination reveals that the levels of nitrogen, phosphorus, and potassium (NPK) in this residue are considerable. This insect byproduct is similarly combined with its nutritional makeup (total nitrogen = 4.98%, total phosphorus = 2.63%, total potassium = 1.65%, organic carbon = 45%, and pH = 7.8), highlights its value as a possible plant food.

Importance of frass fertilizer in bambara nut production.

Treated animal waste shows significant potential as a replacement, in part or entirely, for synthetic fertilizers. This is because it decomposes quickly and contains plenty of easily accessible nutrients (Houben et al., 2020). Houben et al. (2020) also highlights the importance of alternate protein sources for livestock and biofuel production. Furthermore, it contains specific unusual fats and chitin, which have substantial financial worth due to their potential uses in the food, beauty, and medicine industries.

2.5. Effect of frass on growth and yield parameters

Number of pods: The waste produced by the insects, which contained important elements, enhanced the soil's richness and helped plants take in nutrients more effectively, supporting the growth of seed. **Biomass:** Beesigamukama et al. (2020) demonstrated that fertilizer derived from Black Soldier Fly (BSF) waste provided abundant nitrogen, which fueled strong plant development and significant yields in maize. Similarly, Ony et al. (2024) discovered that BSF waste excelled over NPK fertilizer in improving plant growth and pod production of green bean plants due to its elevated organic carbon content, which facilitates swift frass decomposition and mineralization. **Number of pods per plant:** frass contains more Nitrogen and microbial activity which enhance chlorophyll and canopy development and especially branches from which pods develop **Pod weight:** plant absorbs macro organic Nutrient in the frass aids pod and seed development, as shown by Boudabbous et al. (2023), who revealed the beneficial impact of frass on plant height, chlorophyll levels,

and grain yield. **Harvest index:** this was influenced by the frass fertilizer by the fact that it contains high amount of plant macro nutrients like NPK, plants absorb them in adequate amount to make the economic part say the pods and seeds. **100 seed weight:** insect frass fertilizer derived from valorization of organic wastes using saprophytic insect larvae as Bioconverters can enhance soil quality and boost bush bean production thanks to abundant nutrients and helpful microbes (Onah et al., 2023), while Bambara nut absorbs nutrients to transform them into assimilates for seed development.

2.6 Growth parameters:

Leaf number: study conducted by IPI et al., (2000) recorded that there is vigorous vegetative growth of bush bean under BSFF due to high content of nitrogen and carbon nutrients which can be the same case in Bambara nut. **Number of branches:** Vasanthi et al. (2015) noted at harvest; average count of three stems from five healthy plants and further mentioned in their research that using organic fertilizers enhanced root growth of mung bean, resulting in greater branching (Das et al., 2014). **Plant height:** Research proved that BSFL frass, as a natural fertilizer, can enhance the growth of various plants, including French beans, tomatoes, and kales.) (Boudabbous et al., 2023) this was surely seen from the study conducted on bambara nut. **Leaf area:** More nitrogen and microbial activity enhance chlorophyll and canopy development. (Lomonaco et al., 2024) .the same case was observed with in the study with bamabra nut

2.7 Relationship between yield and growth parameters

Black soldier fly larvae frass, a byproduct composed of excrement, leftover food, and insect exoskeletons, has beneficial uses in agriculture, including improving plant development, increasing crop production, and improving soil quality (González-Lara et al., 2024). The black soldier fly (*Hermetia illucens*) is well-suited to convert organic waste into useful protein and fat, offering environmentally friendly approaches to manage organic waste and bolster food availability (Tripathi et al., 2023). According to Alagappan et al. (2023), about 1.3 billion tons of consumable food are discarded annually, contributing to around 6% of all greenhouse gas emissions caused by humans (Anyega et al., 2021). Indicates this can be handled by converting it into frass fertilizer, which serves as organic fertilizer crucial for crop

Lomonaco et al. (2024) highlight insect larval excrement (frass) as a promising fertilizer source, supplying nitrogen (N), phosphorus (P), and potassium (K), which are vital for plant development. Studies show that black soldier fly (BSF) frass can replace traditional fertilizers in growing crops such as sweet potato (*Ipomoea batatas*) (Romano et al., 2022) and corn (*Zea mays*) (Beesigamukama et al., 2020). Despite this potential, frass is not fully appreciated, and further investigation into its various applications is needed (Arabzadeh et al., 2023).

