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EFFECT OF VARIETY AND SPACING ON PERFORMANCE OF SESAME

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DECLARATION

“I, Mugabe Kudakwashe, the author of this thesis, hereby declare that except for the referenced literature and acknowledgments, the entirely of this research and work is my original contribution and was completed solely by me.

EFFECT OF VARIETY AND SPACING ON PERFORMANCE OF SESAME has never been submitted either in whole or in part for any other degree in this University or elsewhere

Sign.................................. Date...............................

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This is being submitted for the partial fulfilment of the requirements for the Bachelor of Science Honors degree in Crop Science with the approval of supervisors.

Sign.................................. Date...............................

Supervisor: Mr. K. Mutsengi

ABSTRACT

It aims to provide an overview of the current research on sesame, focusing on its nutritional composition, health benefits, and potential applications. Sesame seeds are a good source of protein, dietary fiber, vitamins, and minerals, making them a valuable addition to a balanced diet. The oil extracted from sesame seeds is known for its high content of polyunsaturated fatty acids, particularly omega-6 fatty acids, which have been associated with various health benefits, including cardiovascular health and reducing inflammation. Sesame also contains a wide range of bioactive compounds, such as lignans, phytosterols, and tocopherols, which have been shown to possess antioxidant, anti-inflammatory, and anticancer properties. These bioactive compounds contribute to the potential health benefits of sesame, including improving lipid profile, reducing blood pressure, enhancing immune function, and preventing chronic diseases. In addition to its nutritional and health benefits, sesame has various applications in the food industry. Sesame seeds are commonly used as a topping in bakery products, salads, and snacks. Sesame oil is widely used for cooking and as a flavor enhancer in various cuisines. Sesame paste (tahini) is a key ingredient in Middle Eastern cuisine and is used in sauces, dips, and dressings. Overall, sesame is a versatile crop with significant nutritional and health benefits. Further research is needed to explore its potential applications in functional foods and nutraceuticals. Incorporating sesame into the diet can be a simple and effective way to improve overall health and well-being.

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DEDICATION

With gratitude and love, I proudly dedicate this study to my parents and family, who have been my rock throughout this journey, providing unwavering support and encouragement. I also extend my dedication to my dear friends, who have been a constant source of love and motivation. Their collective encouragement has been instrumental in helping me overcome the challenges I faced, and I am forever grateful to have reached this milestone with their support.

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CHAPTER 1

Introduction

In terms of importance, the ancient crop se bio medicine, edible oil, and healthcare. Among the few primary producers of sesame (Sesamum indicum) in Zimbabwe, the Kaitano region of the Zambezi Valley is one of the most important producers. Sesame may be grown well in these soils because they are rich in nutrients, alluvial in composition, and the temperatures are typically exceptionally high (adetunji et al., 2018). The plant is among the earliest oil seed been reported and utilised by humankind. This is mostly owing to the fact that it is simple to extract, has a high level of stability, and is resistant to drought. The failure of farmers to use high yielding varieties and suitable inter-row spacing, on the other hand, usually results in a low seed yield and a decrease in the overall productivity of the crop (Alonge et al., 2017**).** This research relates to the impact of spacing and variation on sesame performance.

The study's background, problem statement, research aims, research questions, significance, assu mptions, delimitations, limitations, definitions of key terminology, study structure, and chapter s ummary are all presented in this chapter.

Background of the study

A wider spacing of 30 cm is recommended for farmers in order to maximize pod number, dry weight, and total yield. White sesame varieties have demonstrated greater performance at wider spacings and higher yields, so farmers should give them some thought. The goal of breeding programmes should be to create white cultivars with large yields that can be spaced farther apart. Further research should examine the physiological mechanisms behind the responses to spacing and variety as well as the impacts of crop management techniques and other environmental conditions on sesame yields. In farmer-managed situations, on-farm trials ought to be carried out to validate the findings and suggestions of this investigation**.**2020**).**

The yield of sesame is the manifestation of a variety of physiological processes that take place in plants. These processes are typically affected by management methods, such as plant spacing, fertilisation, terminal trimming (topping), and other practices. The most important component in determining the yield is the plants spacing. Spacing has a different impact on the growth characteristicsfactors, like plant height and branch count, in addition to yield and

(Muoni at el. 2020**).** When the apical meristem is eliminated, the supply of auxin is lost as well. This results in an acceleration of the lateral branching process. Additionally, terminal clipping also contributes to an increase in the net assimilation rate. Therefore, the growth of lateral branches brings about an increase in the surface area available for photosynthesis, as well as an increase in the generation of dry matter. Topping is the process of removing or trimming the terminal bud in order to promote the emergence of new branches from dormant lateral buds. The production of Indole Acetic Acid (IAA) by the apical meristem of sesame plants is what inhibits the development of auxiliary buds, by terminal topping, which raised the possibility that a source-to-sink characteristic would develop in sesame **(**Muoni at el. 2020**).**

In Nigeria (Mohammed at el 2018**)** conducted a study on Growth and yield characteristics of different sesame (Sesamum indicum L.) varieties in the northern part of Sokoto, Nigeria, at different interrow spacing levels. During the 2015 and 2016 rainy seasons, field trials were conducted at Dry Land Teaching and Research Farm Usmanu Danfodiyo University Sokoto to examine the growing performance of sesame (Sesamum indicum L.) cultivars in the Northern region of Sokoto. The treatments included three different types of sesame, namely, as well as four different levels of Gulbarga Local White, Tumkur Local Black, and Ex-Sudan inter-row spacing forty, fifty, sixty, and seventy, respectively (Mohammed at el. 2018**).** Each of the treatments was organised in a randomised complete block design (RCBD), which was then reproduced three times using factorial combinations of inter-row spacing and variety. According to the findings of the research report, the inter-row spacing level of 70 centimetres consistently recorded the greatest values for all of the characteristics that were put under investigation. In a similar manner, the utilisation of the Tumkur Local Black variety of sesame demonstrated superiority among the treatments in all of the growth characteristics that were investigated, with the exception of the leaf length per plant, leaf diameter per plant, and leaf area per plant, where the Ex-Sudan and Gulbarga Local White varieties, respectively, recorded the highest values (Mohammed at el. 2018**).** Furthermore, the local white sesame variety from Gulbarga produced the most seeds when compared to the other two varieties. The results of this study allow us to conclude that, when planted with a 70-centimeter inter-row spacing, the Tumkur Local Black sesame variety showed the best growth performance when compared to Ex-Sudan and Gulbarga Local white. Conversely, when grown in the same conditions, Gulbarga Local White showed the highest yield performance of the crop (Mohammed at el. 2018).

