BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF CROP SCIENCE

TOPIC: EFFECTS OF FERTILIZER AND POPULATION DENSITY OF SESAME

BUNGIRA RURAMAI B223809B

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCE HONOURS DEGREE (CROP SCIENCE)

SUPERVISOR: Dr Mutssengi
DATE: JUNE 2026

RELEASE FORM

Author : Ruramai Bungira

Reg number : B223809B

Degree : Bachelor of Agricultural science honors degree in Crop Science.

Project title : Effects of fertilizer and population density of sesame.

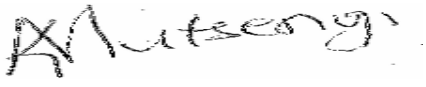
Permission is hereby granted to Bandura University of Science Education Library to produce a single copy of this dissertation and lend such copy for private, scholarly study or scientific research only.

Signed……..

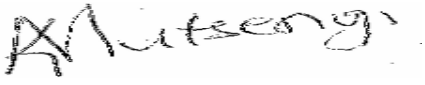
Date……/……/…….
Permanent Address: 541 Crescent Glenview 1 Harare

This thesis was submitted in partial fulfillment of the Bachelor of Agricultural Science Honors Degree in Crop Science with the approval of Supervisor

Mr Mutsengi (Supersvisor)

Signature 

Date 02/09/26

Mr Mutsengi (Chairperson 
Date 02/09/26

DECLARATION

I, RURAMAI BUNGIRA, registration number B223809B, do hereby declare that this dissertation is my own original work and has not been copied from any source without due acknowledgement of the source.

DEDICATION

The project is dedicated to my family, with love and the department of Crop Science.

ACKNOWLEDGEMENTS

This project was sponsored by Bindura University (BUSE) with all required inputs.

Greatest gratitude goes to the Lord God Almighty, without whom the project would not be a success. I thank my family for their unwavering support and love throughout the course of the project. I acknowledge Easi Seeds Head of Agronomy Mr Sigwadi for sharing insights on sesame. I further extend my gratitude to Chikaka our school technician and Mr. Mutemeri for their hands for their technical assistance. I also want to thank Dr Mutsengi for his invaluable knowledge insights.

ABSTRACT

Effect of Fertilizer Type and Population Density on Growth and Yield of Sesame (Sesamum indicum L.) in Shamva, Zimbabwe.

Sesame (*Sesamum indicum L*.) is an important oilseed crop with significant economic potential for smallholder farmers in Zimbabwe. However, productivity remains low due to suboptimal agronomic practices, particularly inadequate fertilization and inappropriate plant spacing. This study was conducted to determine the effects of fertilizer type and population density on the growth and yield of sesame in Shamva, Zimbabwe. The experiment was laid out in a Randomized Complete Block Design (RCBD) with a 3 × 3 factorial arrangement, comprising three fertilizer treatments (inorganic fertilizer, organic fertilizer, and control) and three population densities (low: 25 plants/m², medium: 33 plants/m², and high: 50 plants/m²), replicated three times. Data were collected on plant height, number of leaves, stem girth, number of capsules per plant, 100-seed weight, and final grain yield per plot. Results revealed that inorganic fertilizer significantly ($P<0.001$) outperformed organic fertilizer and the control across all growth and yield parameters, producing the tallest plants (142.5 cm), thickest stems (4.85 cm), most capsules per plant (116.8), and highest grain yield (1.136 kg/plot). Population density significantly influenced plant height, stem girth, capsules per plant, and grain yield, with medium density producing the highest total yield per plot (0.838 kg/plot) despite low density producing the most capsules per plant. The study concludes that inorganic fertilizer combined with medium population density is the most effective strategy for maximizing sesame yield in Shamva. Farmers are recommended to adopt this integrated approach, applying complete NPK fertilizer and planting at approximately 33 plants/m² to achieve optimal productivity. Future research should explore long-term soil health implications, conduct economic analyses, and test variety-specific responses to density.

KEY-A1: Farm Village-style small farm6ha arable + grazing. 99-year lease.

-A2: Farm Commercial single-block farm, from 200ha.

-FTLRP: Fast Track Land Reform Program

Table of Contents

RELEASE FORM 2

DECLARATION 3

DEDICATION 4

ACKNOWLEDGEMENTS 5

ABSTRACT 6

LIST OF FIGURES 10

LIST OF ACRONYMS AND ABBREVIATION 11

CHAPTER 1: INTRODUCTION 12

1.1 Background of the Study 12

1.2 Problem Statement 13

1.3 Justification of the Study 14

1.4 Research Hypotheses 14

1.5 General Objective 15

1.6 Specific Objectives 15

1.7 Scope and Limitations of the Study 16

CHAPTER 2: LITERATURE REVIEW 17

2.1 Effects of Nitrogen Levels on Sesame Growth and Yield 17

2.2 Effects of Plant Population Density on Sesame Performance 20

CHAPTER 3 24

MATERIALS AND METHODS 24

3.1 Study Site 24

3.2 Experimental Design and Treatments 24

3.3 Crop Establishment and Management 25

3.4 Data Collection 26
3.5 Data Analysis 27
CHAPTER 4: RESULTS 28
4.1. Plant height 28
4.2 Stem girth 28
4.2.1Effect of plant density and fertilizer on sesame plant stem girth 28
Effect of fertilizer on stem girth 29
4.2.2 Effects of plant density on sesame plant stem girth 29
4.3 Leaves 30
4.3.1. Effects of fertilizer and plant density on leaves. 30
Effect of fertilizer on sesame plant leaves. 30
4.3.2 Effect of plant density on sesame plant leaves 31
4.4. Number of capsules 31
4.5. 100 Seed weight 32
4.5.2. Effects of plant density on sesame seed weight 33
6. Final grain yield 33
CHAPTER 5: ANALYSIS OF RESULTS 35
5.1 Overview of the Experimental Factors 35
5.2 Analysis of Plant Height 35
5.3 Analysis of Stem Girth 36
5.4 Analysis of Number of Leaves per Plant 37
5.5 Analysis of Number of Capsules per Plant 38
5.6 Analysis of 100 seed weight (g) per plot 39
5.9. Final Grain yield 40

CHAPTER 6: RECOMMENDATIONS AND CONCLUSIONS 40
6.1 Introduction 40
6.2 Summary of Key Findings 41
6.3 Conclusions 42
6.4. Recommendations. 43
6.4.1 Recommendations for Smallholder and Commercial Farmers in Shamva and Similar Regions 43
6.4.2 Recommendations for Future Research. 44
6.5 Final Remarks. 45
REFERENCE 46
APPENDIX 49

LIST OF FIGURES

Table 4.1 Fertilizer and population density on plant height……..29
Table 4.2.1 Effects of fertilizer on sesame plant stem girth……..29
Table 4.2.2 Effects of population density on stem height…….29
Table 4.3.1 Effects of fertilizer on production sesame plant leaf……30
Table 4.3.2 Population density effects on production of sesame plant leaf……..30
Table 4.4 Effects of fertilizer and population density on production of sesame plant capsules……..31
Table 4.5.1 Fertilizer effects on 100 seed weight…….32
Table 4.5.2 Population density effects on 100 seed weight…….…..33
Table 4.6 Effects of fertilizer and population density on final grain yield……..34

LIST OF ACRONYMS AND ABBREVIATION

A1: Small-scale resettlement farm model

A2: Large-scale commercial resettlement farm modelha: Hectares

FTLRP: Fast Track Land Reform Program

Supervisor: Not an acronym, but key role in farm/business structure

FAO: Food and Agriculture Organization.

CHAPTER 1: INTRODUCTION

1.1 Background of the Study

Sesame (*Sesamum indicum L.*) is one of the oldest and most important oilseed crops cultivated worldwide. It produces high quality edible oil that is rich in antioxidants, protein (20%), and carbohydrates (14 to 20%), making it valuable for human nutrition, livestock feed, and industrial applications such as soap, paint, pharmaceuticals, and insecticides (BARI, 1998; Hill, 1972). Despite its potential, sesame remains underutilized in many developing countries, including Zimbabwe.

In Zimbabwe, sesame is grown predominantly in the drier agro ecological regions, where its drought tolerance makes it a valuable alternative to traditional rain fed crops. The major sesame producing areas include Masvingo Province, particularly the districts of Mwenezi and Chiredzi, which together account for about 31% of national marketed sesame according to Charamba I. This region has seen significant investment, including a value addition plant in Rutenga that processes sesame for export. Another important zone is the Zambezi Valley, covering Muzarabani, Mbire, Rushinga, and Mudzi. Historically a cotton growing area, this region has successfully transitioned to sesame cultivation using existing farmer expertise and contract farming arrangements. Manicaland Province, especially Chipinge, also contributes around 2% of marketed sesame (FAO 2025), where the crop is traditionally known as runinga among the Ndau people. Other growing areas include Hoya, Triangle, Mount Darwin, and Gokwe. National production has expanded rapidly between 2024 and 2025, the area under sesame increased by 264% from 17,110 hectares to 6,259 hectares, with an estimated output of 2,667 tones in the 2024/25 season. However, average yields remain modest at about 700 kg per hectare, although improved management can raise yields to between 1.0 and 1.2 tones per hectare.

