BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF CROP SCIENCE

EFFECTS OF INTER ROW SPACING AND FERTILISER LEVELS ON THE PERFOMANCE OF SESAME (SESAMUM INDICUM)

MAPURANGA REBECCA V

B211782B

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

DEDICATION

I dedicate this project to my parents for their unwavering backing and encouragement.

ACKNOWLEDGMENTS

It will be unthinking to fail to express my sincere appreciation to the people who helped me torwards the achievement of this project. I would like to thank my supervisor Mr. K Mutsengi for his tireless effort, undivided attention, unwavering support and technical guidance which l cannot imagine how it could have been without him. My co-supervisor Professor R Mandumbu, thank you for your thorough but vibrant criticism and raising red flags during the course of this project. I also extend my gratitude to Mr Masango from AGRITEX Department for providing sesame seed and compound D fertilizer. I also want to thank Mr. Tarubona from Chibhero Agricultural College for his support in finding research gaps. To my father Tichaona and mother Calista, thank you for giving me bravery as l worked on this project.

I would like to recognize my colleagues Nigel and Noel for their encouragement. Finally, I give praise to the Almighty for giving me the wisdom and strength to carry out this project.

DECLARATION

I, Rebecca Mapuranga formally declare to Bindura University of Science Education that this research project reflects my original research work. It is submitted as part of the requirements of the award of the Bachelor of Agricultural Science Honours Degree in Crop Science. These research findings have never been submitted by any other institutions.

Signature

Date 17/09/2025

Supervisor

I have supervised the research project for the above mentioned student and lm convinced that the research can be submitted.

Signature .... Date ....

ABSTRACT

The study was piloted in Matongorere Village in Murewa, Mashonaland East Province. The project was done in order to investigate the effects of inter row spacing and fertilizer levels on the performance of sesame (Sesamum Indicum L). The trial was laid as a 3 by 4 factorial experiment laid in a Randomized Complete Block Design. The two factors were different inter row spacing's (30cm, 45cm a 60 cm) and different fertilizer levels (0kg /ha, 50kg/ha, 100kg /ha and 150kg /ha. the fertilizer used was compound D whose nutrient composition is N 7%. P14%. K7%. The main objective was to determine effect of inter row spacing and fertilizer level on the performance of sesame. There was significant interaction ($p< 0.05$) between inter row spacing and fertilizer levels on the performance of sesame. The results clearly demonstrate that both inter row spacing and fertilizer levels significantly influenced the vegetative growth, reproductive development, and overall yield of sesame. The best results were obtained by using 45cm inter row spacing combined with 150kg/ha compound D fertilizer in all measured parameters. Adopting to this combination would better light penetration and reduce competition thereby improving growth. Adequate fertilization boosts growth parameters ensuring sustainable sesame production.

This image cannot currently be displayed.

Table of Contents

List of Figures

ABBREVIATIONS

AGRITEX-Agricultural Technical and Extension Services

ANOVA- Analysis of Variance

LSD- Least Significant Difference

NPK- Nitrogen Phosphorous Potassium

CHAPTER 1

1.1 INTRODUCTION

Sesame (Sesamum indicum L) is a crop cultivated annually and it is one of the oldest oilseed crops known to humanity. It is assumed to have initiated in Africa specifically in the Ethiopian highlands over 3000 years ago (Bedigian, 2014). The crop was highly valued due to its seeds with high oil content. which were used as a food source, medicine and lighting. Sesame was traded extensively along the ancient Egyptian and Greek trade routes with records of its use dating back to around 1500 BC (Kristotakis, 2017). The crop is highly valued for its rich oil seeds which are used in a diversity of food products, including baking, cooking and cosmetics. Today the cultivation of sesame is being done in many parts of the world with major producers in Sudan (981,000 tons/ha), Myanmar (890,000tonnes/ha), India (623,000tonnes/ha), China (623,492tonnes/ha), and Tanzania (561,103tonnes/ha), (FAO, 2020).

The current trends in sesame are shaped by its increasing demand, genetic research and breeding programs. Sesame production is on the rise globally, driven by its nutritional and medicinal value. Sesame is a multipurpose crop which have various uses as well as outstanding nutritional content of 42-45 % oil, 20% protein, and 14 -20% carbohydrates (BARI, 2014). The seeds contain high nutritional value that is all vital amino acids and fatty acids are found in it. It is a better source of vitamins and minerals such as calcium which amounts to 6% per 100 g and phosphorus which also amounts to 66.7 per 100g, (Malik et al., 2013). the crop has high content of both good quality, palatable oil which exhibit high grade of stability and resistance to oxidative rancidity because of the presence of endogenous antioxidants such as semisolid, sesamolinol and sesaminol, (Alpaslan et al., 2021). Sesame seeds have many uses which include preparation of varieties of food such as confectioneries, cakes and pastries. The high quantities of oil are used for cooking, manufacturing margarine and in pharmaceutical industries, (Naim et al., 2012). Sesame oil cake is essential for poultry, goat, sheep, fish and cattle. Sesame seeds carries a compound called sesamin, which have been discovered to have anticancer properties, suppressing the growth of cancer cells and inducing apoptosis (cell death), (Harikumar et al., 2010). Research that was in the journal of nutrition found that sesame repressed the growth of human breast cancer cells and induced cell death, (Wu et al., 2011). Anderson et al., (2009), noted that the seeds are rich source of dietary fiber, which can help promote digestive health, avoid constipation and support healthy blood sugar levels. According to a study carried out by Yilmaz et al., (2018), it was found out that sesame oil supplementation enhanced gastrointestinal health and condensed signs of irritable bowel syndrome (IBS) in patients with IBS.

There is a growing focus on sustainable sesame production practices including the use of crop rotation, organic farming and integrated pest management. The development of improved sesame varieties with necessary traits such as high oil content, disease resistant, and drought tolerance has significantly improved sesame production, for example the introduction of "TGX" series of sesame varieties in Africa has led to increased yields and improved disease resistance, (FAO, 2017). According to Kumar et al., (2018), the adoption of mechanized farming practices such as tractor powered planting and harvesting has increased sesame production efficiency and reduced labor costs. The adoption of IPM practices such as crop rotation, biological control and cultural control methods has reduced pesticide use and improved sesame yields, (Mishra et al., 2019). USAID 2020, stated that, "efforts to improve the sesame value chain including processing, storage and marketing have enhanced the quality and availability of sesame products increasing demand and prices for farmers".

1.2 PROBLEM STATEMENT

Sesames productivity remains suboptimal in many regions due to inadequate information on the optimal agronomic practices, particularly spacing and fertilizer levels. The problem is that there are insufficient investigations on the effects of spacing and fertilizer levels on the development, harvest and value of sesame. This knowledge gap limits the development of effective recommendations for farmers, thereby limiting the crops capacity to give significance to food safety and economic development.

1.3 JUSTIFICATION OF THE STUDY

Due to the decline in the production of sesame caused mainly by lack of information and expertise in land preparation and agronomic practices such as spacing as well as fertilizer management. It is therefore estimated that coming up with knowledge on improved agronomic practices will surely lead to increase of sesame production. Thus, this research project is set to equip growers with the state to art production techniques, acquaintance, ability and information in as much as sesame production is concerned having the aim to evaluate the optimum inter row spacing and adequate fertilizer level for better performance of sesame.

1.4 STUDY OBJECTIVES

1.4.1 MAIN OBJECTIVE

To determine the optimal, inter row spacing and fertilizer levels for improved sesame production.

1.4.2 SPECIFIC OBJECTIVES

To measure the effect of varying fertilizer levels and spacing on sesame vegetative growth and development.

To evaluate the influence of fertilizer levels and spacing on reproductive growth parameters.

To assess the effects of spacing and fertilizer levels on sesame yield.

1.5 HYPOTHESES

There is no significant difference in sesame vegetative growth and development among different spacing and fertilizer levels.

There is no significant difference in reproductive growth parameters among different spacing and fertilizer levels.

There is no significant difference in sesame yield among different spacing and fertilizer levels.