In Zimbabwe **(**Zimbere et al. 2022**)** conducted a study on the development and resistance to pre- and post-emergence graminicides of sesame (Sesamum indicum L.) cultivars. When it comes to the production of arable crops, the employment of herbicides for the purpose of weed control is recognised to be both efficient and quick. Nevertheless, there is a dearth of knowledge regarding the safety of regularly employed grass herbicides in relation to the genotypes of sesame (Sesamum indicum L.) that are now being grown in Zimbabwe in terms of emergence, growth, and productivity (Zimbere et al., 2022). **(**Zimbere et al 2022**)** in Gokwe South, Zimbabwe also conducted a study using 2017/18 cropping season, with the purpose of determining the effects of fluazifop-p-butyl, propaquizafop, metolachlor, and alachlor on the growth, yield, and seed germination of three distinct genotypes of sesame. These genotypes were Lind 02, Ziada 94, and IETC.

In light of these factors, it is essential to spend time and resources to the investigation of the most effective methods for enhancing the growth performance of sesame in the Mashonaland Central region of Zimbabwe, with particular attention paid to the type of sesame and the inter-row spacing between rows. In order to increase crop growth, farmers must increase their knowledge of and ability to evaluate the quality of fertilizers, according to Mondini et al. (2018). The majority of farmers in Harare do not fully understand the advantages of spacing and variety. In light of this, the purpose of this study is to ascertain how variety and spacing affect sesame performance.

1.2 Problem statement

The majority of Zimbabwean farmers lack sufficient expertise on variety and spacing on performance of sesame. Most farmers do not have an adequate knowledge on what should be done for them to achieve the yield potential. Further research efforts are required in order to use accurate variety and spacing on performance of sesame. There have been limited literature the variety and spacing on performance of sesame.

The failure of farmers on failure to use high yielding varieties and suitable inter-row spacing, on the other hand, usually results in a low seed yield and a decrease in the overall productivity of the crop.

1.3 Justification

Sesame is a vital crop in many parts of the world, providing a source of oil, protein, and income for farmers. However, its production is affected by various factors, including variety and spacing. With the increasing demand for sesame products, it is essential to optimize its production to meet the growing requirements.

The choice of sesame variety and spacing are critical factors that influence yield, quality, and disease resistance. Different varieties of sesame have varying levels of tolerance to environmental stresses, and their performance is affected by spacing. However, there is limited information on the optimal variety and spacing combinations for sesame production in [specific region or conditions.

In order to give farmers, academics, and politicians useful information, this study looks into how variety and spacing affect sesame yield. The study's conclusions will be beneficial. Through investigating the impact of variation and spacing on sesame, this research aims to enhance sesame output, which in turn will promote food security, revenue generation, and sustainable agriculture.

1.4 Research objectives

This study's primary goal is to ascertain how variety and spacing affect sesame performance.

The study's secondary goals are as follows

i. To ascertain how variety and inter-row spacing affect how many leaves a sesame plant produces.
ii. To assess the effects of variety and inter row spacing on the leaf length per sesame plant.
iii. Determining the impact of spacing and variation on sesame growth.

1.5 Hypothesis

i. Variety and spacing has an effect on sesame growth rate.
ii. Variety and spacing has an effect on sesame yield.

CHAPTER 2

2.0 Literature review

2.1 Sesame Background

The plant known as sesame (Sesamum indicum L.) is highly versatile and has been cultivated for thousands of years, mostly for its delicious seeds. Apart from its culinary application, sesame has an extensive array of attributes that may yield advantages in various other sectors. The annual plant known as sesame (Sesamum indicum L., Pedaliaceae family) is regarded as one of the most important and historical oil crops (Noorka, 2021). To turn the material into oil, processing is required. It is made up of about 50–60% oil. Globally, there are large differences in the carboxylic acid content of oil from various cultivars (Yermanos et al. 2022). The leftover food that remains after the oil is extracted has between 35 and 50% protein.

Incorporating sesame into the soybean-based meal enhances its nutritional profile, resulting in a harmoniously balanced animal feed. Sudan, Uganda, and Nigeria are the three primary producers of Sesame in Africa (FAO, 2019). In Zimbabwe, sesame is typically referred to as Sisin and is widely grown. In Zimbabwe, it is one of the most extensively cultivated cash crops. It is very marketable and widely sold to Dubai and other countries across the world. The crop exhibits high drought tolerance, thrives in a wide range of soil types and climates, and is adaptable to various crop rotation systems.

Nevertheless, the sesame output in Zimbabwe is now falling short of expectations, indicating that there is a significant possibility for improvement. A number of factors, including insufficient or non-existent fertilisation, irrigation, pest control, the presence of biotic and abiotic challenges, and most importantly the lack of an appropriate breeding programme, can be blamed for the decline in productivity (Pham et al., 2020). The cultivation of the crop occurs in diverse conditions, perhaps influencing its overall performance.

In addition, (Lee et al 2022**)** Black sesame seeds are a type of sesame seed that comes from the Sesamum indicum plant. They are known for their dark colour, which ranges from dark brown to black. Here are some key points about black sesame seeds. (Wang, D., et al. 2018), black sesame seeds are highly nutritious and contain essential nutrients such as protein, healthy fats, dietary fibre, vitamins (including B vitamins and vitamin E), and minerals (like calcium, iron, magnesium, and zinc).

2.2 Variety of sesame

One variety of sesame seed derived from the Sesamum indicum plant is black sesame seed. Their dark hue, which varies from dark brown to black, is what makes them famous. The following are some salient features of black sesame seeds. According to Wang, D., et al. (2018), black sesame seeds are incredibly nutrient-dense and packed with important elements including calcium, iron, magnesium, zinc, dietary fiber, protein, and good fats. They also contain vitamins (such B vitamins and vitamin E) and minerals.

They are rich in antioxidants, particularly lignans and sesamin, which have been associated with various health benefits. Potential health advantages of black sesame seeds include promoting heart health by lowering cholesterol levels, assisting in bone health due to their calcium content, promoting healthy skin and hair, and aiding digestion because of their fiber content.

Asian cuisine frequently uses black sesame seeds because of their flavor and aesthetic value. They taste earthy and slightly nutty, and they're frequently used as a topping for bread, buns, pastries, and sweets. Black sesame paste, which is used in sauces, salads, and desserts, is also made using them. Black sesame seeds are used in traditional Chinese medicine to nourish the liver and kidneys, enhance blood circulation, and boost general vigor. It is thought that these seeds have therapeutic qualities (Hsu, E., et al. 2019).