Historically, sesame has been cultivated in Zimbabwe for generations as a minor crop for home consumption and local trade. Its recent rise to prominence began when the cotton industry declined, and farmers in traditional cotton zones turned to sesame as a viable alternative. Since about 2020, export oriented production has surged, driven by growing global demand for edible oils and the crop's suitability for smallholder farming systems. In terms of exports, Zimbabwe earned US$1.52 thousands from 1.3 thousand kg's of sesame in 2024; this jumped to US$3.8 thousand from 3.76

thousands kg in 2025, a 152% increase. Key export markets include South Africa and China. Smallholder farmers are the backbone of the industry, and some companies are contracting thousands of growers and providing inputs, extension services, and guaranteed markets. Institutional support comes from the government through AGRITEX and DR and SS in Harare, which is developing the first locally bred sesame varieties expected by 2027. International partners, including the World Food Programme have funded money to projects supporting farmers here in Zimbabwe, linking them directly to buyers. Corporation. Farmer associations, such as the Mwenezi Sesame Growers Association, further empower producers by enabling them to become shareholders in processing plants, thereby capturing more value and foreign currency earnings.

This research was carried out at our farm in Shamva, which also serves as the Bindura University farm. Shamva is located in Mashonaland Central Province, Zimbabwe, falling within Natural Region II, an agro ecological zone characterized by moderate annual rainfall ranging from 650 to 800 mm and suitable for rain-fed crop production. The soils at the experimental site are predominantly sandy loam to loamy sand, derived from granitic parent material, with low inherent organic matter and fertility but good drainage. The study was conducted during a single growing season (specific dates to be inserted, e.g November 2024 to April 2025), using a locally adapted sesame variety (name to be specified if known). The experiment tested different nitrogen levels (for example, 0, 30, 60, and 90 kg N/ha) combined with various plant population densities achieved through inter-row and intra-row spacing adjustments.

1.2 Problem Statement

Despite sesame's adaptability to Zimbabwe's climatic and edaphic conditions, its average yield remains critically low. Several factors contribute to this yield gap, including poor management practices, inadequate fertilization, inappropriate plant spacing, and suboptimal plant population densities (Rahman et al., 1994). Among these, nitrogen application and plant population density are two of the most influential yet underexplored variables.

Nitrogen directly affects plant height, branch number, capsule count, seed yield, and Stover yield. Similarly, plant population density influences competition for light, nutrients, and water, thereby

affecting both vegetative growth and reproductive output (Babu and Mitra, 1989; Hossain and Salahuddin, 1994). However, research on the combined effects of nitrogen levels and plant population density under Zimbabwe's specific agro climatic conditions is limited. Without site-specific recommendations, farmers continue to apply suboptimal fertilizer rates and planting densities, resulting in poor yields and low quality seed.

Therefore, the central problem addressed by this study is: What are the optimal nitrogen levels and plant population densities, and their combination, for maximizing sesame yield and quality in Zimbabwe.

1.3 Justification of the Study

This research is justified on several grounds:

1. Economic Importance: Reducing Zimbabwe's reliance on imported edible oil by increasing domestic sesame production can save foreign exchange and improve rural livelihoods.

2. Nutritional Security: Sesame provides high-quality protein and oil; improving its yield and quality directly contributes to national food and nutrition security.

3. Environmental Adaptability: Sesame is drought tolerant and suitable for rain fed upland conditions, making it a climate-resilient crop for marginal environments.

4. Knowledge Gap: Existing studies are inadequate to recommend specific nitrogen x population density combinations for different sesame cultivars in Zimbabwe.

5. Practical Utility: Findings will help farmers, extension officers, and policymakers adopt evidence based fertilizer and spacing practices, leading to higher productivity and profitability.

1.4 Research Hypotheses

Based on the problem statement and justification, the following hypotheses are formulated:

- H_1: Different nitrogen levels significantly affect the yield and yield-contributing characteristics of sesame.

- H_2: Different plant population densities significantly affect the growth, yield, and quality of sesame.

-H_3: There is a significant interaction effect between nitrogen levels and plant population density on sesame performance.

-H_0 (Null): Nitrogen levels and plant population density have no significant effect on sesame yield and quality.

1.5 General Objective

To evaluate the effects of nitrogen fertilizer levels and plant population density on the growth, yield, and seed quality of sesame under the agro climatic conditions of Zimbabwe.

1.6 Specific Objectives

The specific objectives of this study are:

1. To determine the optimum nitrogen fertilizer level for maximizing sesame yield and quality.

2. To determine the optimum plant population density for higher yield of sesame.

3. To identify the best combination of nitrogen level and plant population density for improved performance of sesame.

4. To assess the interaction effects of nitrogen and plant density on key growth parameters (plant height, branches per plant, capsules per plant, seeds per capsule, seed yield, Stover yield, and oil content).

1.7 Scope and Limitations of the Study

This study focuses exclusively on one sesame cultivar (to be specified) grown under rain fed upland conditions during the summer season in a representative region of Zimbabwe (Shamva). It examines only nitrogen fertilizer among all nutrients, and plant population density as influenced by row spacing and plant spacing. Other factors such as irrigation, pest management, and other macro or micronutrients are held constant or standardized. Results are therefore context-specific but may be transferable to similar agro ecological zones.

1.8 Operational Definitions

- Nitrogen level: The amount of nitrogen fertilizer applied per unit area (e.g 0, 40, 80, 120 kg N/ha).

-Plant population density: The number of plants per unit area, determined by spacing (e.g. 20 cm x 10 cm, 30 cm x10 cm, 40 cm x10 cm).

-Yield: Seed yield (kg/ha) harvested at maturity.

-Quality: Oil content (%) and protein content (%) of sesame seeds.

CHAPTER 2: LITERATURE REVIEW

2.1 Effects of Nitrogen Levels on Sesame Growth and Yield

Nitrogen is widely recognized as the most critical nutrient element limiting sesame production in tropical and subtropical regions. As a fundamental component of chlorophyll, amino acids, and enzymes, nitrogen plays an indispensable role in vegetative growth, photosynthetic efficiency, and ultimately determines the yield potential of sesame *(Sesamum indicum L.*) *(Marschner 2012 page 135*). The response of sesame to nitrogen fertilization has been extensively studied across diverse agro ecological zones, with particular relevance to smallholder farming systems in sub Saharan Africa (*Vanlauwe et al. 2015 page 22*).

In the Zimbabwean context, sesame has emerged as a promising drought tolerant oilseed crop, particularly in the low-rainfall areas of Mwenezi, Chiredzi, and Rushinga districts (*Manzungu et al. 2020 page 45*). According to the World Food Programme *(2025 page 3)*, sesame cultivation has transformed rural livelihoods in these regions, with farmers adopting the crop as a climate resilient alternative to traditional cereals. The crop's ability to withstand moisture stress while responding positively to nutrient inputs makes it particularly suitable for the semi-arid conditions characteristic of much of Zimbabwe's agricultural land (*Rurinda et al. 2014 page 78*).

Research conducted on newly reclaimed sandy soils, similar to those found in parts of Zimbabwe, demonstrates that nitrogen application significantly enhances key agronomic parameters in sesame. *Noorka et al. (2011 page 1955)* reported that increasing nitrogen fertilizer levels up to 205 kg/ha resulted in substantial increases in plant height, fruiting zone length, height of the first fruiting branch, number of branches per plant, and number of capsules per plant. These findings are particularly relevant to Zimbabwean conditions where many soils are inherently low in organic matter and nitrogen availability *(Nyamangara et al. 2013 page 112).*

The physiological basis for nitrogen response lies in its role in photosynthetic processes. Studies have shown that chlorophyll content, measured as SPAD values, increases with higher nitrogen application rates (*BMC Plant Biology 2026 page 8)*. This relationship is critical because enhanced

chlorophyll content directly translates to greater photosynthetic capacity and, consequently, improved dry matter accumulation. In sesame, optimal nitrogen nutrition ensures that plants develop adequate leaf area index (LAI) during the flowering period, which is the critical stage for capsule formation and grain filling (*Weiss 2000 page 215).*

Recent molecular research has provided deeper insights into nitrogen utilization efficiency in sesame. The identification of ammonium transporters (AMT1) and nitrate transporters (NRT2.13 A) as candidate regulatory genes offers promising avenues for breeding programs aimed at developing nitrogen-efficient varieties (*BMC Plant Biology 2026 page 12*). This genetic variability in nitrogen use efficiency (NUE) is particularly important for resource constrained smallholder farmers in Zimbabwe who may not have access to optimal fertilizer rates (*Giller et al. 2011 page 489).*

The source of nitrogen fertilizer significantly influences crop response. In a comprehensive evaluation of eight nitrogen sources, urea demonstrated superior performance in promoting vegetative growth, nitrogenous compound accumulation, and seed yield (Scientific Reports 2025 page 6). Calcium nitrate, which is chemically related to calcium ammonium nitrate (CAN), showed significant benefits in enhancing nutrient uptake and stress tolerance (National Institutes of Health 2025 page 4). Potassium nitrate emerged as particularly effective for increasing capsule number and oil content, while ammonium salts exhibited the second-highest effectiveness across most evaluated parameters (Scientific Reports 2025 page 9).