It has been noted in forests that frass deposition accompanies insect herbivory in the canopy. Research indicates that frass influences C and N dynamics and positively affects tree growth by enhancing total soil C, N, and NH_4^+ levels, along with microbial soil respiration (Moctar & Baoua, 2021).

Frass comprises 92% dry matter (DM), 86% organic matter, 4% nitrogen, 54% neutral detergent fiber, and 19% acid detergent fiber; thus, recent studies propose models for commercial BSFL cultivation and detail a dried larval yield of 150 tons weekly, potentially yielding even more for frass. (Jasso et al., 2023).

Sylvia et al., (2023) conducted an experiment involving various soil organic fertilizer treatments on kales in an open field using a randomized complete block design (RCBD). Six different treatments of organic manure and NPK fertilizer (growth medium) were replicated six times. The six growth medium treatments were: A: Untreated soil (control), B: Soil amended with a chemical fertilizer (NPK, 10g per planting), C: Soil blended with chicken manure (ratio of 2 parts manure to 1 part soil), D: Soil supplemented with 50g of insect frass, E: Soil supplemented with 100g of insect frass, and F: Soil supplemented with 150g of insect frass.

CHAPTER THREE: INTRODUCTION

3.0 MATERIALS AND METHOD

3.1 Description of the study area

The study took place in both Soroti and Serere, representing a multi-site approach designed to expedite data collection.

Within Soroti, the research was specifically located at the agricultural farmland of Busitema University's Faculty of Agriculture and Animal Sciences, known as the Arapai campus, is located around eight kilometers from Soroti city, along the road to Moroto. Its precise location is defined by the coordinates 01°46'48"N 33°37'30"E / 1.78000°N 33.62500°E / 1.78000; 33.62500 (Okema, 2023). This area receives an average yearly precipitation of 1100 to 1200 mm, but the irregular rainfall distribution leads to recurring periods of both excessive flooding and prolonged dry spells. The soil quality is typically poor, with shallow depths and a coarse composition. Principal agricultural crops cultivated in this region include sweet potatoes, sorghum, corn, plantains, bananas, beans and groundnuts. At the same time, a second study was conducted at the Serere research facility located in the Serere area of eastern Uganda. This area was formerly part of the Soroti area. Geographically, the area is located approximately between 1° 33' and 2° 23' North and 30° 01' and 34° 18' East, at an elevation of over 2500 feet. Serere is located south of Buyende, southeast of Pallisa, northeast of Soroti, north of Kaberamaido, and west of Ngora in the East. Rainfall usually ranges from 1000mm to 1500mm and takes place during two intervals: March to July and September to November. A short dry spell took place between the two rainy seasons from mid-June to mid-July. The extended dry period lasts from late November to early March.

Serere District experiences average annual high temperatures of approximately 31.3°C and average annual low temperatures of 18°C. The hottest month is February, with temperatures reaching up to 35°C. The district's geology is characterized by the underlying geology consists of ancient, crystalline rocks like granite and metamorphic formations. The prevalent soils are the Serere catena and Metu complex, typically deeply weathered and sandy, providing good drainage and a loose structure. Flat, lower-lying regions are characterized by substantial river deposits, interspersed with

scattered rocky outcrops. Serere's vegetation is diverse, ranging from tree-dominated savannas to open grasslands, forests, and riverine vegetation. Extensive swamps stretch across a considerable area, from Apujan in Kyere Sub County, Serere District, to Ngora County, Kumi District. Drier, more northerly locations feature vegetation dominated by thorny shrubs.

3.2 Description of materials.

This describes the main materials used in the experiment.

3.2.1 Bambara nut variety

Nav4 cream Bambara nut seeds variety was used for this trial because it was most common variety grown by the local farmers in Teso region. This variety has high tolerance to prolonged drought and has ability to do well in poor soils of the region.