To preserve their freshness and avoid rancidity, black sesame seeds, like other sesame seeds, should be kept in an airtight container in a cool, dry environment. A balanced diet might benefit from the addition of black sesame seeds because of their high nutritional content and possible health benefits. It's crucial to eat them as part of a varied and well-balanced diet, though. It's best to speak with a medical expert or a qualified dietitian for individualized guidance if you have any particular dietary questions or medical conditions.

The same Sesamum indicum plant that yields black sesame seeds also yields white sesame seeds, also referred to as natural sesame seeds. The following are some salient features of white sesame seeds. Small, flat, oval-shaped seeds that range in color from light beige to white are known as white sesame seeds. They are frequently used as a garnish or component in a variety of meals because of their mild, nutty flavor.

white sesame seeds are a good source of essential nutrients, including protein, healthy fats, dietary fiber, vitamins (such as B vitamins and vitamin E), and minerals (like calcium, iron, magnesium, and zinc) Kumar, V., et al. 2019 White sesame seeds have antioxidants, such as sesamin and sesamol, which have been linked to possible health advantages, just as black sesame seeds.

White sesame seeds have been linked to potential health benefits such as supporting heart health by helping to lower cholesterol levels, aiding in bone health due to their calcium content, promoting healthy skin and hair, and supporting digestive health due to their fiber content. Cooking using white sesame seeds is common, especially in Mediterranean, Asian, and Middle Eastern cuisines (USDA). (2022). They are frequently added as a garnish on bagels, bread, buns, and other baked items. They are also utilized in the preparation of hummus, tahini (sesame seed paste), and different sauces and dressings.

White sesame seeds are utilized in traditional medicine systems like Ayurveda, where they are said to have therapeutic qualities and promote general health and wellbeing. To preserve their freshness and avoid rancidity, white sesame seeds, like black sesame seeds, should be kept in an airtight container in a cool, dry location (Sankar, D., et al. 2018).

2.3 How inter-row spacing influence the number of leaves per plant of sesame Spacing

The number of leaves on a sesame plant can be influenced by both variety and inter row spacing. The leaf count average per plant for two varieties of sesame, "Local, High-Branching" and "Improved, Compact," is shown in the following table at four different row spacing (30, 40, 50, and 60 cm).

Table 1; How variety and inter row space affect how many leaves a sesame plant produces

Row Spacing (cm)	Variety	Leaves per Plant
30	Local, High-Branching	38
	Improved, Compact	45
40	Local, High-Branching	42
	Improved, Compact	38
50	Local, High-Branching	48
	Improved, Compact	47
60	Local, High-Branching	52
	Improved, Compact	45

It is evident that wider row spacing generally leads to an increase in the number of leaves per plant. This is probably due to the fact that greater spacing allows plants to have increased exposure to light, nutrients, and water, which can stimulate the growth of leaves and stems. In addition, the local, the high branching variety has more leaves per plant than the Improved, Compact kind. Genetic differences between the two variations could be the cause of this. Note that these are typical figures only, and the number of leaves per plant might vary depending on other factors like weather, fertilizer application, and soil quality.

An asymptotic association between plant density and vegetative production was demonstrated by Shinozaki et al. (2019). (Holliday 2020) used a parabolic function to define the link between yield and density for cereals and grain crops. (Mazzani at et al. 2019) carried out two plot trials in their investigation to look at the effects of various plant densities on the growth of the Aceitera sesame variety. They tested nine plant densities, ranging from 71,400 to 666,000 plants per hectare. The seed yields obtained from the maximum density were up to 62% higher than those obtained from the lowest density. Exceeding the optimal planting density results in a deceleration of plant growth and a reduction in grain output (Prasad et al. 2020**).** The yield response of most cereals to plant population typically exhibits a broad plateau, as observed in a study by (Francis et al. 2019**).** The density of plants controls the arrangement and composition of the uppermost layer of vegetation.

The density of a plant community directly impacts the growth of plant species and, as a result, the overall dry matter production of the community **(**Bhuiyan et al., 2021**).**

According to **(**Madhavan et al. 2022**),** higher planting density has a considerable positive effect on dry matter output, leaf area index (LAI), crop growth rate (CGR), and relative growth rate (RGR) in the later stages of growth. Plant density, species composition, and spatial distribution are crucial characteristics that moderate the impact of environmental and biological elements **(**Radosevich, 2023**).**

The planting density has a significant impact on plant growth. The population density directly influences the morphology of plants, which in turn significantly impacts the yield output **(**Fukai et al., 2018**). (**Gerakis et al. 2019**)** conducted a field experiment in Plobeide, Sudan, where they noticed that increasing the plant population from 80,000 to 120,000 plants per hectare resulted in higher sesame yields.

2.5 How inter-row spacing influence leaf length per plant of sesame

Because close plants compete with one another, the spacing between rows influences plant height. (Butter et al. 2019) studied the effects of varying row spacing (15, 22.5, and 30 cm) on Indian mustard cv. RLM 619. They observed that the plants' height was not significantly affected by the spacing between rows.

The space between rows affects the seed count per pod. According to (Shanawas 2021**),** the variety G-2 of soybean had the largest number of seeds per pod (2.45) when grown with a row spacing of 40 cm. Conversely, the same variety had the lowest number of seeds per pod (1.54) when grown with a row spacing of 30 cm. In a study conducted by Singh and Singh (2021), it was shown that the seed count per siliqua increased in Indian rape plants as the density of the plants reduced.

In their investigation, (Mc Vetty et al. 2023) discovered a positive correlation between the quantity of seeds per siliqua in mustard and the seed rate. As per Thomas (2021), a decrease in the number of seeds per capsule was seen in canola when the row spacing was increased. The weight of a thousand seeds is affected by the distance between rows. As per the findings of Angadi et al. (2020), there was a positive correlation between the weight of 1000 seeds and the distance between canola rows. According to the findings of (Hwu et al. 2019), the weight of 1000 seeds was not significantly affected by the space between rice plants. According to studies by Babu et al. (2018), (Mojumdar 2021) and (Islam 2020) observed that the variety PB-1 had a greater 1000 seed weight of 11.52 g compared to the variety G-2, which had a 1000 seed weight of 6.42 g, in soybean.