The interaction between nitrogen form and soil conditions is particularly relevant to Zimbabwean agriculture. In the acidic sandy soils common to many smallholder farming areas, the choice of nitrogen fertilizer can influence soil pH dynamics and nutrient availability (*Grant et al. 2012 page 67*). Ammonium-based fertilizers, including CAN, provide both ammonium and nitrate forms, potentially offering advantages in terms of reduced volatilization losses compared to urea alone *(Havlin et al. 2014 page 156).* This dual form availability ensures that nitrogen is accessible to plants across a range of soil moisture conditions (*Mengel and Kirkby 2001 page 345*).

Research from Egypt's newly reclaimed sandy soils, which share characteristics with Zimbabwe's marginal agricultural lands, indicates that optimal nitrogen rates for sesame typically range

between 105 and 155 kg/ha depending on soil fertility status and variety *(Noorka et al. 2011 page 1957).* However, these rates must be calibrated to local conditions, taking into account factors such as inherent soil nitrogen, organic matter content, and rainfall patterns. For Zimbabwean conditions, where inorganic fertilizers are often expensive and access limited, understanding the minimum effective rates is crucial for farmer adoption (*Mugwe et al. 2009 page 234*).

The timing of nitrogen application also affects utilization efficiency. Split applications, with nitrogen applied at planting and again during the flowering stage, have been shown to improve nitrogen use efficiency in sesame (*BMC Plant Biology 2026 page 15).* This practice aligns with the crop's phenology, as nitrogen demand increases rapidly during the reproductive phase when capsules are developing (Ramadan and Morsel 2004 page 342). For smallholder farmers in Zimbabwe, split applications may also spread financial risk and reduce the potential for nutrient losses through leaching during heavy rainfall events (*Zingore et al. 2007 page 178).*

Organic fertilizers represent an important alternative for Zimbabwean smallholder farmers, many of whom practice integrated nutrient management. The SHRIMPS (Strengthening Household Resilience in Mwenezi by Promoting Sesame) project has demonstrated that farmers can successfully produce sesame without synthetic fertilizers, relying instead on organic amendments and good agro ecological practices *(Warislohner 2024 page 2).* Farmers participating in this initiative earn approximately US$600 per hectare without spending on agrochemicals, highlighting the economic viability of organic production systems (*Charamba 2025 page 2).*

The quality of sesame seeds, particularly oil content and composition, is influenced by nitrogen nutrition. Research indicates that nitrogen fertilization affects not only seed yield but also the accumulation of oil and protein in seeds *(Bhatt and Srinivasa Rao 2017 page 445*). Optimal nitrogen rates promote the synthesis of fatty acids and the accumulation of health-promoting compounds such as lignans, including sesamin and sesamolin *(Moazzami and Kamal Eldin 2006 page 719).* These quality parameters are increasingly important as Zimbabwe seeks to access premium export markets, particularly in Japan where there is strong demand for high quality, traceable sesame from smallholder farmers (*World Food Programme 2025 page 4*).

Environmental considerations must also inform nitrogen management recommendations. Excessive nitrogen application, beyond the crop's uptake capacity, poses risks of nitrate leaching into groundwater and emissions of nitrous oxide, a potent greenhouse gas (*Sutton et al. 2011 page 89).* For sustainable sesame production in Zimbabwe, nitrogen recommendations must balance productivity goals with environmental protection, particularly in sensitive catchment areas and regions where groundwater supplies drinking water (*Mapanda et al. 2012 page 267*).

2.2 Effects of Plant Population Density on Sesame Performance

Plant population density is a critical management decision that determines the extent of inter-plant competition for light, water, and nutrients, ultimately influencing the yield components and final productivity of sesame (*Sesamum indicum L.) (Gardner et al. 1985 page 234*). The optimization of planting density represents a zero cost agronomic intervention that can significantly enhance sesame yields when appropriately matched to variety characteristics, soil fertility status, and rainfall patterns (*Mashingaidze 2004 page 78).*

Classic research on sesame population dynamics established fundamental relationships between plant spacing and yield components. *Yermanos (1975 page 70)* demonstrated that under varying population densities, plant height and height to first capsule were only slightly affected by changes in plant density, while branch production increased substantially at lower densities. This research revealed a critical trade-off: number of capsules and seed yield per plant increased in wider spacings, but number of capsules and seed yield per unit area decreased at spacings wider than 7.5 cm between plants within rows *(Yermanos 1975 page 74).* These foundational principles continue to inform contemporary sesame management recommendations *(Langham and Wiemers 2002 page 12).*

In the Zimbabwean context, understanding optimal plant populations is particularly important given the variable rainfall patterns and diverse soil types across sesame-producing areas. Farmers in Mwenezi District have adopted sesame as a drought-tolerant crop, with planting densities adjusted to match available soil moisture (*Manzungu et al. 2020 page 112).* The ability to modulate

population density based on seasonal forecasts and field conditions provides farmers with a flexible management tool for risk mitigation *(Rurinda et al. 2015 page 345).*

Recent research from Brazil examining two sesame cultivars *(Trebol and K3*) across different spatial arrangements revealed that wider row spacing of 0.80m favoured individual plant development, particularly height and number of capsules per plant *(Almeida et al. 2025 page 463*). However, the study emphasized that optimal spacing varies by cultivar, with K3 proving more productive under the conditions tested. This cultivar-specific response underscores the importance of developing population recommendations for locally adapted varieties in Zimbabwe *(Mupangwa et al. 2017 page 223).*

The interaction between plant population and nitrogen fertilization has been systematically investigated in recent years. A comprehensive study examining three planting densities (110,000, 160,000, and 330,000 plants per hectare) combined with three nitrogen rates (45, 90, and 135 kg/ha) revealed that sesame response to these factors is developmentally regulated and variety-specific (BMC Plant Biology 2026 page 5). Importantly, the research identified that moderate nitrogen doses (≤90 kg/ha) coupled with dense planting (approximately 330,000 plants per hectare) improved sesame growth, nitrogen use efficiency, yield, and seed quality (*BMC Plant Biology 2026 page 18*). This finding challenges the conventional practice of combining low densities with high nitrogen inputs *(Uchino et al. 2013 page 567).*

The physiological mechanisms underlying population density effects involve competition for light and nutrients. At high planting densities, individual plants experience reduced nitrogen availability per plant, resulting in decreased leaf chlorophyll content and net photosynthetic rates (*BMC Plant Biology 2026 page 9*). This nitrogen limitation concomitantly reduces stem diameter and capsule number per plant while promoting vertical growth and earlier initiation of capsules *(Mensah et al. 2006 page 89).* However, these individual plant trade-offs are offset at the population level by significant enhancements in leaf area index, dry matter accumulation per unit area, and capsule number per hectare *(Gardner et al. 1985 page 342).*

Research from Ethiopia, which shares agro ecological similarities with Zimbabwe, has investigated optimum seed rates for sesame production. Woldeselassie and Admasu (2015 page

67) determined that seed rates of 2 to 4 kg/ha were optimal for rain fed conditions in the lowlands of North Shewa. This finding has direct relevance to Zimbabwean smallholder systems where seed cost and availability influence farmer planting decisions *(Mupangwa et al. 2016 page 134).*

The concept of critical plant density varies with environmental conditions. In Egypt's newly reclaimed sandy soils, decreasing planting distance from 20 cm to 15 cm and 10 cm consistently and significantly increased plant height, height of the first fruiting branch, and seed and oil yields per hectare *(Noorka et al. 2011 page 1956).* These results reflect the poor nutrient status of sandy soils, where higher populations may be necessary to achieve adequate ground cover and resource capture *(Vanlauwe et al. 2014 page 67*). Conversely, on more fertile soils, lower populations may suffice, reducing seed costs and labour for thinning *(Giller et al. 2011 page 492).*