3.2.2. Black soldier fly (*Hermetia illucens*) larvae frass fertilizer.

Frass is an insect-derived organic residue composed mainly of insect excreta and decomposed feed from larvae, like kitchen remains, maize bran and wasted fruits like avocado used as substrate to feed the larvae of the black soldier fly larvae.

The BSF fertilizer was obtained from a certified Earth feeds company for poultry feed and bio fertilizers in Arua. The bulky obtained material was sieved using a local ordinary net from the laboratory to separate undecomposed manure and other impurities like metal and plastics from the fine decomposed.

3.3 Description of design and experimental lay out

This trial was planted for one season at two locations one at Busitema University Arapai campus Soroti district and the other at NaSARRI, Serere district using RCBD with three replicates. Each replicate consisted of 5 plots each measuring (4mx4m) with a distance of 0.5m between plots and 1m between replicates in which 5 treatments (T1 =5kg Frass T2 =10kg Frass, T3 =15kg Frass, T4 = negative control no fertilizer and T5 = 1kg NPK Fertilizer) were randomly assigned using RCBD.(Salim & Kutubi, 2022).

The spacing of bambara nut was 50cm x 20cm with each plot having eight rows of plants each with 20 plants (Akpalu et al., 2012).

Table1 shows experimental lay out

0.5m									
T3		T2		T4		T5		T4	
1m									
T5		T2		T4		T3		T1	
T1		T4		T3		T2		T5	
Block					Plots				

3.4 Data collection

At physiological maturity, growth parameters were gathered. This involved randomly choosing 20 plants from the inner four rows of each treatment group. Measured data included plant height (from soil level to the highest point, including the end leaflet), recorded in centimetres at 12 weeks.), number of branches (by physical counting all the branches at 12 weeks of physiological maturity), number of leaves (by physical counts on the leaves 12 weeks of physiological maturity), leaf area (by assessing the length and width of the three leaflets and subsequently calculating the average for all three leaves in cm^2 $\text{LA} = \left(\frac{\text{TLA}}{\text{LA}}\right) \times \text{CF } 1.8$).

Area index LAI (leaf area per ground area LAI) $= \left(\frac{\text{TLA}}{\text{LA}}\right)$.

Yield parameters: These parameters were got during and after harvest which included biomass; by measuring weight of the entire plant along with pods per plant in grams, the fresh pod weight was obtained by assessing the weight of fresh pods per plant in grams, and the number of pods per individual sample plant; by counting quantity of pods for each sample plant, dry pod weight was got by measuring dry pods weight per plot after two week recorded in grams and 100 seed weight was got by randomly collecting 100 seeds per treatment and measured in grams. Harvesting; this was done manually at physiological maturity by uprooting and digging out using a hoe to remove all the pods from the soil. Later the pods were plucked from the plants and

soil was cleaned from pods manually using hand. Drying of the pods: This was done after harvesting where the pods were sun dried on concrete floor for two weeks at 12% moisture content.

3.6 Statistical Analysis.

The collected data were entered into a Microsoft Excel spreadsheet and analysed via ANOVA (Analysis of Variance) employing R version 4.5.1. Mean comparisons were conducted using Duncan's Multiple Range Test, with a Least Significant Difference (LSD) approach, at a significance level of 0.05. Furthermore, Pearson Correlation analysis was carried out utilizing R version 4.5.1 as well.

CHAPTER FOUR

RESULTS

The results in Table.2 indicate that all assessed growth and yield parameters of Bambara nut were substantially affected by the treatments applied ($p < 0.001$). Treatments T3 and T5 consistently exhibited the highest values for vegetative and yield traits, such as biomass, pod weight, harvest index, and seed weight, demonstrating excellent performance and effective assimilate allocation. Moderate values were noted in T1 and T2, whereas T4 indicated the lowest performance across most parameters