CHAPTER 2

2.1 LITERATURE REVIEW

2.1.1 Importance of sesame

Apart from its leaves and seeds being eaten sesame has many uses. Sesame seeds are a common ingredient in many cuisines. They add a nutty flavor and crunchy texture to various dishes such as baked goods, salads, stir fries. Sesame seeds are also used as a tipping for bread, bagels and cookies providing a rich source of nutrients. Sesame has also been utilized in old-style remedy for centuries. The seeds are thought to have many benefits health wise including reducing inflammation, improving digestion, supporting bone health and performing as a natural laxative Chen, and (2018). Furthermore, sesame oil has various cosmetic applications. The oil is used in skincare products because of its anti-oxidant and moisturizing properties (Lee, 2018). The oil is also used in hair care products to stimulate hair growth and improve scalp health. Additionally, sesame seeds are used in soap making due to their moisturizing and cleansing properties (Bhavnagar, 2017).

The performance of sesame as a high valued oilseed crop is influenced by various agronomic practices particular spacing and fertilizer applications. Proper spacing and fertilizer levels are crucial for maximizing sesame production as they directly influence plant growth, light interception, nutrient availability and finally, the yield of sesame seeds. However, optimal spacing and fertilizer levels for maximum yield and quality of sesame are not well established and may vary based on environmental conditions, soil types, and local agricultural practices. This research aims to evaluate the impact of different spacing methods and fertilizer levels on the growth and yield of sesame to identify the most effective agronomic strategies for improving sesame productivity and sustainability in different agricultural contexts.

2.1.2 Botany

As a broad-leafed plant, sesame can stretch to a height of 1,5m to 2m subject to the variety and the growing conditions. Its shape, size, growing behavior, color of flowers and the size of seeds also differs. Sesame is regarded as a drought tolerant crop but good soil moisture is recommended for its growth and high yield. The color of its stem can be light green t purple. It has a deep thin taproot of about 1m long with a well dispersed secondary root system for maximum use of soil moisture. The lower leaves of a sesame plant are broad and sometimes lobed while the upper leaves are narrow as a way to allow sunlight penetration. The size of the leaves varies from 3 to 17,5 cm in length and 1 to 1,7 cm in width and the petiole length of about 1 to 5 cm.it has dull, darkish green or light green with a yellowish tint color and they are hairy. Sesame plant yields bell shaped flowers that begin to grow in the leaf axils. at 35 to 45 days after planting, flowering starts and it can continue for 75 to 85 days in most varieties. Sesame does self-pollination but cross pollination is also common. The fruiting structure of a sesame seed is a capsule or pod with a size altered by environmental factors. The capsule is close to the stem and it contains about 50 to 90 small seeds, (Sharma et al., 2019).

2.1.3 Adaptation

Cultivation of sesame expanses from lowland to mid altitudes (300 -1700m). It achieves better in altitudes ranging from 650 to 1250m. It also grows well in frost free and warm areas. According to Kurmar et al., (2018), it needs hot conditions during growth to produce maximum yields. Temperatures of about 25 to 37 degrees Celsius are optimum for its development and higher yield. Temperatures below 20 degrees Celsius for any length of time inhibits germination and a temperature of less than 18 degrees Celsius after emergency will lead to lagging growth of seedlings. Sesame can adapt to various soil types but it performs best on well drained and medium textured fertile soils with 5 to 8 soil pH (Langham 2017).

Sesame can be harvested 90 to 120 days after planting in most varieties. When harvesting, the matured plants are cut, shoved and stacked to dry. In other areas, the stalks are left in the field. As the plants dry, the capsules open and some of the seed can fall out. Under sunny conditions, will be ready for threshing within 2 weeks.

2.2 EFFECTS OF SPACING ON THE PERFOMANCE OF SESAME

The production of sesame can be hindered by many things and these include absence of plant population and inter row spacing references. As plant population rises, competition among plants become more forceful, limiting the growth and progress of each plant. Sesame yields decreases as the row spacing increases. Improving plant population is also very essential in enhancing grain yield in a precise environment. best spatial arrangement of plants for effective canopy development, water and nutrient utilization and pest control maximizes yield of sesame. These relationships are also vital for optimal physiological function of the crop. In sesame, yield is the function of the number of plants per unit area, number of branches per plant, number of capsules per plant and number of seeds per capsule. Adequate spacing between plants ensures that each individual receives sufficient light for photosynthesis, leading to better plant growth and higher yields. Proper spacing also improves air circulation reducing the risk of fungal diseases. By preventing overcrowding plants can access nutrients more efficiently from the soil.

According to Unde et al., (2015), in a range of spacing's, the spacing of 60cm by 15 cm gave highest plant height of 88cm at all growth stages of crop growth and spacing of 30cm by 15 cm produced lowest plant height of 56,4cm. The wider row and plant spacing might have given adequate rooting and moisture extraction pattern to the plant which in turn would have better absorption of water and nutrients from the soil resulting in tallest plants, Shinde et al., (2011). The spacing of 60cm by 15 cm produced significantly higher mean number of branches per plant which was at par with 45cm by 10 cm. the wider plant spacing enhanced mean number of branches over remaining spacing's owing to better geometric arrangement resulting in better absorption of moisture and nutrients due to lesser competition for growth factors between plants. Sivagamy and Rammohan, (2013) also found out that where the spacing of 60cm by 15cm recorded significantly higher mean total dry matter per plant over the rest of other spacing's.

According to Sanjay et al., (2020), number of branches per plant recorded at 30 and 60 days after sowing and at harvest was found significantly higher in in the treatment with 45cm inter row. Sivagamy and Rammohan, (2013) also indicated that the treatment with 45 cm recorded the highest number of capsules per plant. Maximum number of capsules per plant under medium spacing (45cm), might be due to better geometric arrangement which help in enhanced photosynthesis rate which consequently might have more inversion of photosynthate from source to sink and as a result more manifested capsules per plant. Hemalatha et al., (2019), also found similar line of results which indicated that competition free environment enables the crop to use nutrients efficiently which contributed to improved crop performance.

2.3 EFFECTS OF FERTILISER APPLICATION ON THE PERFOMANCE OF SESAME

Plant nutrition is key input that should be implemented in order to advance crop yields (Shahab et al., 2015). In research done in India, lower productivity of sesame was attributed due to the use of sub optimal rates of fertilizer and poor management of sesame this indicates the need to increase the productivity of sesame through optimization of nutrients. Nutrient imbalance has also been proved to be an important factor limiting the full expression of sesame yield potential (Okpara et al., 2007).

Between the sesame growers in Nigeria, application of fertilizers has not been a common practice because it is regarded a minor crop that can perform well even on nutrient deficient soils and this is likely to be the situation in Zimbabwe (Haruna and Usman., 2015). It has been demonstrated that sesame grown in soils that were fertilized using 100 up to 150kg/ha yielded more highly than the one grown in soils without fertilizer (Jakuso and Usman, 2013). The application of optimum nutrients at the right time is essential for increasing seed yield (Khan, 2016).

Supplying enough nitrogen is crucial for carbohydrates and protein metabolism, promoting cell division and cell enlargement. It also aids in the synthesis of proteins, nucleic acids, nucleotides, enzymes, vitamins and chlorophyll (Jasimuddin, 2014). Nitrogen affects flowering and fruiting in sesame production. Shirazy et al., (2015), reported that soils that were below nitrogen critical range of 10-15kg/ha resulted in good crop growth. Zainab et al., (2016), reported that nitrogen application of 60-150kgN/ha increased plant height and leaf area index of sesame, due to the role of N in enhancing physiological processes, (Lorlamen et al., 2014). Zainab et al., (2016) also reported that application of nitrogen fertilizer up to 80kg/ha increased the number of branches per plant, dry matter yield, leaf area and number of capsules per plant. These results indicate that a low nitrogen application increased the number of capsules per plant while a high application increased seed yield (Sultana et al., 2011).

Ali and Jan (2014) observed that the supply of high levels of inorganic nitrogen fertilizers increased sesame seed protein content. Nina et al., (2016), reported that the oil content of sesame increased with increasing nitrogen application up to 45-95kg/ha. This could be due to enhancement of lipid metabolism by phosphorus which increased seed oil yield. Basavaraj et al., (2020) reported that the application of NPK fertilizer at 60-75kgN/ha, 45-75kgP/ha and 22, 5-40kgK/ha resulted in high sesame seed yield when compared to the control. Carlson et al., (2009) reported that sesame responded less to higher doses of organic fertilizer and concluded that the application of 36kgN/ha, 9kgP/ha and 9kgK/ha was enough to improve seed yield.