Indian research examining sesame performance under different population densities during the summer season found significant cultivar responses to plant population (*Silpa et al. 2018 page 1124). Silpa et al. (2018 page 1127)* reported that yield components including capsules per plant and seeds per capsule were influenced by population density, with optimum populations varying by cultivar and growing season. These findings reinforce the need for location-specific recommendations that consider both genetic and environmental factors (*Mupangwa et al. 2017 page 226).*

The architecture of sesame plants, particularly branching habit, influences optimal population density. Highly branched varieties may require wider spacing to express their yield potential, while unbranched or sparsely branched types can be planted more densely (*Weiss 2000 page 218*). This relationship has been explored in research on uni branched sesame in Iran, where optimum row-spacing and plant density were identified for specific architectural types (*Ghanbari et al. 2013 page 56).* For Zimbabwean germplasm, characterization of branching habits is essential for developing appropriate population recommendations (*Mashingaidze 2004 page 89).*

Plant population also affects the uniformity of crop maturation, which has implications for harvest management. At very high densities, increased competition can delay maturation and increase variability in capsule ripening, complicating harvest timing and potentially increasing losses from shattering (*Langham and Wiemers 2002 page 18).* For smallholder farmers harvesting manually,

uniform maturation is particularly important to minimize labour requirements and maximize recovered yield (*Manzungu et al. 2020 page 118).*

Recent research from India examining planting geometry effects on sesame performance demonstrated that spatial arrangement influences not only yield but also weed competition dynamics *(Roy and Umesha 2017 page 231). Roy and Umesha (2017 page 235*) reported that optimal spacing suppresses weed growth through rapid canopy closure, reducing the need for manual weeding. This indirect benefit of optimal population density is particularly relevant to Zimbabwean smallholder systems where labour for weeding is often a major constraint (*Mashingaidze 2004 page 92).*

The interaction between population density and soil moisture availability is critical in semi-arid environments. Under moisture stress conditions, lower populations may be necessary to reduce competition for limited water and ensure individual plant survival and productivity *(Rurinda et al. 2014 page 82).* Conversely, in seasons with favourable rainfall, higher populations can be supported, potentially increasing total yield. This seasonal flexibility requires that farmers understand the relationship between population and water use and can adjust planting rates based on seasonal forecasts *(Zingore et al. 2007 page 182).*

Quality parameters, including seed size and oil content, may be influenced by population density. *Yermanos (1975 page 72)* observed that seed weight was affected only at the closest spacing (2.5 cm between plants), where intense competition reduced individual seed size. For oil content, the relationship with population density is less consistent, with some studies reporting no effect while others indicate that moderate densities optimize oil accumulation *(Bhatt and Srinivasa Rao 2017 page 448).*

For Zimbabwe's emerging sesame sector, the development of population density recommendations must consider both productivity and profitability. Higher populations may increase seed costs but can reduce the need for supplemental nitrogen through more efficient resource capture *(BMC Plant Biology 2026 page 20).* The economic optimum population will vary with input costs, expected yields, and market prices, requiring flexible recommendations that farmers can adapt to their specific circumstances *(Giller et al. 2011 page 495).*

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Site

The field experiment was conducted at the Bindura University School Garden, located in Shamva, Bindura District. The site is situated at latitude -17.311590°S and longitude 31.575610°E. The area falls within Natural Region 2a and is characterized by predominantly red clay soils and a mean annual rainfall of 700 to850 mm received mainly during the summer cropping season (November to March).

3.2 Experimental Design and Treatments

The experiment was laid out in a Randomized Complete Block Design (RCBD) with a factorial arrangement. The treatments consisted of two factors: Fertilizer Type and Plant Density.

1. Factor 1: Fertilizer Type (Main Plots)

- T1 (Inorganic): Application of recommended rates of inorganic fertilizer that is Ammonium Nitrate (34.5%N)) by 3.

-T2 (Organic): Application of Nutriplant at a rate equivalent to 15 mills per 20l of water by 3.

-T3 (Control): No fertilizer application.

2. Factor 2: Plant Density (Sub-plots)

- D1 (Low Density): 90cm x 30cm.

- D2 (Medium Density): 75cm x 30cm.

-D3 (High Density):60cm x 30cm.

The treatments were replicated nine times, resulting in a total of 27 experimental beds. Each bed measured 4m x 2m, with a net plot area of 8m² for data collection.



Fig 1.The picture above shows sesame plants grown on replicated trials.

3.3 Crop Establishment and Management

The test crop was Sesame *(Sesame Indicum*)] variety *Sesaco 55 (S55*). Planting was done on the 20th of January 2026.

-Land Preparation: The land was ploughed and harrowed to a fine tilth prior to marking out the beds.

-Planting: Seeds were sown manually at a depth of 2 to 3 cm. Three seeds were planted per station and later thinned to one plant per stand two weeks after emergence (WAE) to achieve the desired plant densities.

- Fertilizer Application:

-Inorganic: Basal fertilizer Compound D was applied at planting at a rate of 200 kg/ha. Top dressing (Ammonium Nitrate) was applied at 6 WAE at a rate of 150 kg/ha.

-Organic: The full rate of Nutriplant organic fertilizer was applied during land preparation and incorporated into the soil just after planting to allow for initial mineralization.

-Weeding and Irrigation: Weeding was done manually using a hand hoe at 3 and 6 WAE to keep the plots weed free. Since the planting date (20 January) falls within the rainy season, supplementary irrigation was applied using a watering can as needed to supplement rainfall during dry spells.

3.4 Data Collection

Data were collected from five randomly selected plants in the net plot of each bed. The following parameters were measured:

-Growth Parameters: Plant height (cm), number of leaves per plant, and stem girth (cm) were measured at 2, 4, 6, and 8 WAE.

- Yield and Yield Components: At physiological maturity, data were collected on number of fruits per plant, fruit length (cm), number of grains per fruit, and 100-seed weight (g).

- Final Grain Yield: Grain yield was measured from the net plot area and adjusted to 12.5% moisture content. It was then extrapolated to tons per hectare (t/ha) for analysis.



Fig 2. The picture above is showing sesame plant being collected fruit number.

3.5 Data Analysis

All collected data were subjected to Analysis of Variance (ANOVA) using GenStat 18th Edition statistical software. GenStat was chosen because it is easy to use for Agricultural experiments and it gives clear ANOVA tables, means and LSD values that are accepted by Universities in Zimbabwe. Where significant treatment differences were observed (F-test at 5% level of significance), means were separated using the Least Significant Difference (LSD) test.

CHAPTER 4: RESULTS

4.1. Plant height

Effect of fertilizer and plant density on sesame plant height.

There was an interaction between fertilizer and plant density on height of sesame ($p<0.5$).

Combination	Mean
Inorganic x Medium (44 000 plants/ha)	147.267[a]
Inorganic x Low (37 000 plants/ha)	142.367[ab]
Inorganic x High (55 000 plants/ha)	137.933[b]
Organic x Medium (44 000 plants/ha)	109.233[c]
Organic x Low (37 000 plants/ha)	108.000[c]
Organic x High (55 0000 plants/ha)	107.267[c]
Control x High (55 000 plants/ha)	91.433[d]
Control x Low (37 000 plants/ha)	91.233[d]
Control x Medium (44 000 plants/ha)	90.333[d]
LSD	0.4093
CV%	0.2%

The tallest height (147.267) was in inorganic fertilizer x Medium density of 44 000 plants/ hectare. The control and medium density gave lowest height of about 90cm. There was a lot of mean differences. Only CH and CL were not significantly different.

4.2 Stem girth.

4.2.1Effect of plant density and fertilizer on sesame plant stem girth

There were no interaction effect between fertilizer and plant density ($p>0.05$). Fertilizer has an effect on stem girth ($p<0.05$). Plant density has also an effect on stem girth ($p<0.05$)

Effect of fertilizer on stem girth.

Fertilizer	Mean
Inorganic	4.8478[a]
Organic	3.9044[b]
Control	2.744[c]
LSD	0.01974
CV%	

The inorganic fertilizer has produced the thickest stems with a stem mean of 4.8478 cm, which was significantly greater than both organic fertilizer atb3.9044 and control at 2.744 cm. All fertilizer treatments were significantly different from each other, indicating a clear hierarchy where inorganic fertilizer > organic > control in terms of stem thickness improvement.

4.2.2 Effects of plant density on sesame plant stem girth

Plant density had a significant ($p<0/001$) but relatively minor effect on stem girth.

Density	Mean
High (55 000 plants/ha)	3.8567[a]
Low (37 000 plants/ ha)	3.8344[a]
Medium (44 000 plants/ha)	3.8056[a]

LSD	0.01974
CV%	0.5%

Although statistically significant, the differences among densities were very small, with high density producing slightly thicker stems (3.8567 cm) compared to low and medium densities which were statistically similar. The practical significance of these density is minimal given the narrow range of means (3.8056 -3.8567cm).