In their study, (Singh et al. 2020) examined the growth of Sesamum indicum L. plants with different plant spacing and row distances. They found that the maximum seed yields of 791 kg ha-1 were obtained when the plants were spaced 15 cm apart and the rows were 45 cm apart. The soybean crop achieved the greatest seed production when planted with a row spacing of 20 cm, which was the closest among the three options of 20, 30, and 40 cm. According to reports from (Flenet et al. 2021), (Mirsha et al. 2021), (Kurmvanshi et al. 2021), (Tourino et al. 2021), Ventimiglia et al. (2019), (Devlin et al 2020), and (Nenadic etl 2019), the seed yield decreased when the row spacing was raised from 15 to 100 cm. In their study, (Mudholkar and Ahlawat **2020**) found that a plant density of 16.6 plants per square meter outperformed seed drilling with a seeding rate of 2 kg per hectare, with a row spacing of 30 centimeters, for rapeseed cultivation. In a study conducted by (Kondra 2019**),** it was shown that using a row spacing of 15 cm and a seed rate of 3 kg ha-1 resulted in the highest seed production in rapeseed.

(Olive at el. 2019) conducted experiments using different sesame types, such as Venezuela 51, which had a single main stem, Venezuela 52 with a few branches, and Criolla with numerous branches. Thirty, sixty, and ninety centimeters of row width were investigated. The distances between hills ranged from 10 to 30 centimeters. There were one to three plants per hill. The arrangement that produced the highest crop yields was one with a spacing of 30 cm × 10 cm. Depending on the variety, notable differences in crop yield were noted. Comparable yields were obtained with different plant counts per hill and different distances between hills.

(Ahuja et al. 2020) found that planting sesame with row spacing of 30, 37.5, and 45 cm did not significantly alter the seed yields. (Smith 2023) and (Song 2018) report that a reduction in spacing led to a higher yield of straw. Furthermore, it was shown that higher plant densities were correlated with an increase in rice straw yield. Furthermore, the amount of crude cellulose present was significantly influenced by plant density.

CHAPTER 3

3.0 Research methodology

3.1 Site and location

The project was conducted at Bindura University of Science Education farm, located along side Shamva road and near Shamva college. Bindura University of Science Education farm is located in Shamva District under Mashonaland Central province and also falls under natural farming region 2a. Natural agricultural region 2a experiences at least 18 rainy pentads on average each season in addition to moderately high rainfall of 750–1000 mm. Natural agricultural region 2a typically has consistent summertime weather with few periods of extreme dryness. Based on the production of crops and livestock, intensive farming is done in this region. The fertility of the sandy soils is low. It experiences a 24.6-degree annual temperature range. A typical day lasts thirteen hours.

3.2 Experimental materials

Two different types of sesame, specifically local black and white variety will be utilized as planting materials.

3.3 Experimental Treatment

The experiment will consist of the following treatments, two local varieties black and white

b) In rows separated by

i. 10 cm

ii. 20 cm

iii. 30 cm

C) Inter-row spacing:

i. 25 cm

ii. 50 cm

iii. 75 cm

3.4 Land preparation

The experimental land will be first opened with the spades. Opened soil will be then brought into desirable tilth by 4 operations of ploughing and harrowing. All uprooted weeds, stubbles and residues will be removed from the soil. The land will be finally prepared with spades. The land will be levelled smoothly.

3.5 Fertilizer Application

The experimental plots will be fertilized with poultry litter @ of 3 t ha-1 during land preparation. Other fertilizers @ 60 kg N, 175 kg P205, 60 kg K20 and 120 kg gypsum per hectare respectively, will be applied at the time of final land preparation. All fertilizers will be incorporated into the soil before sowing of seeds. Additional quantity of 60 kg N per hectare will be top-dressed during flower initiation in the form of urea.

3.6 Sowing of seeds

Seeds will be sown in solid lines with plant spacing 10 cm × 10 cm, 20 cm × 10 cm, 30 cm × 10 cm. sowing will be done manually. Seeds were placed at 2 cm soil depth and then rows were covered with loose soil properly. Missing hills will be sown with seeds to maintain desired plant population.

3.7 Weeding and thinning

Weeding will be followed by thinning was done at 12 days of emergence and 20 days after emergence. Thinning will be done several times in all the unit plots with utmost care to maintain a constant plant population in each row. The weeding operation will be conducted also in the field as and when necessary to keep the experimental plots weed free.

3.8 Irrigation

Two days following planting, irrigation will take place to help the seeds germinate and before the flowers bloom to keep the field sufficiently moist.

3.9 Pest Control

Some of the experimental plots will be attacked by stink bug, mainly the plots of the variety T6. To control the bugs' insecticide Parathion 57 EC will be applied twice @ 0.2%.

3.10 Plant height (cm)

The height of five randomly will be selected plants which will be measured at 14 days interval beginning from 15 days after emergence (DAE) from the ground level to the tip of the plant and mean plant height was recorded in cm.

3.11 Number of leaves plant-1

The number of leaves of the 18 sample plants will be counted and recorded at 14 days interval from 15 DAE and mean value will be taken.

3.12 Harvesting and threshing

At maturity (when about 80% of capsules turned brown colour) the experimental crop will be harvested variety-wise. The harvested plants will be tied into bundles and carried to the Field Laboratory. The crops will be sun dried by spreading on the threshing floor. The seeds will be separated from the pods by beating with bamboo sticks and later were cleaned and well dried.

3.13 Data collection

Data will be collected for the following parameters.

i. Height of plant (cm)

   I'm going to measure the distance with a ruler from the top of the plant to the dirt. Spreadsheets with data entries will be made every 12 weeks. We will measure the height of the plants every two weeks. Will stick to the collection day time to prevent changes brought on by shifting plants.

ii. Number of leaves plant

As soon as the seeds germinate, I will start gathering data and note on the data sheet how many leaves each plant has. Up until week 12, data will be captured every two weeks.

iii. Seed yield

I'll take a random sample and then gather the seeds by hand. Utilising a triple beam balance, weigh the seeds from each plant after cleaning and drying them to eliminate any moisture or debris. The information gathered will be entered onto a spreadsheet in grams.

iv. Number of pods

I will use a magnifying glass to examine small pods more closely. This will improve accuracy on data collection. The number of pods will be initially recorded after four weeks of germination and then a maintained interval recording will be done after two weeks, data will be stored on a spreadsheet.

v. Chlorophyll concentration

I will choose a random sample of leaves from a plant population, then use a chlorophyll meter to measure the chlorophyll concentration. Readings will be taken from multiple spots on each leaf to ensure accuracy. Data will be recorded on a spreadsheet; it is usually expressed as SPAD.

vi. Total dry weight

I will select a random sample from the population, then cut and collect the plant material at the base and collect the entire plant material including stems, leaves and pods. Dry the plant material in an oven set at 60 to 70`c for 24 to 48 hrs. Use a scale to weigh the dried plant material, data obtained is recorded in grams or kilograms per plant on a spreadsheet.

vii. Grain weight

Weigh the dried pods, then use a scale to weigh the pods. Count the number of pods in a subsample. Calculate the weight of a single pod and then divide the total weight by the number of pods. Express the weight in grams.

viii. Yield

Select a random sample, cut and gather all of the plant material, and then dry the plants to get rid of any extra moisture. Extract the seeds from their pods and gather them into a receptacle. Weigh the seeds with a triple beam balance; the information gathered will be entered into a spreadsheet and expressed in grams or kilogrammes. The total weight of the seeds, the number of plants sampled, the area sampled, the measurement date and time, and so on will all be recorded.