Weiss (2020) stated that the number of capsules per plant increased with increasing NPK rate up too 125kg/ha which is said to be attributed to increased number of flower buds, number of flowers and multiple flowers in the axils of lower nodes on the main stem. The highest number of capsules per plant was observed at 125kg/ha followed by 100kg/ha (Abdul et al., 2017). Maximum yield was observed when NPK was applied at the rate of 125kg/ha while the lowest seed yield was observed in the control.

CHAPTER 3

METHODOLOGY

3.1 DESCRIPTION OF THE STUDY AREA

The experiment was carried out in Matongorere village which is situated in ward 9 of Murewa District in Mashonaland East Province of Zimbabwe. The area is under agro ecological region 11a, which is known for its relatively high rainfall and fertile soils. Murewa receives an annual rainfall of 600 to 800 mm primarily during the rainy season from November to March. During the time of the experiment, the temperatures were quite optimal with extreme temperatures around 26 degrees Celsius and minimum around 17 degrees Celsius. The experiment was done on sandy soils which are characterized by good water drainage.

3.2 EXPERIMENTAL DESIGN AND FIELD LAYOUT

The trial was put as a 3 by 4 factorial experiment laid in a Randomized Complete Block Design. The two factors were different inter row spacing's (30cm, 45cm an 60 cm) and different fertilizer levels (0kg /ha, 50kg/ha, 100kg /ha and 150kg /ha. The fertilizer used was compound D. The trial was replicated three times and the blocking factor was slope.

3.3.1 Land preparation

The soil was tilled by an ox drawn plough to a depth of 20cm to allow physical support of the plant and the use of adequate moisture and nutrients. The plots constructed for planting measured 1 by 2m, a pathway of 0,5m and randomly the treatments were assigned to the plots.

3.3.2 Variety

The variety "Sarada" (YLM 66) variety was used. It is a well-regarded, high yielding variety, yielding about 1125kg /ha and good oil content of about 50.3%. The variety is highly resistant to some diseases affecting sesame such as powdery mildew. It is a medium variety which takes around 90-100 days to mature, making it suitable for various growing conditions.

3.3.3 Transplanting

20 planting stations were made in each plot. The seedlings were transplanted to the field using the specified spacing and fertilizer level for each treatment. Seedlings that were healthy and of the same height were used for the research.

3.3.4 Watering

Plants were watered immediately after transplanting. Supplementary irrigation was only done during dry spells since this research was done during the rainfall season.

3.3.5 Weed management and pest control

Weed control was done by physically removing the weeds using small hoes and hand pulling. Insecticides like Thiamethoxam was used for the control of aphids at 0.3g per liter of water.

3.4 DATA COLLECTION

3.4.1 Plant height

Plant height was measured at 2 weeks intervals from one week after transplanting up to week 10. The measurements were taken using a tape measure from the ground to the tip of the upper leaf and the height of the plants was expressed in centimeters. The plant height of randomly selected plants was used to deduce the growth rate of the plants. A sample of 5 plants from the net plot was measure and then averaged.

3.4.2 Number of flowers per plant

Number of flowers per plant were obtained through physical counting of the visible flowers on the plant. A sample of 5 plants were selected in each plot in a random way then averaged.

3.4.3 Number of Pods per plant

Number of pods per plant were obtained through physical counting of the visible pods on the plant. A sample of 5 plants were randomly selected in each plot then averaged.

3.4.5 Number of branches per plant

The number of branches was also done through physical counting of each selected plant.

3.4.6 Mean pod weight

After the crop had reached physiological maturity, the pods were harvested from each plot and were put aside. The pods were measured using a balance to obtain the final yield.

3.5 DATA ANALYSIS

The data collected was subjected to the analysis of variance (ANOVA) to determine the effectiveness of different row spacing and different fertilizer levels on the performance of sesame using Genstat (version 17). The tests were done at 0.05 probability level. Means of significant treatment difference were separated using the least significant difference (LSD) procedure.

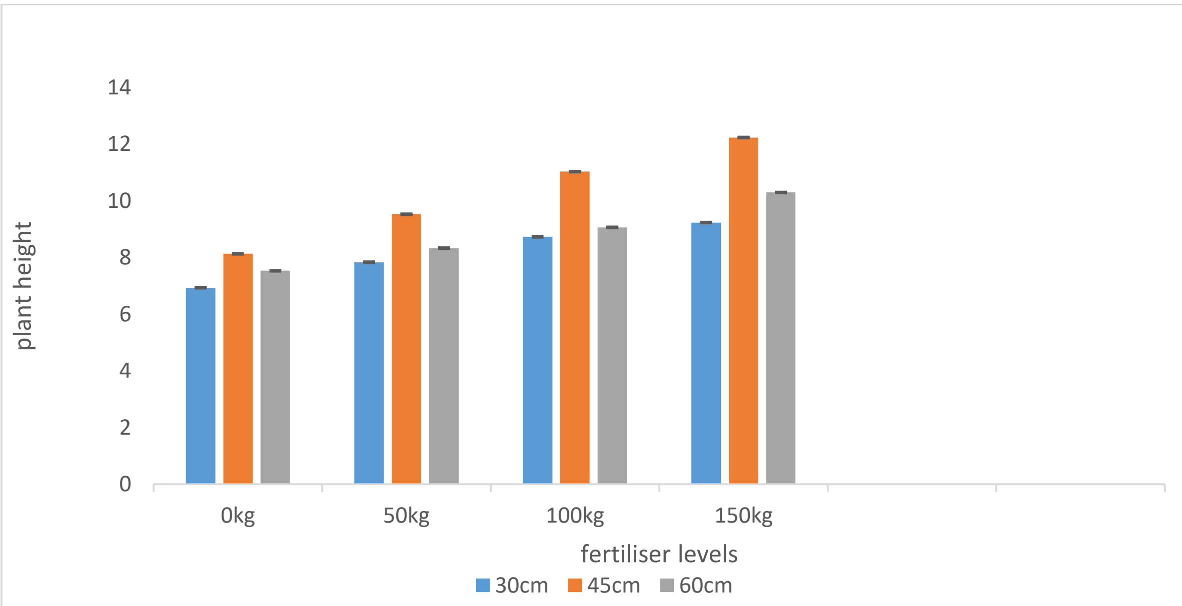
CHAPTER 4

RESULTS

4.1 PLANT HEIGHT

4.1.1 Plant height at week 4

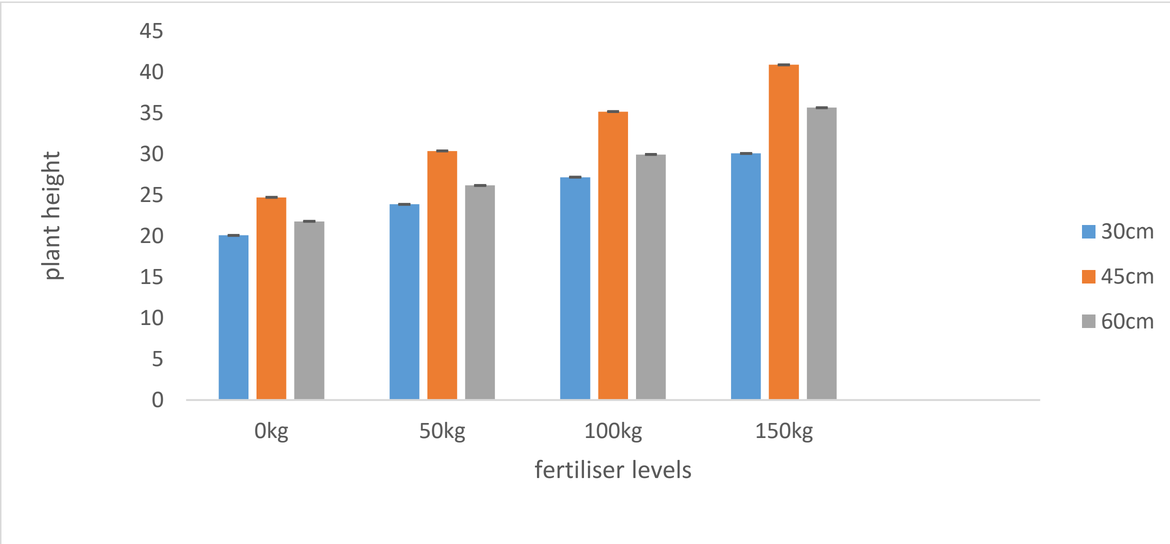
Figure 1 : Effects of plant spacing and fertiliser levels at week 4



The graph above displays that there was interaction ($p<0.05$) among plant spacing and fertiliser levels on the plant height at week 4. The increase in fertiliser levels from 0kg to 150kg, the plant height was also increasing across all spacing treatments. Also, at each fertiliser level, increasing spacing from 30cm to 45cm and 60cm also led to a rise in plant height. The combination of 150kg fertilizer with 45cm spacing produced the highest plant height of 12.233cm. In contrast the lowest plant height (6.933cm) was noted in the 0kg fertiliser with 30cm spacing treatment. Some treatments yielded similar results. For instance, the combination of 60cm spacing with 0 kg fertiliser(7.533cm) showed values close to the 30cm spacing with 50kg fertiliser which had 7.833 cm.