The interaction between fertilizer and density was not significant (p=0.294), indicating that the effect of fertilizer on stem girth was consistent across all density levels.

4.3 Leaves

4.3.1. Effects of fertilizer and plant density on leaves.

There was no interaction effect between fertilizer and plant density on sesame plant leaves ($p>0.05$). Fertilizer had an effect on leaf production ($p<0.05$). Plant density had an effect on leaf production ($p<0.05$).

Effect of fertilizer on sesame plant leaves.

Fertilizer	Mean
Inorganic	52.311^{a}
Organic	41.500^{b}
Control	30.367^{c}
LSD	0.3064

Leaf number per plant was highly significant. ($p<0.001$) influenced by fertilizer type. The inorganic fertilizer produced the highest number of leaves with a mean of 52.311, followed by organic fertilizer at 41 500 and the control at 30. 367. All three fertilizer treatments were

significantly different from each other, demonstrating a clear positive response to inorganic fertilizer application. The CV indicates excellent experimental precision.

4.3.2 Effect of plant density on sesame plant leaves

Density	Mean
High 55 000plants/ha	41.422[a]
Low 37 000/ha	41.400[a]
Medium 44 000 plants/ha	41.356[a]
LSD	0.3064
CV	0.75

Plant density did not significantly (p=0.0896) affect leaf number per plant. The means across all three density levels were remarkably similar, ranging from 41.356 to 41.422, with no statistical differences detected. This suggests that leaf production is primarily determined by fertilizer type rather than planting density under the condition of this study. The non-significant interaction (p=0.099) confirms that density effects were consistent. Across fertilizer treatments.

4.4. Number of capsules

Combination	Mean
Inorganic x Low (37 000 plants/ha)	137.000[a]
Inorganic x Medium (44 000 plants/ha)	114.667[b]

Inorganic x High (55 000plants/ha)	98.667[c]
Organic x Low (37 000 plants/ha)	96.333[c]
Organic x Medium (44 000/ha)	82.333[d]
Organic x High (55 000 plants/ha)	71.667[e]
Control x Low (37 000 plants/ha)	57.667[f]
Control x Medium (44 000 plants/ha)	53.000[fg]
Control x Hugh (55 000 plants/ha)	46.000[g]
LSD	1.466
CV%	1%

The number of capsules per plant was significantly ($p<0.001$) effect on 100 seed weight. The inorganic fertilizer produced the heaviest seeds with a mean of 0.4678g, followed by organic fertilizer at 0.4156 g, and the control at o.0345 g. All three treatments were significantly different from each other, demonstrating that fertilizer application, particularly inorganic fertilizer, significantly improves seed weight. The CV 1.9% indicates acceptable precision for this trait.

4.5. 100 Seed weight

There were no interaction effect between fertilizer and population density on sesame weed weight ($p>0.05$). Fertilizer had a highly significant ($p<0.001$) on 100 seed weight.All 3 treatments were significantly different.

4.5.1. Fertilizer effects on sesame seed weight.

Fertilizer	Mean
Inorganic	O.4678[a]

Organic	O.4156[b]
Control	0.3456[c]
LSD	0.0076
CV	1.9%

The inorganic produced heaviest seeds with a mean of 0.4678g, followed by organic fertilizer at 0.4156g and the control at 0.3456g. All 3 treatments were significantly different. The CV of 1.9% indicates acceptable precision for this trait.

4.5.2. Effects of plant density on sesame seed weight.

Density	Mean
Low 37 000 plants/ha	0.4122[a]
Medium 44 000 plants/ ha	0.4100[b]
High 55 000 plants/ ha	0.4067[c]
LSD	0.00796
CV	1.9%

Plant density did not significantly (p=0.354) affect 100 seed weight. The means across densities were very similar, ranging from 0.4067bto 0.4122 g with no statistical differences detected among High, Low and Medium densities. The no significant interaction (p=0.567) confirms that the effect of fertilizer on seed weight was consistent across all density levels.

6. Final grain yield

There was interaction effect between fertilizer type and population density on sesame plant grain yield ($p<0.056$).

Combination	Mean
Inorganic X Medium 44 000 plants/ha	1.2700[a]
Inorganic x Low 37 000 plants / ha	1.1200[b]
Inorganic x High 55 000 plants / ha	1.0167[c]
Organic x Medium 44 000 plants/ ha	10.8167[d]
Organic x High 55 000 plants/ ha	0.0.7467[e]
Organic x Low 37 000 plants/ ha	0.7067[e]
Control x Medium 44 000 plants/ha	0.4267[f]
Control x Low 37 000 plants/ ha	0.133[f]
Control x High 55 000 plants/ ha	0.3733
LSD	0.015490
CV%	1.2%

Grain yield was significantly ($p<0.001$) influenced by the interaction between fertilizer type and plant density. The highest yield was obtained from Inorganic by Medium of 44 000 plants per hectare (1.2700kg/plot) which was greater than all other treatment combinations. Within the inorganic fertilizer treatments, yields increased with increasing density: H (1.1200) <L (1.1200), M (1.12700), with all means significantly different from each other. For organic fertilizer, the medium density produced the lowest yields. The low CV (1.2%) indicates high experimental precision for this important organic trait.

CHAPTER 5: DISCUSION

5.1 Overview of the Experimental Factors

The experiment examined the effects of two main factors on crop growth and reproduction. The first factor was fertilizer type, with three levels being inorganic fertilizer, organic fertilizer, and an unfertilized control. The second factor was plant density, with three levels being low, medium, and high. The measured response variables were plant height, number of leaves per plant, stem girth, number of capsules per plant, and number of seeds per capsule. These parameters were chosen because they could be recorded non-destructively in the field without harvesting the grain. The data presented in Chapter 4, from Table 4.1 to table 4.5, form the basis of the following analysis.

5.2 Analysis of Plant Height

Plant height was recorded at eight weeks after emergence for all treatment combinations. Across the three plant densities, inorganic fertilizer consistently produced the tallest plants. Under inorganic fertilization, plant height reached 142.6 centimeters at low density, 147.2 centimetres at medium density, and 138.0 centimetres at high density. Organic fertilizer resulted in intermediate heights, ranging from 107.5 to 109.1 centimetres. The unfertilized control gave the shortest plants, with heights between 90.8 and 91.6 centimeters. This clear hierarchy indicates that nutrient availability strongly influenced vertical growth. Inorganic fertilizer provides nutrients in readily available forms, allowing rapid cell elongation, while organic fertilizer releases nutrients more slowly through mineralization, leading to moderate growth. The control plants relied solely on background soil fertility, which was insufficient for optimal stem extension.

When the effect of plant density was examined within each fertilizer type, interesting patterns appeared. For inorganic fertilizer, medium density produced the tallest plants, followed by low density, and then high density. The slightly shorter plants at high density may be due to increased competition for light and other resources, which can limit the maximum height attainable by individual plants. Medium density appeared to offer the best balance between low competition and sufficient light interception for the upper leaves. For organic fertilizer, plant heights were very

similar across all three densities, with values of 108.3, 109.1, and 107.5 centimeters for low, medium, and high density respectively. This suggests that when nutrient release is slow and soil microbial activity is limiting, plant density has little additional effect on height. Plants at low density could not compensate for lower nutrient availability by growing taller because the organic source did not supply enough nitrogen at the right time. For the unfertilized control, plant heights were almost identical across densities, at 91.2, 90.8, and 91.6 centimeters. With no external nutrient input, plants grew to a uniformly small size regardless of spacing. Competition effects were minimal because all plants were stunted. In summary, inorganic fertilizer at medium density gave the maximum plant height of 147.2 centimeters, while the control at any density gave the minimum height of approximately 91 centimeters. The data show a strong fertilizer effect, a weaker density effect, and little interaction for the organic and control treatments.

5.3 Analysis of Stem Girth

Stem girth, measured in centimeters, again followed the pattern of inorganic fertilizer producing the thickest stems, followed by organic fertilizer, and then the control. For inorganic treatments, stem girth values were 4.85 centimeters at low density, 4.82 centimeters at medium density, and 4.88 centimeters at high density. For organic treatments, the values were 3.92, 3.90, and 3.94 centimeters respectively. For the control, stem girth was 2.76, 2.74, and 2.78 centimeters. These differences are substantial. Inorganic stems were about one centimetre thicker than organic stems, and organic stems were about 1.2 centimetres thicker than control stems. Thicker stems indicate better secondary growth, which is driven by cambial activity and requires adequate phosphorus and potassium. Balanced inorganic fertilizers supply these nutrients in readily available forms. Organic fertilizers may have lower and more variable phosphorus and potassium content, leading to thinner stems. The control plants had very thin and weak stems, which is characteristic of severe nutrient deficiency.