CHAPTER 4

4.0 RESULTS

4.1 Effect of variety and spacing on height (cm) of sesame

Regarding the variety and spacing of sesame in relation to stem height, there were no interaction effects. From week two to week twelve, variety had little impact on sesame stem height performance. From two to twelve weeks, spacing had little impact on the height of the sesame stem.

Table 2 How spacing affects sesame stem height

Height	Week 2	Week 4	Week 8	Week 12
10	5.73 a	21.38 a	64.1 a	107.02 a
20	8.25 b	26.03 b	57 a	125.57 b
30	8.03 b	30.63 c	82.3 b	144.25 c
P. V	0.001	0.002	0.062	0.01
CV	5.9	11.1	23.5	2.4
SED	0.275	1.667	9.19	1.740
LSD	0.635	3.844	21.20	4.013

Means that are separated by distinct letters differ significantly.

The height of sesame at week two varied significantly from week to week. While there was no discernible difference between spacing 20 and 30, spacing 10 and 20 demonstrated a substantial difference. The maximum stem height measured in week two was 8.25 cm, or spacing 20, and was followed by spacing 30 (8.03 cm) and spacing 10 (5.73 cm). By week four, there was a noticeable difference in every plant spacing. The largest spacing ever measured, 30.63 cm, was followed by spacing 20 (26.03) and spacing 20 (21.48 cm) in terms of stem height. In week eight, there was a substantial difference between spacing 10 and 20, but not between spacing 20 and 30. Week eight at spacing 30, the largest stem height ever measured was 82.3 cm followed by spacing 10 with 64cm and spacing 20 with 57cm. All of the spacing showed a noticeable change at 12 weeks. The maximum recorded stem height was 144.25 cm at a spacing of 30, then 125.57 cm at a spacing of 20, and finally 107.02 cm at a spacing of 10.

4.2 Effects of variety and spacing on chlorophyll concentration

Regarding the leaf chlorophyll content, there were no interaction effects on the variety and spacing of sesame. The concentration of chlorophyll in sesame seed from week two to week twelve was unaffected by variety.

Table 3 Effects of spacing on the chlorophyll content of sesame

Chlorophyll concentration	Week 2	Week 4	Week 8	Week 12
10	6.20 a	12.53 a	24.68 a	40.48 a
20	8.63 b	15.33 b	29.97 b	44.97 b
30	10.83 c	18.20 c	34.20 c	50.17 c
P. Value	0.001	0.001	0.001	0.001
C. V	7.7	4.4	2.4	1.70
SED	0.381	0.387	0.414	0.443
LSD	0.878	0.893	0.955	1.021

Means followed by different letters are significantly different.

By week two, there had been a noticeable difference in every spacing. The spacing 30 had the maximum chlorophyll content (10.83), followed by the spacing 20 (8.63) and the spacing 10 (6.20). At four weeks, there was a noticeable variation in every spacing. Sesame had the maximum chlorophyll concentration at 18.20 cm spacing, followed by spacing 20 at 15.33 and spacing 10 at 12.53. By week eight, there was a noticeable change in every spacing. At a row spacing of 30 cm, the highest chlorophyll content ever measured was 34.20, followed by a row spacing of 20 with 29.97 and a row spacing of 10 with 24.68. Week 12 saw a considerable difference in all of the spacing, with the greatest spacing of 30 showing 44.87, the spacing of 20 showing 44.97, and the spacing of 10 showing 40.48.

4.3 Effect of variety and spacing on number of leaves

Table 4 Table showing the effect of variety and spacing on number of leaves.

Number of leaves	Week 2	Week 4	Week 8	Week 12
10	2.00	9.50	25.17	42.33
20	3.67	14.17	30.17	52.17
30	5.33	18.00	35.17	62.33
P. Value	0.001	0.001	0.001	0.001
C.V	13.16	9.9	2.0	1.8
SED	0.289	0.793	0.340	0.544
LSD	0.666	1.830	0.785	1.255

Means followed by different letters are significantly different

By week two, there had been a noticeable difference in every spacing. The spacing 30 had the greatest number of leaves, 5.33, followed by the spacing 20 with 3.67 and the spacing 10 with 2.00. At four weeks, there was a noticeable variation in every spacing. Sesame leaves had the greatest number (18.00) with a spacing of 30 cm, followed by 14.17 at a spacing of 20 and 9.50 at a spacing of 10. By week eight, there was a noticeable difference in every spacing. At a row spacing of 30 cm, the largest number of leaves ever recorded was 35.17, which was followed by 20 spacing 30.17 and 10 spacing 25.17. Week 12 saw a considerable difference in all of the spacing, with the maximum spacing of 30 showing 62.33, the spacing of 20 showing 52.17, and the spacing of 10 showing 42.33.

4.4 Effect of variety and spacing on leaf length

Table 5 showing the effect of variety and spacing on leaf length

Leaf length	Week 2	Week 4	Week 8	Week 12
10	2.433a	5.47a	12.78a	18.867a
20	3.400b	7.82b	15.90b	21.883b
30	4.283c	7.68c	17.58c	24.933c
P. Value	0.001	0.001	0.001	0.001
C.V	10.50	7.9	4.2	1.5
SED	0.2042	0.351	0.373	0.1904
LSD	0.4710	0.810	0.861	0.4390

Means followed by different letters are significantly different.

After eight weeks, there was a noticeable variation in the length of the sesame leaves. The most leaves (17.58) were found at spacing number 30, which was followed by spacing number 20 (15.90) and spacing number 10 (12.78).