4.1.2 Plant height at week 6

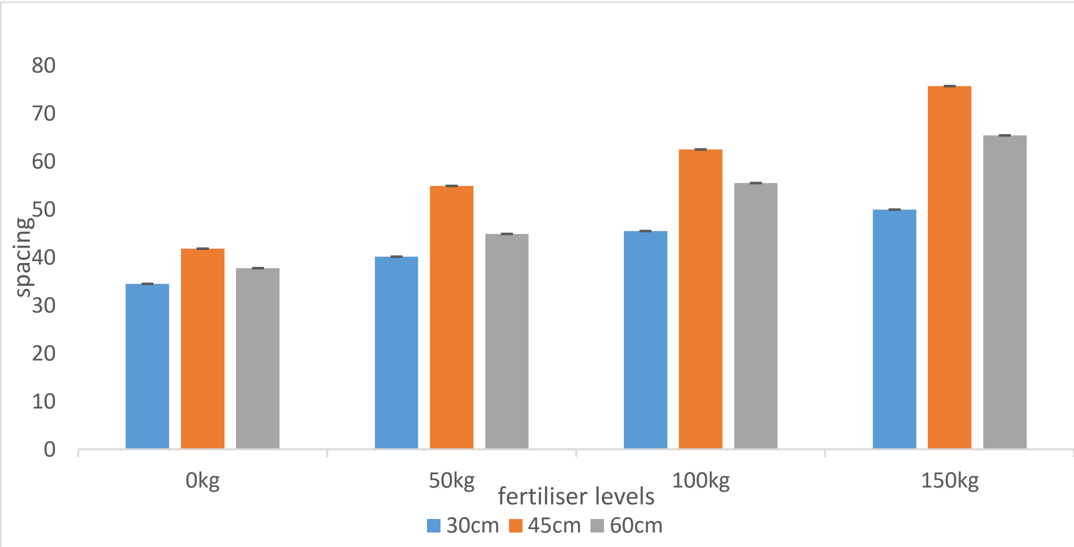
Figure 2 : Effects of spacing and fertiliser levels on plant height at week 6



The above graph shows that there was interaction ($p<0.05$) between spacing and fertiliser levels on plant height. Plant height increased as the fertiliser levels increased. Increasing the spacing from 30cm to 45cm resulted in taller plants but the effects were most pronounced at 45cm spacing. The maximum plant height was observed in the combination of 150kg fertiliser with 45cm spacing yielding an average height of 40.933cm. The lowest plant height was found under the 0kg fertiliser with 30cm spacing treatment which recorded a height of 20.1cm. There were almost similar results between the combination of 30cm spacing with 150kg fertilizer (30.1cm) and 60cm spacing with 100kg fertiliser (29.967cm). Another pair with similar outcomes was 30cm spacing with 100kg fertiliser (27.2cm) and 60cm with 50kg fertiliser (26.2cm).

4.1.3 Plant height at week 8

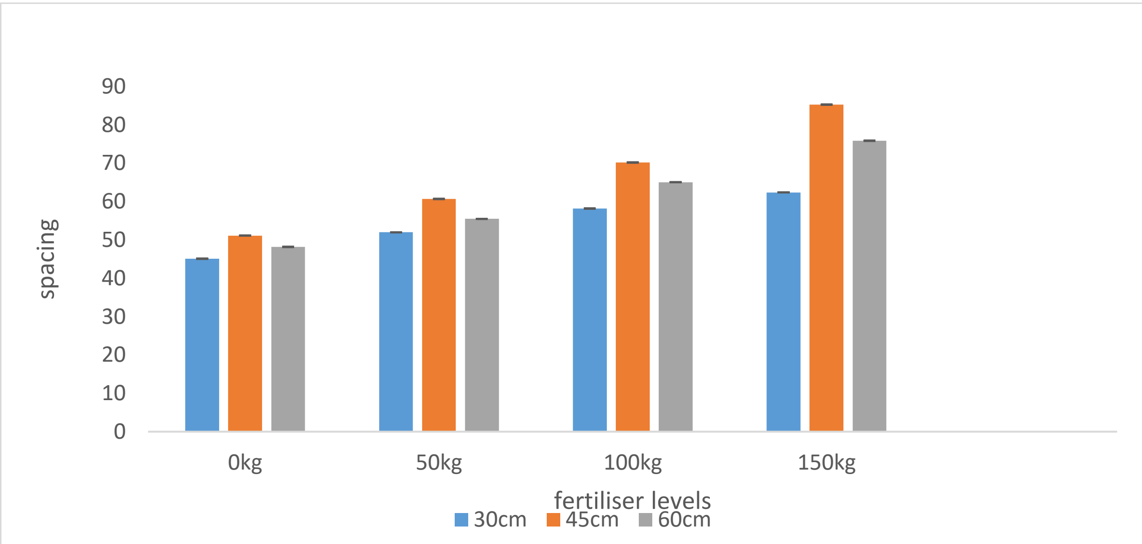
Figure 3 : Effects of spacing and fertilizer levels on plant height at week 8



The above graph displays that there was interaction ($p<0.05$) between spacing and fertilizer levels on plant height. The highest plant height was recorded at 45cm spacing with 150kg fertilizer measuring 75.7cm. A medium plant height of 44.9cm was observed at 60cm spacing with 50kg fertilizer. The least plant height was observed at 30cm spacing with 0kh fertilizer measuring 34.5 cm. there almost similar results in the treatments of 45cm spacing and 100kg fertilizer (62.5cm) and 60cm spacing and 150kg fertilizer (65.4).

4.1.4 Plant height at week 10

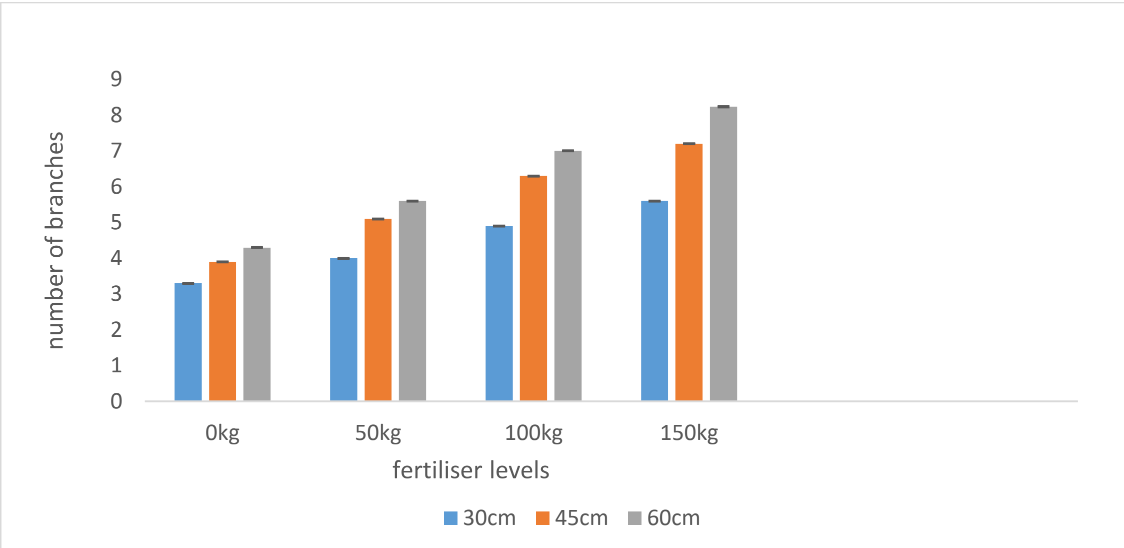
Figure 4 : Effects of spacing and fertilizer levels on pant height at week 10



The results stated in the above graph shows that there was interaction ($p<0.05$) between spacing and fertilizer levels on plant height. The highest plant height was recorded at 45cm spacing with 150kg with moderate measuring 85.3cm. wider spacing with moderate fertilizer resulted in average plant growth as seen in treatment with 60cm spacing and 50ka fertilizer which gave a plant height of 55.5 cm. the least plant height was recorded at 30cm spacing with 0kg fertilizer measuring 45.1 cm.