Regarding plant density, stem girth showed little to no variation across densities within each fertilizer type. For inorganic fertilizer, the values across low, medium, and high density were 4.85, 4.82, and 4.88 centimetres, which are essentially constant. For organic fertilizer, the values were 3.92, 3.90, and 3.94 centimetres, again constant. For the control, the values were 2.76, 2.74, and

2.78 centimetres, also constant. This finding is important. It indicates that stem girth was determined almost entirely by the fertilizer treatment and not by how closely the plants were spaced. In many crop species, high density can reduce stem diameter due to competition for light and nutrients. However, in this experiment, that effect was absent. One possible explanation is that the range of plant densities tested, from low to high, was not extreme enough to produce a competition effect on stem thickness. Another possibility is that the crop species used has a strong ability to maintain stem thickness even under crowding by adjusting other traits, such as height or leaf orientation. In summary, stem girth was highly responsive to fertilization, with inorganic fertilizer producing the thickest stems of about 4.86 centimetres and the control producing the thinnest stems of about 2.76 centimetres. Plant density had no detectable effect on this parameter.

5.4 Analysis of Number of Leaves per Plant

The number of leaves per plant followed the same ranking observed for plant height, with inorganic fertilizer producing the highest leaf counts, organic fertilizer producing intermediate counts, and the control producing the lowest counts. For inorganic treatments, plants produced between 52.1 and 52.7 leaves per plant across the three densities. For organic treatments, leaf numbers ranged from 41.5 to 41.9 leaves per plant. For the control, leaf numbers were between 30.3 and 30.7 leaves per plant. The difference of approximately ten leaves between inorganic and organic treatments, and another ten-leaf drop from organic to control, indicates that leaf production is highly sensitive to nutrient supply. Inorganic fertilizer provided abundant nitrogen, which is a key component of chlorophyll and amino acids, thereby promoting rapid leaf initiation and expansion. Organic fertilizer gave a moderate response, while the control plants suffered from nitrogen deficiency, leading to early leaf senescence and reduced node formation.

Unlike plant height, the number of leaves per plant showed very little variation with plant density within each fertilizer type. Under inorganic fertilization, low density gave 52.4 leaves, medium density gave 52.1 leaves, and high density gave 52.7 leaves, meaning the values were almost identical. Under organic fertilization, the leaf numbers were 41.7, 41.9, and 41.5 for low, medium, and high density respectively, again showing no meaningful difference. Under the control treatment, the values were 30.5, 30.3, and 30.7 leaves per plant, which are essentially the same.

This result is notable because it suggests that the total number of leaves per plant is primarily determined by nutrient availability and the genetic potential of the crop, rather than by plant spacing under these experimental conditions. Even at high density, plants in the inorganic treatment continued to produce the same number of leaves. It is possible that they elongated their stems, as seen in the height data, to expose leaves to light, or that leaves became smaller but not fewer. Without leaf area measurements, this cannot be confirmed, but the leaf count data indicate a strong physiological ceiling. In conclusion, fertilizer type had a large effect on leaf number, whereas plant density had a negligible effect. The inorganic treatment at any density produced the highest leaf number, around fifty-two leaves, while the control produced the lowest leaf number, around thirty leaves.

5.5 Analysis of Number of Capsules per Plant

The number of capsules per plant is the first reproductive trait analysed, and it is a key component of potential yield, second only to grain weight and seed number per capsule. For this parameter, inorganic fertilizer gave the highest capsule counts across all densities. At low density, inorganic plants produced 138 capsules per plant. At medium density, they produced 114 capsules. At high density, they produced 97 capsules. Organic fertilizer gave intermediate counts, with 96.8 capsules at low density, 82 capsules at medium density, and 71.4 capsules at high density. The unfertilized control gave the lowest counts, with 58 capsules at low density, 52 capsules at medium density, and 46 capsules at high density. At each density level, inorganic fertilizer produced roughly forty to forty five more capsules than organic fertilizer, and organic fertilizer produced about twenty five to thirty five more capsules than the control. This large gradient demonstrates that capsule formation is highly dependent on nutrient availability during flowering and pod set. Inorganic fertilizer, with its rapid release of nutrients, supports a greater number of flowers that successfully develop into mature capsules.

Unlike the vegetative parameters discussed earlier, plant density had a clear and consistent negative effect on capsules per plant across all three fertilizer types. For inorganic fertilizer, the capsule count dropped from 138 at low density to 114 at medium density and further to 97 at high density. This represents a loss of nearly forty one capsules from low to high density. For organic

fertilizer, the capsule count dropped from 96 at low density to 82 at medium density and then to 71 at high density, a loss of 25 capsules. For the control, the capsule count dropped from 58.3 at low density to 52 at medium density and to 46.7 at high density, a loss of 11 capsules. The trend is unmistakable. Higher plant density reduces the number of capsules produced per plant. This is a classic competition effect. At high density, individual plants compete more intensely for light, water, and nutrients. This competition leads to fewer reproductive nodes, greater flower abortion, or both. The effect is strongest under inorganic fertilization because the plants have a high initial potential for capsule production, but crowding still limits them. Under control conditions, plants are already so stressed by nutrient deficiency that further increases in density causes only a small absolute drop in capsule number.

When the interaction between fertilizer type and density is considered, a notable pattern emerges. The absolute reduction in capsule number from low to high density is largest for inorganic fertilizer, at forty one capsules, and smallest for the control, at 11 capsules. However, the relative reduction, expressed as a percentage, is similar across treatments. Inorganic loses about thirty percent of its low-density capsule count, organic loses about twenty-six percent, and control loses about twenty percent. This suggests that while competition operates in all treatments, well-fertilized plants are more responsive to spacing because they have more capsules to lose. In conclusion, the maximum number of capsules per plant, 138 was recorded for inorganic fertilizer at low density. The minimum number 46 was recorded for the control at high density. Both fertilizer type and plant density had strong effects on this parameter, with a clear negative density-response curve.

5.6 Analysis of 100 seed weight (g) per plot.

The 100 seed weight (also called seed mass) reflects the efficiency of seed filling and the accumulation of assimilates during the late reproductive stage. In this study, inorganic fertilizer produced the heaviest seeds (0.47g), followed by organic fertilizer (0.41 g), while the unfertilized control gave the lightest seeds (0.35 g). This trend was consistent across all three plant densities, indicating that nutrient availability was the dominant factor controlling seed weight under the tested conditions.

The heavier seeds from inorganic fertilization can be explained by the rapid and balanced supply of essential nutrients, particularly nitrogen and phosphorus, which support prolonged

photosynthetic activity and effective translocation of carbohydrates into developing seeds. Organic fertilizer released nutrients more slowly, leading to moderate seed weight, whereas the control plots experienced acute nutrient deficiency, resulting in poor seed development and lighter seeds. Plant density did not influence 100-seed weight within each fertilizer type, suggesting that competition between plants was not severe enough to reduce individual seed mass, even at the highest density.

5.9. Final Grain yield

Grain yield per plot (plot size 2 m x 4 m =8 m^2) is the final outcome of the combined effects of fertilizer and plant density on all yield components. The highest yield (1.26 kg/plot) was recorded from inorganic fertilizer combined with medium plant density (75x30 cm). This combination achieved the best balance between plant population and per plant productivity: medium density had more plants per plot than low density, but without the excessive inter-plant competition that occurred at high density, which reduced capsules per plant and seed weight.

Inorganic fertilizer at low density produced a high number of capsules per plant (138) and heavy seeds (0.47 g), but the lower plant population resulted in a lower total plot yield (1.11 kg/plot) compared to medium density. At high density under inorganic fertilization, competition for light, water, and nutrients reduced yield to 1.01 kg/plot. Under organic fertilizer, plot yields were much lower (0.71 to 0.81 kg/plot), with the highest again at medium density (0.81 kg/plot), but this was only about 64% of the inorganic medium density yield. The control plots yielded very poorly (0.38 to 0.43 kg/plot), confirming that without external nutrient supply, sesame production on the Shamva soils is not economically viable. Overall, the combination of inorganic fertilizer and medium plant density maximised grain yield per plot because it optimized both resource availability and plant population.

CHAPTER 6: RECOMMENDATIONS AND CONCLUSIONS

6.1 Introduction

This chapter provides a synthesis of the research findings on the effects of fertilizer type and population density on the growth and yield of sesame (Sesamum indicum L.) conducted in Shamva. The primary aim of the study was to identify the optimal agronomic practices that can enhance sesame productivity in the local agro-ecological conditions. The conclusions are drawn directly from the results presented in Chapter 5, and the subsequent recommendations are designed to be practical and evidence-based for various stakeholders, from smallholder farmers to future researchers.