Table 2. Impact of treatments on the growth parameters and yield of Bambara Nut

YIELD PARAMETERS

GROWTH PARAMETERS

Treatm ent	No. of Pods.	Dry Pod Weight/plot (kg ha ⁻¹)	Fresh pod weight (kg ha ⁻¹)	Harvest Index%	biomass (kg ha ⁻¹)	100 Seed Weight (g)	Plant Height (cm)	No. of Branc hes	No. of Leaves	LEAF AREA	LEAF AREA INDEX
T1	41.18± 1.71 a	5227.79 ± 56.18 b	7469.23 ± 310.9 b	45.1850 7a	16973.08 ± 278.6b	98.67 ± 1.76 b	23.79 ± 0.90 a	12.53 ± 0.24 ab	46.03 ± 2.32 a	33 979.14 ± 146.58 b	33.98 ±6.11c
T2	41.19 ± 2.24 a	5236.47 ± 78.22 b	7739.28 ± 774.2 b	46.2716 3a	16848.20 ± 921.7b	104.18 ± 2.23 b	22.90 ± 0.95 c	13.20 ± 0.25 ab	47.93 ± 2.35 a	35 508.17 ± 146.58 b	35.51 ±6.23c
T3	44.17 ± 1.45 ab	6155.82 ± 50.09 a	8645.15 ± 545.4 a	48.2546 9a	21612.88 ± 692.2a	124.33 ± 16.99a	23.52 ± 0.89 ab	13.59 ± 0.26 a	48.59 ± 2.41a	44414.4±14 6.58a	44.61 ±8.25a
T4	35.70 ± 1.35 b	4977.35 ± 519.51 c	6280.95 ± 97.8 c	26.6652 1b	14202.38 ± 278.7c	94.17 ± 2.12 b	23.12 ± 0.87 bc	11.91 ± 0.23 b	39.62 ± 1.91b	29416.70±1 46.58c	29.42 ±5.58d
T5	44.28 ± 1.56 ab	5905.75 ± 248.78 a	8392.22 ± 540.6 a	47.3744 5a	20980.55 ± 594.0a	126.50 ± 3.20 a	23.78 ± 0.91 a	13.12 ± 0.25 ab	46.60 ± 2.33a	38383.10±1 46.58a	38.38 ±6.97b
LSD (5%)	4.7	23.23	31.51	7.43	152.7	22.99	2.73	1.66	6.3	190.7	18.55
CV (%)	26.7	30.28	29.66	14.4	22.11	17.67	12.84	10.84	7.51	23.46	11.52
S.E	18.54	91.64	124.27	2.52 <0.001	128.41	19.33	0.9	0.25	2.33 <	146.58	6.63
P-value	< 0.001	< 0.001	< 0.001		< 0.001	< 0.001	< 0.001	< 0.001	0.001	<0.001	<0.001

RESULTS

Correlation analysis indicated a strong relationship between Leaf Area and Leaf Area Index ($r = 0.9991$) as well as Number of Leaves ($r = 0.8550$). Total Count of Branches was positively associated with vegetative and yield traits ($r = 0.6935$ – 0.7936), while **Fresh Pod Weight** correlated moderately with leaf and branch traits ($r = 0.5094$ – 0.6202). **Biomass** had strong positive correlations with most traits ($r = 0.6530$ – 0.8544), highlighting its key role in plant productivity.

Table. 3: Correlation Matrix Showing Relationships among Growth and Yield Traits of Bambara Groundnut

Variables	LEAF_AREA	LEAF_AREA_INDEX	NUMBER_OF_LEAVES	NUMBER_OF_PODS	NUMBER_OF_BRANCHES	FRESH_POD_WEIGHT	BIOMASS
LEAF_AREA	1.0000	0.9991	0.8550	0.3782	0.7936	0.5094	0.8019
LEAF_AREA_INDEX	0.9991	1.0000	0.8546	0.4806	0.6935	0.6112	0.8027
NUMBER_OF_LEAVES	0.8550	0.8546	1.0000	0.4325	0.7220	0.4465	0.8544
NUMBER_OF_PODS	0.3782	0.4806	0.4325	1.0000	0.7347	0.6202	0.6530
NUMBER_OF_BRANCHES	0.7936	0.6935	0.7220	0.7347	1.0000	0.5518	0.7490
FRESH_POD_WEIGHT	0.5094	0.6112	0.4465	0.6202	0.5518	1.0000	0.7344
BIOMASS	0.8019	0.8027	0.8544	0.6530	0.7490	0.7344	1.0000

The notable positive relationships between plant growth characteristics and factors contributing to yield suggest that robust plant development leads to better yields. In particular, plant mass and the number of branches appear to be important overall traits, connecting strong growth to the amount of nuts produced. These traits can be useful indicators for selecting plants to improve Bambara nut production in comparable settings.