4.2 NUMBER OF BRANCHES

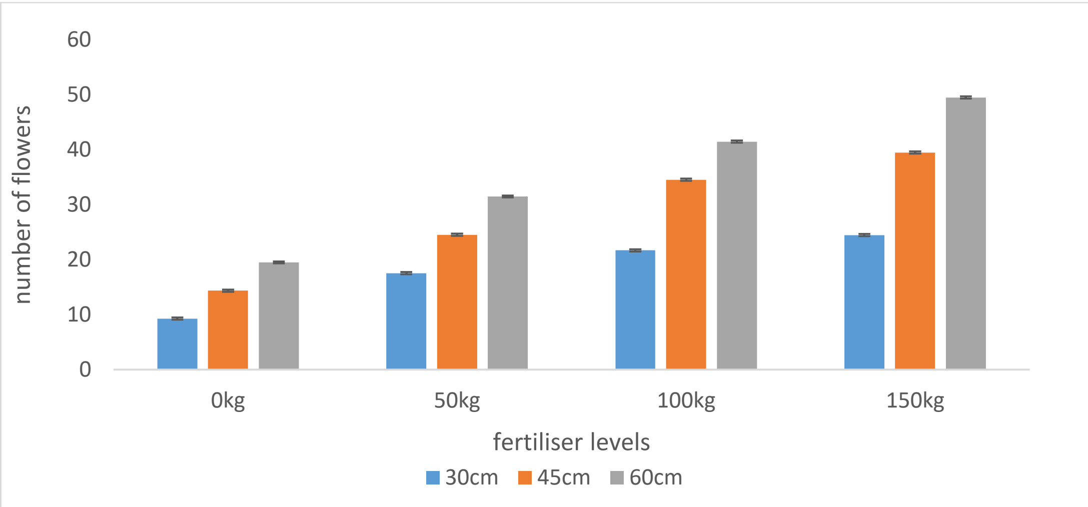
Figure 5: Effects of spacing and fertilizer levels on number of branches



The above graph shows that that there was interaction ($p<0.05$) between spacing and fertilizer levels on number of branches. As fertilizer input increased from 0kg to 150kg, there was a consistent increase in the number of branches across all spacing levels. Wider spacing also tended to promote more branching at each fertilizer level. The highest number of branches was recorded at the combination of 150kg fertilizer and 60cm spacing, producing an average of 8.2333 branches per plant. The minimum number of branches was detected in the treatment with 0kg fertilizer and 45cm spacing yielding just 3.9 branches.

4.3 NUMBER OF FLOWERS

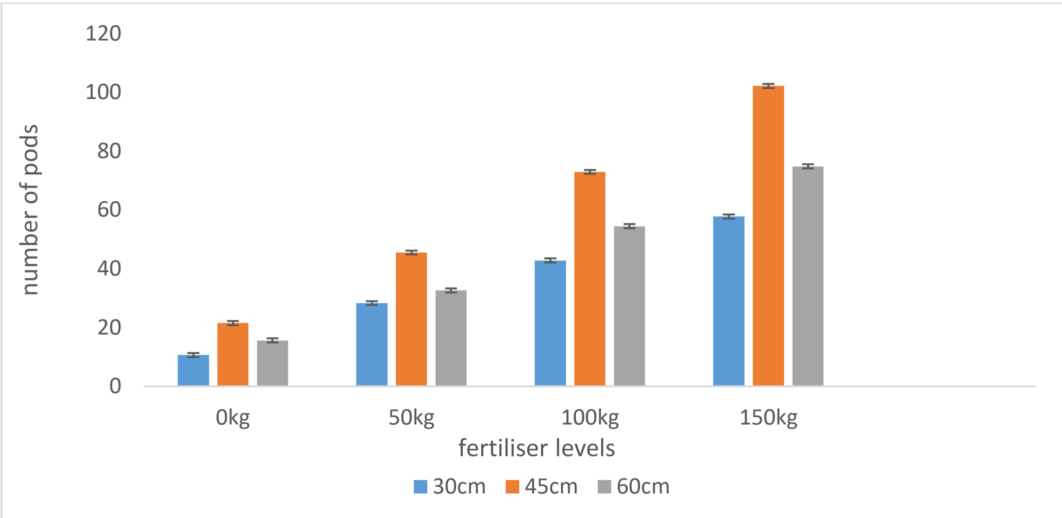
Figure 6: Effects of spacing and fertilizer level on number of flowers



The graph above shows that there was interaction ($p<0.05$) between spacing and fertilizer levels on the number of flowers. The maximum number of flowers was recorded at 60cm spacing with 150kg fertilizer, measuring 4.5 flowers. The combination 45cm spacing and 50kg fertilizer yielded 24.5 flowers giving a moderate result. The least number of flowers was noted at 30cm spacing with 0kg fertilizer measuring 9.3 flowers.

4.5 NUMBER OF PODS

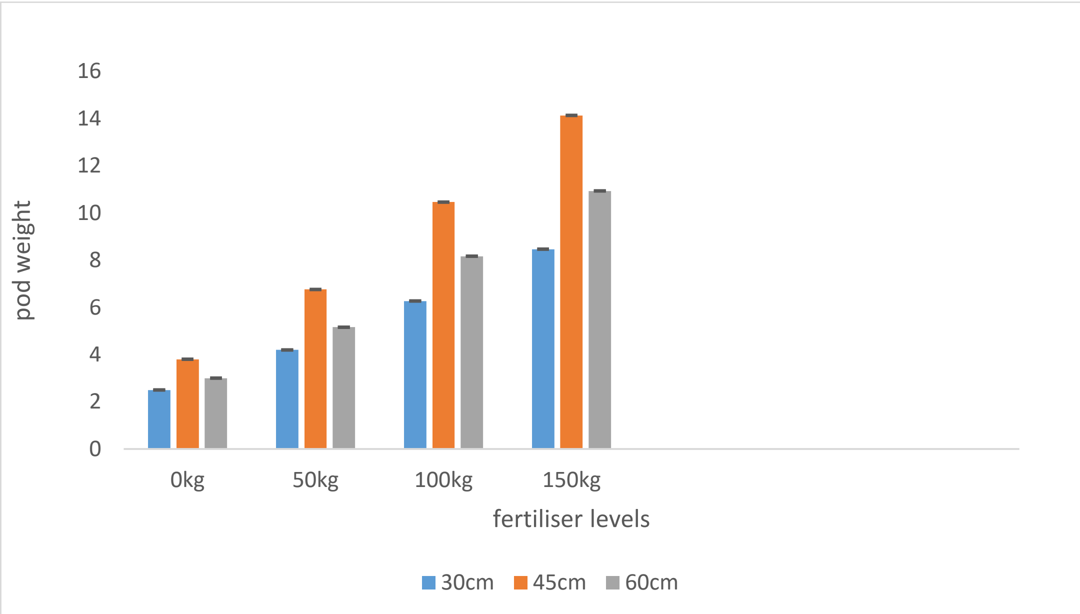
Figure 7: Effects of spacing and fertilizer levels on number of pods



The graph above shows that there was interaction ($p<0.05$) between spacing and fertilizer levels on number of pods. 45cm spacing and 150kg fertilizer treatment produced the highest number of pods (102.17). 45 cm spacing and 50kg fertilizer treatment was at medium with 45.47 pods. The lowest number of pods (10.6) were obtained from the treatment with 30cm spacing and 0 kg fertilizer.

4.6 FINAL POD WEIGHT

Figure 8: Effects of spacing and fertilizer level on pod weight



The above graph shows that there was interaction ($p<0.05$) between spacing and fertilizer levels on pod weight. The highest pod weight was obtained from 45cm spacing and 150kg fertilizer measuring 14.1 kg while the lowest pod weight was found in treatment with 30cm spacing and 0kg fertilizer which had 2.5 kg. 45 cm spacing and 100kg fertilizer obtained a moderate pod weight of 10.4 kg.