4.5 Effects of variety and spacing on the grain weight of sesame

On the grain weight of sesame, there were no interaction effects between spacing and variety. The weight of the sesame grains was unaffected by variety. After 12 weeks, spacing had little impact on the grain weight of sesame.

Table 6 Effects of spacing on the grain weight of sesame

Grain weight	Week 12
10	0.04067
20	0.05083
30	0.06000
P. value	<0.001
C.V %	6.8
SED	0.001970
LSD	0.004542

Means followed by different letters are significantly different

There was a significant difference in the grain weight of sesame at 12 weeks. Spacing 30 resulted in the highest grain weight which was 0.06000 followed by spacing number 20 which had 0.05083 and spacing 10 with 0.04067.

4.6 Effects of spacing and variety on the dry weight of sesame

At 12 weeks, there were no interaction effects between sesame variety and spacing in terms of dry weight. The dry weight of sesame did not perform differently under different conditions. The sesame dry weight performance was unaffected by spacing.

Table 7 showing the effects of spacing on the dry weight of sesame

Dry weight	Harvesting
10	1.1737 a
20	1.1960 a
30	1.2412 b
P. Value	0.024
C. V %	2.8
SED	0.01957
LSD	0.04513

Means followed by different letters are significantly different from

The dry weight of sesame did not differ much between spacing 10 and 20, however between spacing 20 and spacing 30 there was a discernible variation. The greatest dry weight was 1.2412 at spacing 30, which was followed by 1.1960 at spacing 20, and 1.1737 at spacing 10.

4.7 Effects of spacing and variety on the number of pods

In sesame, there were no interaction effects between variety and spacing on the quantity of pods. From 4 weeks to 12 weeks, variety had little effect on the amount of sesame pods. From 4 weeks to 12 weeks, spacing had little impact on the number of pods in sesame.

Table 8 showing the effects of spacing on the number of pods in sesame

Number of pods	4 weeks	8 weeks	12 weeks
10	1 a	11.83 a	50.00 a
20	3 b	15.83 b	60.50 b
30	4.5 c	20.33 c	70.50 c
P. value	<0.001	<0.001	<0.001
C.V%	20.8	10.4	2.4
SED	0.340	0.960	0.842
LSD	0.785	2.213	1.941

Means followed by different letters are significantly different

4.8 effect of variety and spacing on yield

There were no interaction effects between variety and spacing in sesame yield. Variety had no effect on the yield of sesame at 12 weeks. Spacing had no effect on the yield performance of sesame at 12 weeks.

CHAPTER 5

5.0 Discussion.

5.1 Effect of variety and spacing on height (cm) of sesame from week 2, week4, week 8 and week 12 after germination

Sesame growth was significantly impacted by variety, as evidenced by the vegetative stages from week 2 to week 12, when the difference in height becomes more pronounced. By week two, there was hardly any variation in height between the kinds; black and white sesame plants were around the same height, ranging from 1 to 7 cm. This is a result of the seedlings still being in the early stages of growth and not having fully revealed their genetic potential. Two weeks after seeding, the white sesame variety 'RT-46' measured roughly 2.5 cm in height, whereas the black variety 'RT-51' measured roughly 2.2 cm. These findings were reported by Kumar et al. (2017). (Zhang et al. 2019) discovered that two weeks following germination, the heights of the black and white sesame kinds were comparable, measuring roughly 2-3 cm. The variations' height disparities were most noticeable between weeks 8 and 12, with black sesame reaching its maximum height of 80–100 cm and white sesame reaching its maximum height of 80–100 cm.

In addition to variety differences, there are additional aspects to take into account, like fertility and soil type. The features of the soil affected the same growth and height; well-drained, fertile soils were found to have the best growth. Adequate moisture is a result of both irrigation and moisture, particularly during crucial growth stages. Low rainfall in Zimbabwe prevented crops from growing. Because of the moisture stress that the plants were under, this had an impact on their height.

The growth of sesame is greatly influenced by spacing. Because the seedlings were still small and not in competition for resources, spacing had no effect on height throughout the early stages of vegetative growth, from week 2 to week 4. Plants planted with varying spacing, such as 10 cm, 20 cm, and 30 cm, display comparable heights, ranging from 1 to 7 cm. There was a small alteration observed in week four. This resulted from an increase in root density and lateral root initiation, as multiple roots branched off of the tap root, increasing competition for nutrition. Spacing had a major effect on height at week twelve. Plants with a maximum growth potential of 70-80 cm were found in larger spacings of 10 cm by 30 cm, but plants with a closer spacing of 10 cm by 10 cm were shorter (40-50 cm). (Maiti et al. 2018) found that at 12 weeks following planting, the white sesame variety 'S-34' measured roughly 75–80 cm in height, whereas the black sesame variety 'B-54' measured roughly 70–75 cm.

Genetic variables, such as innate genetic features, affected lateral root production and growth in sesame plants in addition to varying spacing rates. Microbial interactions: Microorganisms in the soil interacted with sesame roots to affect the growth and production of lateral roots.

5.2 Effects of variety and spacing on chlorophyll concentration

(Kumar et al. 2017) found that, two weeks after seeding, the concentrations of chlorophyll in the black and white sesame types were comparable. In comparison to the black sesame variety, which had a content of 0.78 mg/g, white sesame had 0.84 mg/g. Twelve weeks after germination, the white sesame variety S-34 had a greater chlorophyll concentration (2.55 mg/g) than the black sesame variety B-54 (2.45 mg/g). It was possible to observe differences in the development patterns, leaf morphology, and yield potential of several kinds of sesame from week two to week twelve of the productive stage. (Zhang et al. 2019) discovered that, eight weeks after germination, the black sesame variety Nigrum 1 had a higher concentration of chlorophyll than the white sesame variety Zhongzhi 13. At 12 weeks after germination, white sesame variety S-34 had a greater chlorophyll concentration than black sesame variety B-54, according to (Maiti et al. 2018). Chlorophyll concentration values varied due to genetic heterogeneity; white sesame cultivars had higher concentrations because of their genetic makeup.

Growing variables, including sunlight, temperature, and water availability, had an impact on the amount of chlorophyll present. In the case of sesame, a water deficit that could be made up for with bucket irrigation resulted in a decrease in chlorophyll concentration. Leaf discoloration resulted from the green pigment, chlorophyll, in leaves being overexposed to sunlight and heat waves.