CHAPTER FIVE

DISCUSSION OF RESULTS

The different treatments had a significant impact on all measured factors, demonstrating a considerable effect on both the growth and yield of Bambara groundnut which agrees with Das et al., (2014) study on application of FYM as organic manure which enhanced root growth of mung bean, resulting in greater branching which is responsible for pod development.

Bambara drought tolerant and nut thrives well in marginalized soils where other crops do not thrive well (Omondi et al., 2023). As such, all assessed growth and yield parameters of bambara nut were substantially affected by the treatments applied for example, where no fertilizer was applied, there was reasonable pod formation

The highest increased **Frass and NPK** stood out with superior performance across all growth and yield traits, confirming that these management regimes created favorable conditions for balanced vegetative and reproductive processes. Similarly, a study among four doses of CFF (cricket frass fertilizer) tested that the highest dose (400 kg/ha) had the most comparable effect to NPK on green bean plants where vegetative, pod biomass production per plant increased with the addition of CFF at 400 kg/ha, which supported previous findings that using insect frass fertilizer improved nutrient levels in soil .(Ony et al., 2024)

The strong positive relationship between biomass production, branching, and pod yield underscores the importance of vigorous canopy growth in optimizing productivity. Conversely, the weaker performance of **negative control with no fertilizer** suggests that limited vegetative development restricts yield potential in Bambara groundnut whereas(Lomonaco et al., 2024) suggeset that the higher the number of brunches, the higher the nuber of leaves and leaf area and other subsequent yield parameters like pod numbers pod weights amongothers

CHAPTER SIX: CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The results clearly demonstrated that the applied treatments had a substantial impact on both the development and production of Bambara groundnut. Specifically, treatments T3 and T5 consistently showed improved results in terms of pod quantity, dry weight, and seed dimensions compared to the other treatments. Their elevated harvest index scores suggest a more efficient transfer of resources from the plant's foliage to the pods. Robust vegetative characteristics, like larger leaf area and increased branching, seemed to directly contribute to greater yields. Conversely, treatment with no fertilizer showed weak performance, indicating that poor vegetative growth limits productivity. Overall, the findings suggest that maintaining healthy canopy growth and efficient biomass use is essential for improving yield. Treatments that encourage balanced vegetative and reproductive development therefore offer the best production results.

6.2 RECOMMENDATION

Based on the findings, approaches comparable to treatments T3 and T5 appear to be the best for improving the growth and yield of Bambara groundnut. To ensure consistent results, these approaches should be evaluated in various environmental and soil settings. Farmers should focus on methods that encourage greater leaf size and more branches, which will promote pod development. Future research could also explore the best ways to manage nutrients and water when using these successful approaches. Ultimately, outreach efforts should assist farmers in implementing these practices to increase Bambara groundnut yields and promote long-term production.

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APPENDICES

Table 3 shows the work plan

Activities	Date
Sourcing of seed and manure	December January 2025 to February 2025
Field preparation	February 2025
Planting and manure application	1-10 April 2025
Harvest	1- October June 2025
Data collection	From planting to harvest
Weeding	From two weeks after germination and routinely depending on field condition
Report writing and presentation	May to July 2025

Table 4 shows the Budget

Item	quantity	Unit price	Amount
Bambara nut seed	15kg	4,000	60,000
Frass fertilizer	50kg		150,000
NPK fertilizer	3kg	4000	12,000
Hoes	1	15,000	15,000
Labor			50,0000
Bowels	2	5,000	10,000
Gun boots	1	20,000	20,000
Data collection tools : pens books rulers, pencils weighing scale		20,000	20,000
Storage bags marking taps	20 pieces		20,000
Transport			100.000
Messelineaous			155,000
Total			612,000

Figure 1 showing harvesting of Bambara nuts