CHAPTER 5

DISCUSSION OF RESULTS

5.1. PLANT HEIGHT

Across all weeks 4, 6, 8, and 10 the tallest sesame plants were detected under the treatment of 150 kg /ha with 45 cm spacing. At week 4, plants under this treatment reached a height of 12.23 cm, continuing to 40.93 cm by week 6, 75.7 cm by week 8, and 85.3 cm by week 10. This trend reveals a strong, positive interaction between satisfactory fertilizer availability and moderately spaced planting. Nitrogen plays a central role in chlorophyll formation, protein synthesis, and overall vegetative development. According to Ali et al., (2012), sesame plants supplied with sufficient nitrogen show greater leaf area, stem elongation, and biomass accumulation compared to those under nitrogen stress. The sustained vegetative growth observed here suggests that the 150 kg /ha rate met the crop's increasing nutritional demands during each growth stage.

The usefulness of the 45 cm spacing can be attributed to its balance between resource availability and efficient plant population. This spacing likely reduced intra-specific competition while maintaining enough plant density to use land effectively. Studies by Girma and Zeleke (2017) support this finding, stating that medium plant spacing in sesame guarantees improved light penetration, air circulation, and root development, contributing to improved plant architecture and height. Thus, the mixture of high fertilizer and moderate spacing appears to have created an environment where sesame plants could thrive, taking full advantage of nutrients and space without the stress associated with overpopulation or underutilization of resources.

In contrast, the lowest plant heights were recorded under the 0 kg /ha with 30 cm spacing treatment. Plant height in this group started at 6.93 cm in week 4 and only reached 45.1 cm by week 10. This underperformance can be credited to two major limitations which are nitrogen deficiency and excessive intra-specific competition. Nitrogen is vital for early plant vigor and continued vegetative growth. In its deficiency, sesame plants experience stunted growth due to limited cell division, leaf expansion, and chlorophyll content (Teklay et al., 2014). These physiological limitations result in slower growth rates, fewer nodes, and ultimately shorter plants. Furthermore, nitrogen-deficient plants are often pale, with thinner stems and smaller leaves, all of which give rise to reduced height. When combined with a narrow spacing of 30 cm, the negative effects of nitrogen deficiency are magnified. The closeness of plants increases competition for already limited resources, such as light, water, and nutrients. Kebede et al., (2018) perceived that close spacing under low fertility conditions often leads to crowding stress, restricted root growth, and poor canopy expansion. This combination reduces the photosynthetic effectiveness of plants and suppresses their vertical growth.

Therefore, the 0 kg N/ha and 30 cm spacing treatment created an unfavorable growing environment that restricted both nutrient access and physical development, resulting in the lowest observed plant heights across all growth stages.

5.2. NUMBER OF BRANCHES

At 30 cm spacing, branching was lower across all fertilizer levels. Under no fertilizer application, the mean number of branches was only 3.3, signifying poor vegetative growth likely because of intense plant to plant competition for light, nutrients, and water. As fertilizer levels improved, branching improved to 4.0, 4.9, and 5.6 branches per plant at 50, 100, and 150 kg/ha respectively. These increases reveal the plant's positive response to added nitrogen and phosphorus, which are known to enhance cell division, vegetative growth, and shoot development (Ali et al., 2019). However, the close spacing likely limited the full potential of these nutrients, as competition remained high.

The 45 cm spacing provided moderate plant population pressure, resulting in remarkably higher branch numbers across all fertilizer levels. Unfertilized plants had 3.9 branches, which increased to 5.1, 6.3, and 7.2 as fertilizer levels rose. The increased branching under moderate spacing and fertilization suggests better canopy architecture and nutrient partitioning, consistent with outcomes by Gebremariam and Desta (2020), who noted that optimal spacing boosts light interception and air circulation, improving plant morphology. The phosphorus-rich Compound D formulation likely contributed to shoot and root development, aiding better nutrient foraging and biomass accumulation.

The 60 cm spacing produced the maximum number of branches per plant. Without fertilizer, branching was at 4.3 already higher than any fertilized treatment at 30 cm. With cumulative fertilizer application, the branch count rose to 5.6, 7.0, and peaked at 8.23 branches per plant at 150 kg/ha. This spacing fertilizer combination was the most effective, directing to a critical interaction were adequate spacing maximized nutrient uptake and photosynthetic efficiency. These results agree with Yirga and Debre (2016), who observed that wider spacing's reduced competition, promoting enhanced branching and reproductive structure formation.

Overall, the most critical treatment combination was 60 cm spacing with 150 kg/ha of Compound D, which gave the highest number of branches. This suggests that sesame plants require not only sufficient nutrients particularly nitrogen and phosphorus but also enough space to fully express their growth potential. The nitrogen in Compound D likely enhanced vegetative growth, while phosphorus supported shoot differentiation and root extension, all of which are necessary for robust branching (Mahalakshmi et al., 2021). However, while wider spacing supported better individual plant performance, the trade-off with plant population density must be considered when computing yield per hectare.

5.3 NUMBER OF FLOWERS

At the 30 cm spacing, flower number per plant increased from 9.27 (0 kg/ha) to 24.47 (150 kg/ha). Although higher fertilizer levels improved flowering at this close spacing, the entire values remained lower than those observed at wider spacing's. This is likely because of severe plant to plant competition for light, nutrients, and water in the narrower configuration. According to Zewdie and Tehulie (2019), dense spacing in sesame reduces light penetration and restricts canopy expansion, negatively affecting photosynthesis and consequently floral development. The partial progress with Compound D fertilizer suggests that nutrient availability, mainly phosphorus and potassium, alleviated some of the competitive stress by enhancing root activity and reproductive initiation (Badshah et al., 2017).

The 45 cm spacing offered a better balance between competition and individual plant resource acquisition. At this spacing, flower numbers increased from 14.37 (0 kg/ha) to 39.5 (150 kg/ha). The progressive increase demonstrates the positive interaction between moderate spacing and nutrient availability. Compound D fertilizer, with its great phosphorus content, likely inspired floral initiation by stimulating root development and early maturity (Ramesh et al., 2023). Additionally, potassium plays a key role in enzyme activation and flower establishment, which could further explain the major gains in flower numbers (Olowe, 2007).

The maximum number of flowers was noted at 60 cm spacing with 150 kg/ha fertilizer, reaching 49.5 flowers per plant. This spacing provided ample room for canopy expansion and allowed each plant to fully exploit soil resources. Reduced competition improved light interception and assimilate partitioning to reproductive organs. The accessibility of phosphorus through Compound D would have also boosted energy transfer via ATP during flowering (Akpan et al., 2022), while potassium enhanced translocation of assimilates to support continuous flower production.

The critical combination of 60 cm spacing with 150 kg/ha fertilizer emerged as the most effective in promoting flowering, followed closely by 45 cm × 150 kg/ha. The role of spacing is evident in reducing stress and facilitating morphological plasticity, while fertilizer enhances internal physiological processes responsible for floral induction and differentiation. On the other hand, lowest flower numbers were observed under 30 cm spacing and 0 kg/ha, reflecting the compounded stress of nutrient deficiency and overcrowding. Plants under these conditions may prioritize vegetative survival over reproductive output, a phenomenon noted in stressed sesame stands (Mubarak et al., 2016).

5.4 NUMBER OF PODS

At 30 cm spacing and 0 kg fertilizer, plants recorded the lowest pod number (10.6), likely due to intense plant to plant competition for nutrients, light, and moisture. Without external nutrient input, the close spacing likely exacerbated competition, reducing plant capacity to develop branches and pods. As the fertilizer level increased to 50 kg, pod number improved significantly to 28.27, suggesting that the introduction of phosphorus and potassium through Compound D enhanced root and flower development, while nitrogen supported vegetative expansion (Ramesh et al., 2023). At 100 kg, the pod number further rose to 42.8, and at 150 kg, it reached 57.73, showing a strong fertilizer response even under dense spacing.

Under 45 cm spacing, the response to fertilizer was even more pronounced. With no fertilizer, pod number was 21.47, already higher than the fertilized 30 cm treatment, suggesting that moderate spacing alone reduced competition and enhanced reproductive potential. At 50 kg, pod number increased to 45.47, while 100 kg resulted in 72.9 pods, and the highest value (102.17) was observed at 150 kg fertilizer. This treatment combination (45 cm × 150 kg) produced the most pods overall, highlighting that a moderate spacing paired with optimal nutrient availability creates ideal conditions for pod formation. Phosphorus, a key component of Compound D, is particularly crucial at flowering and pod-setting stages, promoting higher reproductive efficiency (Badshah et al., 2017).