6.2 Summary of Key Findings

The research clearly established that both fertilizer application and plant population density have significant impacts on sesame performance, with a notable interaction effect that determines overall yield.

1. Fertilizer Effect: Inorganic fertilizer (a combination of Ammonium Nitrate and Compound D) was the most effective treatment. It consistently outperformed the organic fertilizer (Nutriplant) and the control across almost all measured traits. This resulted in the tallest plants (142.5cm), thickest stems (4.85cm), most capsules per plant (116.8), and highest grain yield (1.136 kg/plot). In contrast, the organic fertilizer led to moderate improvements over the control, while the control plants exhibited the poorest growth and yield.

2. Population Density Effect: The plant population density had a significant effect on plant architecture and yield.

- Low density (25 plants/m^2): Plants produced the highest number of capsules per plant (97.0) due to reduced competition and greater branching.

-Medium density (33 plants/m^2): This treatment resulted in the tallest plants and, critically, the highest total grain yield per plot (0.838 kg/plot). This represents an optimal balance between individual plant productivity and total plant population.

- High density (50 plants/m^2): Plants in this treatment had the thinnest stems, fewest capsules per plant (72.1), and the lowest overall yield.

3. Interaction Effect: The interaction between fertilizer and density was significant and is the most crucial finding for practical application.

- The absolute best treatment combination for maximizing yield per plot was Inorganic fertilizer applied at a Medium population density, which produced 1.270 kg/plot. This is because the high nutrient availability from inorganic fertilizer could be effectively utilized by a moderately dense plant population, maximizing both per-plant and per-area productivity.

-Conversely, the worst performing treatment was the Control (no fertilizer) at High density, which yielded only 0.373 kg/plot. This highlights that using inappropriate agronomic practices can lead to severe yield penalties.

-Applying inorganic fertilizer at a high density was inefficient, as plants competed for resources and could not fully benefit from the added nutrients. Applying it at a low density was also inefficient, as the land was not fully utilized.

6.3 Conclusions

Based on the objectives, data analysis, and discussion of this study, the following conclusions can be drawn:

1. Inorganic Fertilizer is Superior for Yield in the Short Term: In the context of a single growing season on the soils of Shamva, inorganic fertilizer is the most effective option for achieving high sesame yields. Its rapid nutrient release and high concentration of balanced nutrients (N, P, K) address the immediate needs of the "heavy feeder" sesame crop, particularly during its critical growth and capsule-filling stages.

2. Medium Plant Population is the intermediate plant population of approximately 33 plants/m^2 represents the optimal balance for sesame production in this region. It allows plants enough space to develop branches and capsules while still maximizing the number of productive plants per unit area.

3. Fertilizer and Density Must Be Managed Together: The single most important conclusion is that fertilizer and population density are not independent factors. Their significant interaction means that for a farmer to achieve maximum profit and yield, they must apply the correct fertilizer type and the correct planting density simultaneously. The best outcome is achieved when a high-nutrient input (inorganic fertilizer) is combined with a spatial arrangement (medium density) that allows each plant to efficiently use those nutrients.

4. Density Cannot Compensate for Poor Nutrition: This study clearly demonstrated that adjusting plant population density cannot compensate for a lack of essential nutrients. Without adequate fertilization (the control), yields remained low and stagnant across all densities.

5. Project Success: The experiment was conducted with high reliability, as indicated by the low Coefficient of Variation (CV %) values. This confirms that the experimental procedures, from field layout to data collection, were robust and that the results are a true reflection of the treatment effects.

6.4. Recommendations.

The following recommendations are proposed for different target groups based on the study's conclusions.

6.4.1 Recommendations for Smallholder and Commercial Farmers in Shamva and Similar Regions

1. Adopt a Balanced Fertilization Strategy: Farmers are strongly advised to invest in inorganic fertilizers, specifically a complete NPK blend (like Compound D) combined with a nitrogen top-dressing (like Ammonium Nitrate) or a split application of a fertilizer suited for sesame. This provides the crop with the high nutrient concentration it needs for rapid growth and high yields.

2. Optimize Planting Density: Instead of broadcasting seeds or planting too close together, farmers should plant sesame at a medium density. Based on this research, a spacing of 30 cm between rows and 10 cm within the row (or similar, to achieve approximately 33 plants/m^2) is recommended to achieve the optimal plant population.

3. Integrate Practices for Best Results: Farmers must understand that adopting one good practice while neglecting another is counterproductive. The key to achieving high yields, such as the 1.27 kg/plot (or approximately 1,270 kg/ha) recorded in this trial, is to combine inorganic fertilizer with medium plant density.

4. Consider Long Term Soil Health: While inorganic fertilizer was the best performer for immediate yield, its continuous use can have negative long-term effects on soil health, such as acidification. Where possible, farmers should consider integrating organic fertilizers (like manure or Nutriplant) into a broader soil management plan to maintain soil organic matter and microbial activity, even if it means slightly lower yields in the short term. A combined approach (integrated nutrient management) could be explored in future trials.

6.4.2 Recommendations for Future Research.

1. Long term, Multi Season Trials: A key limitation of this study was that it was conducted over a single season and at one location. Future research should be replicated over multiple seasons (e.g 3 to 5 years) to confirm the consistency of these findings under varying rainfall patterns and to study the residual effects of fertilizer on the soil. Trials at different locations across Zimbabwe would also help to validate the recommendations for different soil types and climatic zones.

2. Economic Analysis (Cost benefit): This study focused on agronomic yield. A detailed economic analysis should be conducted to determine the profitability of the different treatments. This would involve calculating the cost of inputs (seed, inorganic fertilizer, organic fertilizer, labor) versus the market value of the sesame yield. This would provide farmers with clear evidence of the financial return on investment.

3. Investigate an Integrated Nutrient Management (INM) Approach: Given the benefits of both inorganic (yield) and organic (soil health) fertilizers, research should be designed to test various combinations of the two. For example, trials could explore the effect of applying a reduced rate of inorganic fertilizer in combination with an organic amendment to see if a balance between high yield and soil sustainability can be achieved.

4. Density and Varietal Interaction: The study was conducted with a single, unspecified sesame variety. Different sesame varieties have different branching habits (e.g. single stem vs. branched types). Future research should test the optimal population density for different commercial varieties commonly grown in Zimbabwe to provide variety-specific recommendations.

6.5 Final Remarks.

In conclusion, the research successfully demonstrated that the yield of sesame in Shamva can be significantly enhanced through the precise management of fertilizer and plant population. The optimum treatment combination, Inorganic fertilizer at Medium population density, resulted in a three and a half-fold increase in yield compared to the worst performing combination. While organic fertilizers hold value for long term soil conservation, inorganic fertilizers are currently the most reliable tool for maximizing productivity and securing farmers' income in a single season. This study provides a strong scientific basis for extension services to advise farmers on the importance of adopting a holistic approach where inputs and planting systems are optimized together. Ultimately, the goal is to help Zimbabwean farmers, particularly those in areas like Shamva, to harness the full potential of sesame as a profitable and resilient crop.

REFERENCE

-Mujaya, I. M., & Yerokun, O. A. (2003). Response of Sesame to Plant Population and Nitrogen Fertilizer in North Central Zimbabwe. Sesame and Safflower Newsletter, 18, 64-69.This is the foundational publication on your topic. It found that increasing plant population was the main factor causing seed yield to increase, explaining 48% of variation in yield.

- Mujaya, I. M. (2011). Growth and yield components of sesame (Sesamum indicum L. landrace matsai) in response to plant population and nitrogen rate, at Gwebi, Zimbabwe (Master's thesis, University of Zambia). This comprehensive thesis provides detailed data on how increasing population decreased branch and capsule number per plant but increased overall yield.

- Nyamadzawo, G., Mandumbu, R., Zengeza, T., & Mapfeka, R. (2019). Challenges and opportunities faced in Sesame production in Zambezi Valley, Zimbabwe. RUFORUM Working document series.This source provides valuable context on production constraints and opportunities specific to the Zambezi Valley, one of Zimbabwe's major sesame growing areas.

- Kambikambi, T. T., Mwala, M. S., and Mbewe, D. M. N. (1997). Relationship between yield and yield components of sesame. African Crop Science Conference Proceedings, 3(1), 169-174. This Zambian study on the relationship between yield and yield components can be cited for comparative discussion on sesame physiology.

-Mwatawala, H., Alex, S., & Magasha, O. (2025). Determinants of Smallholder Participation in Sesame Farming. Evidence from Chalinze District, Tanzania. Rural Planning Journal, 27(1), 25-41 .This study covers factors influencing smallholder participation in sesame farming in Tanzania.