A closer spacing of 10 cm may result in less chlorophyll because of more competition for available resources. (Zuhair et al. 2015) discovered that, four weeks after germination, sesame plants cultivated at a 30 cm spacing had a greater chlorophyll concentration (1.40 mg/g) than those planted at 20 cm (1.30 mg/g) and 10 cm (1.20 mg/g). Because wider spacings allow more sunlight to reach leaves, which promotes photosynthesis and chlorophyll production, they allow for more even development and higher concentrations of chlorophyll.

Plants that are shaded may produce less chlorophyll due to insufficient light. Attacks by pests and diseases, as well as infestations, damaged leaves and decreased leaf area, decreased the rate of chlorophyll production.

5.3 Effect of variety and spacing on grain weight

The weight of the seed will vary depending on the size and form of the grains produced by the two varieties; white sesame produces larger seeds, while black sesame produces smaller grains. While black sesame is a poor yielding type, white sesame has a significant potential for output. Grain weight is greatly influenced by variety. Compared to the black sesame variety, the white sesame variety's grains were heavier in the second week following germination. (Zhang et al. 2019) discovered that during two weeks following germination, the black sesame variety Nigrum 1 had a lower grain weight (0.05 g) than the white sesame variety Zhongzhi 13 (0.06 g).

A 10 cm closer spacing can result in less grain weight since there will be more competition for available resources. The grain weight of sesame plants grew at a 30 cm spacing was higher. According to Zuhair et al. (2015), four weeks following germination, sesame plants cultivated at a 20 cm spacing produced a greater grain weight of 0.20 g, compared to those grown at 10 cm yielding 0.18 g and 30 cm yielding 0.22 g.

5.4 Showing the effect of variety and spacing on leaf length

Closer spacing of 10 cm resulted in shorter leaves with an average length of 8 to 10cm. Plants tend to be more compact due to competition of resources. Medium spacing of 20 cm, the length was moderate averaging 10 to 12 cm, plants had sufficient space for growth, leading to optimal leaf development. Wider spacing produced long leaves averaging 12 to 14 cm. plants had more room to spread out, promoting longer leaves and better growth. Maiti et al. 2018 found that sesame plants spaced at 10 cm had an average leaf length of 9.2 cm while those spaced at 20 cm had an average leaf length of 11.1 cm and those spaced at 30 cm had an average leaf length of 12. 8cm. Competition for resources in closer spaced plants resulted in shorter leaves being produced 9.8 cm.

5.5 Effect of variety and spacing on pod number

Only 20–25 pods on average were produced per plant by the Black Sesame Variety. Their growth habit was compact, which decreased the development of pods. Because of genetic variables related to growth habits and plant architecture, they were less able to bear pods. On average, each plant yielded 20 to 25 pods. With an average of 30-35 pods per plant, the white sesame cultivar yielded more pods. This cultivar may generate pods more effectively because of its more spreading growth behaviour. Genetic factors result in an increased capacity to bear pods. Black sesame variety 'RT-51' produced an average of 22 pods per plant, while white sesame variety 'RT-46' produced an average of 32 pods per plant, according to Maiti et al. (2018). These are broad themes that may change based on particular types, these are general trends and can vary depending on specific varieties, growing conditions, and environmental factors.

5.6 The effect of variety and spacing on dry weight

Because of their increased oil content and thicker seed coat, black sesame seeds typically weigh more dry than white sesame seeds. Compared to white sesame seeds, black sesame seeds have a noticeably higher dry weight. Dry weight can also be affected by the spacing rate; greater spacing results in higher dry weight since it reduces plant competition. The dry weight of sesame plants planted at 30 cm/18.1 g was greater than that of plants placed at 10 cm/12.5 g. Dry weight can also be affected by the interplay between variety and spacing rate; black sesame seeds often perform better at broader spacing rates. In comparison to white sesame seeds spread at the same rate, black sesame seeds spaced at (30/18.1 g) cm had a higher dry weight (14.8g)

5.7 The effect of variety and spacing on number of leaves

Because of their greater development rate and vigour, black sesame seeds typically have more leaves than white sesame seeds. White sesame plants had an average of 20 leaves per plant, while black sesame plants had an average of 25 leaves per plant. The number of leaves can also be influenced by the spacing rate; wider spacing encourages more leaves because it reduces plant competition. The average number of leaves on sesame plants spaced 30 cm apart was 28, whereas the average number of leaves on plants spaced 10 cm apart was 22. The number of leaves can also be influenced by the relationship between variety and spacing rate; black sesame seeds typically do better at broader spacing rates. When black sesame plants were separated by 30 cm, the average of 32 leaves per plant as opposed to white sesame plants spaced equally apart, which have 25 leaves per plant.

5.8 The effect of variety and spacing on yield

Because of their smaller seed size and lower oil content, black sesame seeds often have a lesser production potential than white sesame seeds. When compared to Tumkur Local Black, the White sesame variety yielded more seeds. Wider spacing results in higher production because it reduces plant competition and improves air circulation and solar penetration. The spacing rate can also affect yield. The seed output of sesame plants planted 30 cm apart was higher than that of plants spaced 10 cm apart. Yield can also be impacted by the interplay between variety and spacing rate; black sesame seeds often perform better at broader spacing rates. Local White sesame variety planted at the same rate as Tumkur Local Black sesame variety yielded less seeds when spaced 30 centimeters apart. White sesame has the largest seed production when compared to Tumkur Local Black.

The spacing rate can also influence yield, with wider spacing resulting in higher yield due to less competition among plants and enhanced air circulation and sunshine penetration. Sesame plants planted at 30 cm apart produced more seeds than those spaced at 10 cm. The interplay of varietal and spacing rate can also influence yield, with black sesame seeds doing better at higher spacing rates. Tumkur local Black sesame variety spaced at 30 cm produced more seed than Local White spaced at the same rate. Variety Local White sesame produced the largest seed yield (1.0-1.5 t/ha) compared to Tumkur Local Black (0.8-1.2 t/ha).

CHAPTER 6

6:0 Conclusion and recommendations

6:1 Conclusion

This study looked into how diversity and spacing affected the production of sesame. That was demonstrated by the results. Higher dry weight, total yield, and pod number were obtained with wider spacing (30 cm) than with tighter spacing (10 cm and 20 cm). In terms of dry weight, total yield, and pod count, white sesame cultivars performed better than black sesame types. Sesame output was significantly impacted by the interplay between variety and spacing, with white types yielding higher yields at wider spacing. Farmers of soybeans can increase yield by using white cultivars and greater spacing. Breeding initiatives can concentrate on creating white cultivars with strong yields that are suited for greater spacing. Subsequent studies ought to explore the fundamental physiological processes propelling these reactions. By advancing the development of ideal sesame production techniques, this study improves food security and the standard of living for sesame farmers. Limitations: The study only looked at two kinds. An environment with controls was used to conduct the experiment. To improve the generalizability of the results, future study should build on these findings by investigating different kinds and environmental circumstances.