In the 60 cm spacing, a slightly different pattern emerged. The unfertilized treatment produced 15.57 pods, which was higher than the 30 cm spacing at the same fertilizer level but lower than 45 cm. This spacing allowed better light interception and canopy expansion, but wider spacing may have underutilized available field resources (Zewdie & Tehulie, 2019). Fertilized treatments improved pod numbers substantially: 32.6 at 50 kg, 54.43 at 100 kg, and 74.8 at 150 kg. Although this was a positive increase, these values remained consistently lower than those at 45 cm spacing across corresponding fertilizer levels, indicating that while reduced competition was beneficial, the plant population density might have been too low to maximize yield per area.

A notable similarity was observed between some treatments: the 30 cm × 100 kg (42.8 pods) and 60 cm and 50 kg (32.6 pods) combinations showed closer pod numbers, as did 30 cm × 150 kg (57.73 pods) and 60 cm and 100 kg (54.43 pods), suggesting compensatory effects between spacing and fertilizer. These observations affirm the interaction between spacing and nutrient input in sesame cultivation—highlighting how increasing one factor can sometimes compensate for limitations in the other (Akpan et al., 2022).

5.5 POD WEIGHT

At the 30 cm spacing, pod weights were generally the lowest across fertilizer levels. Without fertilizer, plants recorded only 2.5 kg, reflecting severe inter-plant competition in the dense arrangement, which likely limited access to nutrients, water, and light (Zewdie & Tehulie, 2019). As fertilizer was added, pod weight improved to 4.2 g at 50 kg/ha, 6.27 g at 100 kg/ha, and 8.47 g at 150 kg/ha. The increasing trend illustrates the positive impact of macronutrient supplementation, particularly phosphorus, which is critical in energy transfer during seed development (Ramesh et al., 2023). However, the dense spacing limited the full expression of fertilizer benefits.

In contrast, the 45 cm spacing showed the most substantial gains in pod weight. With no fertilizer, pod weight was 3.8 g, already higher than the fertilized 30 cm treatment. At 50 kg/ha, it rose to 6.77 g, then 10.47 g at 100 kg/ha, and peaked at 14.13 g with 150 kg/ha, the highest pod weight overall. This combination (45 cm × 150 kg/ha) represents the critical treatment, suggesting that moderate spacing optimizes plant access to nutrients and photosynthetic resources while maintaining sufficient plant population to maximize yield per unit area (Akpan et al., 2022). The balanced NPK formulation in Compound D likely played a pivotal role, with nitrogen promoting vegetative vigor, phosphorus enhancing reproductive development, and potassium supporting seed filling (Badshah et al., 2017).

At the 60 cm spacing, unfertilized plants recorded a pod weight of 3.0 g, marginally higher than the 30 cm spacing. The wider spacing likely reduced intra-specific competition and improved root expansion but at the cost of reduced plant population density. With fertilizer, pod weights increased to 5.17 g at 50 kg/ha, 8.17 g at 100 kg/ha, and 10.93 g at 150 kg/ha. Though the values were notable, they did not surpass those observed at 45 cm spacing, suggesting a diminishing return from overly wide spacing. This aligns with earlier studies that showed excessive spacing might lead to suboptimal land use efficiency, despite enhancing individual plant performance (Olowe, 2007).

Comparing across treatments, the combined effect of 45 cm spacing and 150 kg/ha of Compound D fertilizer was most effective for enhancing pod weight. The reason lies in the ideal balance between plant density and resource availability, which minimizes intra-plant competition while allowing nutrient uptake efficiency to peak. Additionally, the phosphorus in Compound D is especially beneficial at flowering and formation of pods, while potassium aids in translocation of assimilates and pod maturation (Srinivas et al., 2018).

CHAPTER 6

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

This research was conducted in order to evaluate the effects of inter row spacing and varying levels of Compound D fertilizer on the growth and yield performance of sesame. The results clearly demonstrate that both inter row spacing and fertilizer levels significantly influenced the vegetative growth, reproductive development, and overall yield of sesame. Among the combinations tested, the 45 cm inter row spacing combined with 150 kg/ha of Compound D fertilizer consistently gave the best performance across all measured parameters:

6.1.1 Vegetative Growth

There is significant difference ($P<0.05\%$) in sesame vegetative growth and development among different spacing and fertilizer levels. At 10 weeks, the highest plant height (85.3 cm), highest number of branches (7.2), and overall superior growth was observed in combination of 45cm spacing and 150kg fertilizer.

6.1.2 Reproductive Growth

There is significant difference ($P<0.05\%$) in reproductive growth parameters among different spacing and fertilizer levels. treatment combination of 45cm spacing and 150kh fertilizer also produced the highest number of flowers (39.5) and the greatest number of pods (102.17), resulting in the highest pod weight.

6.1.3 Yield Potential

There is significant difference in sesame yield among different spacing and fertilizer levels. The 45 cm spacing at 150 kg/ha significantly outperformed all other treatments in terms of pod number and weight, showing an optimal balance between plant density and nutrient availability.

On the other hand, 45 cm spacing at 100 kg/ha also performed well and showed strong growth and yield responses, although not as high as 150 kg/ha. Meanwhile, 30 cm spacing, even at higher fertilizer levels, was less effective, likely due to competition among closely spaced plants. 60 cm spacing performed moderately well, but had lower plant populations per unit area, which reduced the overall yield despite good individual plant performance.

6.2 RECOMMENDATION

Farmers aiming for improved sesame yield and growth are strongly recommended to adopt to an inter row spacing of 45 cm with 150 kg/ha of Compound D fertilizer. This combination provided the best balance between vegetative and reproductive growth, leading to the highest yields. For farmers with limited access to fertilizers, 45 cm spacing with 100 kg/ha of Compound D still offers good productivity and can be a viable alternative, especially under resource-limited conditions. Though narrow spacing increases plant population, it cannot be ideal due to lower yield per plant due to competition for nutrients, light, and space. It is not recommended, even with higher fertilizer levels.

However, additional research can be conducted under different soil types and climatic conditions to confirm the consistency of these findings and optimize fertilizer timing for sesame crops.

REFERENCES

Calfskin S M, Arstan H, Artiogle and N Isler 2004. "Effect of planting method and plant population on growth and yield of sesame (sesamun indicum l) in a Mediterranean type of environment". Asia Journal of Plant Sciences 3(5):610-613

Shehu H E, J D Kwara and M K Sandabe 2010. "Effect of NPK Fertilizer on Yield, Content and Uptake of NPK b Sesame. International Journal of Agriculture and Biology. ISSN print 1560-8530; ISSN on line 1814-9596. 01-060/DNK/2010/12-6-845-850

Haruna I M (2011). Dry matter partitioning and grain yield potential in sesame (Sesamum Indicum L) as influenced by poultry manure, nitrogen and phosphorus at Semaru, Nigeria. Journal of Agricultural Technology 7(6): 1571-1577

Malik M A, Saleem F, Cheema M A and Ahmad S (2013). Influence of different levels of Nitrogen on productivity of sesame under varying planting pattern. Int J of Agric and Biology 5(4):490-492

Muhamman M A and Gungula D T (2018). Growth parameters of sesame as affected by nitrogen and phosphorus levels .J Sustainable Dev in Agric and Env 3(2):80-86

Bedigian, D. (2004). History and Lore of Sesame in Africa. In J. Janick (Ed.), Horticultural Reviews (Vol. 31, pp. 1-53). John Wiley & Sons.

Fuller, D. Q. (2003). African crops and the origins of African agriculture. In K. Neumann, A. Butler, & S. Kahlheber (Eds.), Food, Fuel and Fields (pp. 23-49). Heinrich Barth Institute.

Kritsotakis, K. (2017). Sesame: A Review of Its History, Botany, and Uses. Journal of Food Science and Technology, 54(4), 1010-1023.

FAO (2017). Sesame production and trade in Africa. Food and Agriculture Organization of the United Nations.

Kumar, V., et al. (2018). Mechanization in sesame production: A review. Journal of Agricultural Engineering Research, 54(2), 147-157.

Langham, D. R. (2007). Sesame. In J. Janick (Ed.), Horticultural Reviews (Vol. 34, pp. 299-317). John Wiley & Sons.

Li, Z., et al. (2020). Precision agriculture in sesame production: A review. Journal of Precision Agriculture, 21(2), 257-272.