- Hyera, D., and Isango, E. (2024). Boosting Productivity. The Impact of Improved Sesame Varieties on Small-Scale Farmers in Mtwara, Tanzania. NG Journal of Social Development, 14(1), 46-61. This article discusses how improved sesame varieties can boost productivity for small-scale farmers in Tanzania.

-Singini, D. (2025). Climate resilient crops for planetary health: Strengthening cowpea, sesame, and sorghum value chains for food systems transformation and land health restoration in Malawi. Tropentag 2025. This study discusses sesame's potential as a climate-resilient crop in Malawi's drought prone districts.

- Khidir, M. O. (1972). Natural Cross-Fertilization in Sesame Under Sudan Conditions. Experimental Agriculture, 8(1), 55-59. A classic agronomy study on sesame from Sudan.

- Khidir, M. O., and Khattab, A. H. (1972). Oil, Protein and Dry Matter Development in Sesame Seed. Experimental Agriculture, 8(1), 61-65. Another foundational reference on seed development from Sudan

- Srikanth et al. (2009a), and Valadabadi and Farahani (2010) found that wider spacing reduces competition, improving resource utilization and photosynthetic activity. Conversely, higher densities increase competition, reducing individual plant growth.

- Hashemi et al. (2005) and Dawadi and Sah (2012) reported that increasing plant density linearly decreased yield components like kernels per ear, while higher population density still increased total grain yield.

- Akbar et al. (2016) and Mangal et al. (2017) found that grain and stover yield increased with higher planting density, and that applying higher nitrogen rates at optimum densities further boosted yields.

- Mburu, Simmonds, and Pilbeam (1999) demonstrated that N fertilizer increased LAI when water was not limiting, while high planting density increased LAI if both water and N were sufficient.

- Tefera et al. (2022) conducted a meta-analysis in Ethiopia showing that N fertilizer (31.5–65.9%) and plant density (42–72.4%) each increase maize yield, and their interaction can boost yield by 27.6–95.9%.

- Yan et al. (2022) studied Arabidopsis and found the biomass-density relationship is regulated by N availability, and N availability was more important than density in regulating leaf N and P stoichiometry.

- Li et al. (2020) found that one-time slow-released fertilizer combined with appropriate density (7.5×10^4 plants ha^{-1}) produced the highest grain yields and N use efficiencies.

APPENDIX

Analysis of variance for plant height.

Variate: Plant_Height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	4.985E-01	2.493E-01	4.46	

BLOCK.*Units* stratum					
FACTOR_1_FERTLIZER	2	1.239E+04	6.194E+03	1.108E+05	<.001
FACTOR_2_PLANT_DENSITY	2	5.203E+01	2.602E+01	465.19	<.001
FACTOR_1_FERTLIZER.FACTOR_2_PLANT_DENSITY					
	4	8.673E+01	2.168E+01	387.70	<.001
Residual	16	8.948E-01	5.593E-02		
Total	26	1.253E+04			

Analysis of variance for plant leaves.

Variate: Plant_Height

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	4.985E-01	2.493E-01	4.46	
BLOCK.*Units* stratum					
FACTOR_1_FERTLIZER	2	1.239E+04	6.194E+03	1.108E+05	<.001
FACTOR_2_PLANT_DENSITY	2	5.203E+01	2.602E+01	465.19	<.001
FACTOR_1_FERTLIZER.FACTOR_2_PLANT_DENSITY					
	4	8.673E+01	2.168E+01	387.70	<.001
Residual	16	8.948E-01	5.593E-02		
Total	26	1.253E+04			

Analysis of variance for plant leaves.

Variate: Leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.30296	0.15148	1.61	

BLOCK.*Units* stratum					
FACTOR_1_FERTLIZER	2	2167.16963	1083.58481	11529.77	<.001
FACTOR_2_PLANT_DENSITY	2	0.02074	0.01037	0.11	0.896
FACTOR_1_FERTLIZER.FACTOR_2_PLANT_DENSITY					
	4	0.88148	0.22037	2.34	0.099
Residual	16	1.50370	0.09398		
Total	26	2169.87852			

Analysis of variance for plant leaves.

Variate: Leaves

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.30296	0.15148	1.61	
BLOCK.*Units* stratum					
FACTOR_1_FERTLIZER	2	2167.16963	1083.58481	11529.77	<.001
FACTOR_2_PLANT_DENSITY	2	0.02074	0.01037	0.11	0.896
FACTOR_1_FERTLIZER.FACTOR_2_PLANT_DENSITY					
	4	0.88148	0.22037	2.34	0.099
Residual	16	1.50370	0.09398		
Total	26	2169.87852			

Analysis of variance for number of capsules

Variate: Number_of_Capsules_plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.5185	0.2593	0.36	

BLOCK.*Units* stratum					
FACTOR_1_FERTLIZER	2	18760.0741	9380.0370	13071.54	<.001
FACTOR_2_PLANT_DENSITY	2	2796.5185	1398.2593	1948.54	<.001
FACTOR_1_FERTLIZER.FACTOR_2_PLANT_DENSITY					
	4	552.8148	138.2037	192.59	<.001
Residual	16	11.4815	0.7176		
Total	26	22121.4074			

Analysis of variance for number of capsules

Variate: Number_of_Capsules_plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.5185	0.2593	0.36	
BLOCK.*Units* stratum					
FACTOR_1_FERTLIZER	2	18760.0741	9380.0370	13071.54	<.001
FACTOR_2_PLANT_DENSITY	2	2796.5185	1398.2593	1948.54	<.001
FACTOR_1_FERTLIZER.FACTOR_2_PLANT_DENSITY					
	4	552.8148	138.2037	192.59	<.001
Residual	16	11.4815	0.7176		
Total	26	22121.4074			

Analysis of variance for 100 seed weight.

Variate: %100_seed_weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.00005185	0.00002593	0.41	
BLOCK.*Units* stratum					
FACTOR_1_FERTLIZER	2	0.06769630	0.03384815	533.66	<.001
FACTOR_2_PLANT_DENSITY	2	0.00014074	0.00007037	1.11	0.354
FACTOR_1_FERTLIZER.FACTOR_2_PLANT_DENSITY	4	0.00019259	0.00004815	0.76	0.567
Residual	16	0.00101481	0.00006343		
Total	26	0.06909630			

Analysis of variance 100 seed weighgt

Variate: %100_seed_weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.00005185	0.00002593	0.41	
BLOCK.*Units* stratum					
FACTOR_1_FERTLIZER	2	0.06769630	0.03384815	533.66	<.001
FACTOR_2_PLANT_DENSITY	2	0.00014074	0.00007037	1.11	0.354

FACTOR_1_FERTLIZER.FACTOR_2_PLANT_DENSITY					
	4	0.00019259	0.00004815	0.76	0.567
Residual	16	0.00101481	0.00006343		
Total	26	0.06909630			

Analysis of variance for grain yield.

Variate: Final_grain_yield_kg_plot

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.00020000	0.00010000	1.26	
BLOCK.*Units* stratum					
FACTOR_1_FERTLIZER	2	2.40642222	1.20321111	15198.46	<.001
FACTOR_2_PLANT_DENSITY	2	0.07575556	0.03787778	478.46	<.001
FACTOR_1_FERTLIZER.FACTOR_2_PLANT_DENSITY					
	4	0.04482222	0.01120556	141.54	<.001
Residual	16	0.00126667	0.00007917		
Total	26	2.52846667			

Analysis of variance for grain yield.

Variate: Final_grain_yield_kg_plot

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
BLOCK stratum	2	0.00020000	0.00010000	1.26	
BLOCK.*Units* stratum					
FACTOR_1_FERTLIZER	2	2.40642222	1.20321111	15198.46	<.001
FACTOR_2_PLANT_DENSITY	2	0.07575556	0.03787778	478.46	<.001

FACTOR_1_FERTLIZER.FACTOR_2_PLANT_DENSITY					
	4	0.04482222	0.01120556	141.54	<.001
Residual	16	0.00126667	0.00007917		
Total	26	2.52846667			

Tawonga Taruberekera

Ruramai Bungira Disserrtation 2026

Dissertations

Document Details

Submission ID
trn:oid:::2945:395705872

Submission Date
Jun 25, 2026, 10:08 PM GMT+2

Download Date
Jun 25, 2026, 10:21 PM GMT+2

File Name
Ruramai Bungira Disserrtation 2026.docx

File Size
476.0 KB

54 Pages

10,365 Words

60,626 Characters

12% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

Filtered from the Report

- Bibliography
- Quoted Text

Exclusions

- 64 Excluded Matches

Match Groups

114 Not Cited or Quoted 10%
Matches with neither in-text citation nor quotation marks

21 Missing Quotations 2%
Matches that are still very similar to source material

Top Sources

7% Internet sources
8% Publications
9% Submitted works (Student Papers)