Mishra, J. S., et al. (2019). Integrated pest management in sesame: A review. Journal of Pest Science, 92(2), 537-547.

Sharma, P. C., et al. (2019). Irrigation management in sesame production: A review. Journal of Irrigation and Drainage Engineering, 145(10), 04019042.

USAID (2020). Sesame value chain development in Africa. United States Agency for International Development.

Wang, L., et al. (2019). Genomic research in sesame: A review. Journal of Genetics and Genomics, 46(10), 537-547.

APPENDICES

Appendix 1: ANOVA for the effect of spacing and fertilizer levels on plant height at week 10

Variate: plant_height_week_4cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.485000	0.242500	188.29	
block.*Units* stratum					
spacing_cm	2	26.495000	13.247500	10286.29	<.001
fertiliser_levels_kg	3	46.929722	15.643241	12146.52	<.001
spacing_cm.fertiliser_levels_kg	6	3.389444	0.564907	438.63	<.001
Residual	22	0.028333	0.001288		
Total	35	77.327500			

Tables of means

Variate: plant_height_week_4cm

Grand mean 9.0750

spacing_cm	30	45	60
	8.1833	10.2333	8.8083

fertiliser_levels_kg	0	50	100	150
	7.5333	8.5667	9.6111	10.5889

spacing_cm	fertiliser_levels_kg	0	50	100	150
30		6.9333	7.8333	8.7333	9.2333
45		8.1333	9.5333	11.0333	12.2333

60	7.5333	8.3333	9.0667	10.3000

Appendix 2: ANOVA for the effects of spacing and fertilizer levels on plant height at week 6

Variate: plant_height_week_6_cm

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	7.489E-01	3.744E-01	74.14	
block.*Units* stratum					
spacing_cm	2	3.402E+02	1.701E+02	33677.21	<.001
fertiliser_levels_kg	3	8.745E+02	2.915E+02	57715.44	<.001
spacing_cm.fertiliser_levels_kg	6	3.312E+01	5.520E+00	1092.94	<.001
Residual	22	1.111E-01	5.051E-03		
Total	35	1.249E+03			

Tables of means

Variate: plant_height_week_6_cm

Grand mean 28.853

spacing_cm	30	45	60
	25.325	32.817	28.417

fertiliser_levels_kg	0	50	100	150
	22.211	26.833	30.789	35.578

spacing_cm fertiliser_levels_kg 0 50 100 150

30	20.100	23.900	27.200	30.100
45	24.733	30.400	35.200	40.933
60	21.800	26.200	29.967	35.700

Appendix 3: ANOVA for the effects of spacing and fertilizer levels on plant height at week 8

Variate: plant_height_week_8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	1.017E+00	5.086E-01	82.21	
block.*Units* stratum					
spacing_cm	2	1.574E+03	7.868E+02	1.272E+05	<.001
fertiliser_levels_kg	3	3.241E+03	1.080E+03	1.746E+05	<.001
spacing_cm.fertiliser_levels_kg	6	2.891E+02	4.818E+01	7786.70	<.001
Residual	22	1.361E-01	6.187E-03		
Total	35	5.104E+03			

Tables of means

Variate: plant_height_week_8

Grand mean 50.739

spacing_cm	30	45	60
	42.550	58.742	50.925

fertiliser_levels_kg	0	50	100	150
	38.044	46.689	54.511	63.711

spacing_cm	fertiliser_levels_kg 0	50	100	150
30	34.500	40.200	45.500	50.000
45	41.833	54.933	62.500	75.700
60	37.800	44.933	55.533	65.433

Appendix 4: ANOVA for the effects of spacing and fertilizer levels on plant height at week 10

Variate: plant_height_week_10

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	7.872E-01	3.936E-01	65.22	
block.*Units* stratum					
spacing_cm	2	9.260E+02	4.630E+02	76718.00	<.001
fertiliser_levels_kg	3	3.460E+03	1.153E+03	1.911E+05	<.001
spacing_cm.fertiliser_levels_kg	6	2.558E+02	4.263E+01	7064.10	<.001
Residual	22	1.328E-01	6.035E-03		
Total	35	4.643E+03			

Tables of means

Variate: plant_height_week_10

Grand mean 60.806

spacing_cm	30	45	60
	54.425	66.833	61.158

fertiliser_levels_kg	0	50	100	150
	48.144	56.067	64.489	74.522

spacing_cm	fertiliser_levels_kg 0	50	100	150
30	45.100	52.000	58.200	62.400
45	51.133	60.700	70.200	85.300
60	48.200	55.500	65.067	75.867

Appendix 5: ANOVA for effects of spacing and fertilizer levels on the number of branches per plant

Variate: number_of_branches_per_plant

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	1.0005556	0.5002778	1801.00	
block.*Units* stratum					
spacing_cm	2	20.7005556	10.3502778	37261.00	<.001
fertiliser_levels_kg	3	51.6008333	17.2002778	61921.00	<.001
spacing_cm.fertiliser_levels_kg	6	2.2616667	0.3769444	1357.00	<.001
Residual	22	0.0061111	0.0002778		
Total	35	75.5697222			

Tables of means

Variate: number_of_branches

Grand mean 6.2

spacing_cm	30	45	60
	7.6	5.1	5.9

fertiliser_levels_kg	0	50	100	150
	4.1	5.0	9.9	5.7

spacing_cm	fertiliser_levels_kg	0	50	100	150
30		3.4	4.2	17.9	4.9
45		4.2	5.1	5.4	5.7
60		4.9	5.9	6.3	6.6

Appendix 6: ANOVA for the effects of spacing and fertilizer levels on the number of flowers

Variate: number_of_flowers

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	16.89056	8.44528	143.35	
block.*Units* stratum					
spacing_cm	2	1800.31722	900.15861	15279.16	<.001
fertiliser_levels_kg	3	2818.37556	939.45852	15946.23	<.001
spacing_cm.fertiliser_levels_kg	6	205.52278	34.25380	581.42	<.001
Residual	22	1.29611	0.05891		
Total	35	4842.40222			

Tables of means

Variate: number_of_flowers

Grand mean 27.322

spacing_cm	30	45	60
	18.242	28.233	35.492

fertiliser_levels_kg	0	50	100	150
	14.378	24.522	32.567	37.822

spacing_cm	fertiliser_levels_kg	0	50	100	150
30		9.267	17.533	21.700	24.467
45		14.367	24.533	34.533	39.500
60		19.500	31.500	41.467	49.500

Appendix 7: ANOVA for the effects of spacing and fertilizer levels on the number of pods.

Variate: number_of_pods

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	15.7950	7.8975	10.89	
block.*Units* stratum					
spacing_cm	2	4035.9800	2017.9900	2783.14	<.001
fertiliser_levels_kg	3	19540.7933	6513.5978	8983.33	<.001
spacing_cm.fertiliser_levels_kg	6	1018.6400	169.7733	234.15	<.001
Residual	22	15.9517	0.7251		
Total	35	24627.1600			

Tables of means

Variate: number_of_pods

Grand mean 46.57

spacing_cm	30	45	60
	34.85	60.50	44.35

fertiliser_levels_kg	0	50	100	150
	15.88	35.44	56.71	78.23

spacing_cm	fertiliser_levels_kg	0	50	100	150
30		10.60	28.27	42.80	57.73
45		21.47	45.47	72.90	102.17
60		15.57	32.60	54.43	74.80

Appendix 8: ANOVA for the effects of spacing and fertilizer levels on pod weight.

Variate: pod_weight_kg

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.495556	0.247778	144.29	
block.*Units* stratum					
spacing_cm	2	71.260556	35.630278	20749.40	<.001
fertiliser_levels_kg	3	332.864444	110.954815	64614.86	<.001
spacing_cm.fertiliser_levels_kg	6	16.377222	2.729537	1589.55	<.001
Residual	22	0.037778	0.001717		
Total	35	421.035556			

Tables of means

Variate: pod_weight_kg

Grand mean 6.9889

spacing_cm	30	45	60
	5.3583	8.7917	6.8167

fertiliser_levels_kg	0	50	100	150
	3.1000	5.3778	8.3000	11.1778

spacing_cm	fertiliser_levels_kg	0	50	100	150
30		2.5000	4.2000	6.2667	8.4667
45		3.8000	6.7667	10.4667	14.1333
60		3.0000	5.1667	8.1667	10.9333