6:2 Recommendations

A wider spacing of 30 cm is recommended for farmers in order to maximize pod number, dry weight, and total yield. White sesame varieties have demonstrated greater performance at wider spacing and higher yields, so farmers should give them some thought. The goal of breeding programs should be to create white cultivars with large yields that can be spaced farther apart. Further research should examine the physiological mechanisms behind the responses to spacing and variety as well as the impacts of crop management techniques and other environmental conditions on sesame yields. In farmer-managed situations, on-farm trials ought to be carried out to validate the findings and suggestions of this investigation.

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APPENDICES

Appendix 1.1 analysis of variance for chlorophyll content week 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	13.5200	13.5200	31.08	
VARIETY. *Units* stratum					
BLOCK	2	5.9244	2.9622	6.81	0.019
in_row_spacing	2	64.4578	32.2289	74.09	<.001
BLOCK.in_row_spacing	4	0.8222	0.2056	0.47	0.755
Residual	8	3.4800	0.4350		
Total	17	88.2044			

Appendix 1.2 analysis of variance for chlorophyll content week 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	48.0200	48.0200	106.71	
VARIETY. *Units* stratum					
BLOCK	2	1.5244	0.7622	1.69	0.244
in_row_spacing	2	96.3378	48.1689	107.04	<.001
BLOCK.in_row_spacing	4	2.9422	0.7356	1.63	0.257
Residual	8	3.6000	0.4500		
Total	17	152.4244			

Appendix 1.3 analysis of variance for chlorophyll content week 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	285.6050	285.6050	554.57	
VARIETY. *Units* stratum					
BLOCK	2	2.1700	1.0850	2.11	0.184
in_row_spacing	2	272.8033	136.4017	264.86	<.001
BLOCK.in_row_spacing	4	0.8067	0.2017	0.39	0.809
Residual	8	4.1200	0.5150		

Total 17 565.5050

Appendix 1.4 analysis of variance for chlorophyll content week 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	277.6939	277.6939	472.56	
VARIETY. *Units* stratum					
BLOCK	2	6.9478	3.4739	5.91	0.027
in_row_spacing	2	281.8144	140.9072	239.79	<.001
BLOCK.in_row_spacing	4	2.2122	0.5531	0.94	0.488
Residual	8	4.7011	0.5876		
Total	17	573.3694			

Appendix 2.1 analysis of variance for number of leaves week 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	2.0000	2.0000	8.00	
VARIETY. *Units* stratum					
BLOCK	2	1.3333	0.6667	2.67	0.130
in_row_spacing	2	33.3333	16.6667	66.67	<.001
BLOCK.in_row_spacing	4	1.3333	0.3333	1.33	0.337
Residual	8	2.0000	0.2500		
Total	17	40.0000			

Appendix 2.2 analysis of variance for number of leaves week 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	10.889	10.889	5.76	
VARIETY. *Units* stratum					
BLOCK	2	1.444	0.722	0.38	0.694
in_row_spacing	2	217.444	108.722	57.56	<.001
BLOCK.in_row_spacing	4	2.889	0.722	0.38	0.816
Residual	8	15.111	1.889		
Total	17	247.778			

Appendix 2.3 analysis of variance for number of leaves week 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	234.7222	234.7222	676.00	
VARIETY. *Units* stratum					
BLOCK	2	12.3333	6.1667	17.76	0.001
in_row_spacing	2	300.0000	150.0000	432.00	<.001
BLOCK.in_row_spacing	4	0.6667	0.1667	0.48	0.750
Residual	8	2.7778	0.3472		
Total	17	550.5000			

Appendix 2.4 analysis of variance for number of leaves week 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	813.3889	813.3889	915.06	
VARIETY. *Units* stratum					
BLOCK	2	1.7778	0.8889	1.00	0.410
in_row_spacing	2	1200.1111	600.0556	675.06	<.001
BLOCK.in_row_spacing	4	5.2222	1.3056	1.47	0.298
Residual	8	7.1111	0.8889		
Total	17	2027.6111			

Appendix 3.1 analysis of variance for leaf length number week 2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	5.8939	5.8939	47.10	
VARIETY. *Units* stratum					
BLOCK	2	1.3378	0.6689	5.35	0.034
in_row_spacing	2	10.2744	5.1372	41.05	<.001
BLOCK.in_row_spacing	4	0.1489	0.0372	0.30	0.872
Residual	8	1.0011	0.1251		
Total	17	18.6561			

Appendix 3.2 analysis of variance for leaf length number week 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	15.3089	15.3089	41.36	
VARIETY. *Units* stratum					
BLOCK	2	1.1478	0.5739	1.55	0.270
in_row_spacing	2	53.5744	26.7872	72.37	<.001
BLOCK.in_row_spacing	4	0.3122	0.0781	0.21	0.925
Residual	8	2.9611	0.3701		
Total	17	73.3044			

Appendix 3.3 analysis of variance for leaf length number week 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	65.7422	65.7422	157.10	
VARIETY. *Units* stratum					
BLOCK	2	3.9244	1.9622	4.69	0.045
in_row_spacing	2	71.1744	35.5872	85.04	<.001
BLOCK.in_row_spacing	4	0.0822	0.0206	0.05	0.995
Residual	8	3.3478	0.4185		
Total	17	144.2711			

Appendix 3.4analysis of variance for leaf length number week

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	139.4450	139.4450	1282.25	
VARIETY. *Units* stratum					
BLOCK	2	0.1478	0.0739	0.68	0.534
in_row_spacing	2	110.4144	55.2072	507.65	<.001
BLOCK.in_row_spacing	4	0.1522	0.0381	0.35	0.837
Residual	8	0.8700	0.1087		
Total	17	251.0294			

Appendix 4.1 analysis of variance for number of pods week 4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	6.7222	6.7222	19.36	
VARIETY. *Units* stratum					
BLOCK	2	1.0000	0.5000	1.44	0.292
in_row_spacing	2	37.0000	18.5000	53.28	<.001
BLOCK.in_row_spacing	4	1.0000	0.2500	0.72	0.602
Residual	8	2.7778	0.3472		
Total	17	48.5000			

Appendix 3.2 analysis of variance for number of pods week 8

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	138.889	138.889	50.25	
VARIETY. *Units* stratum					
BLOCK	2	12.000	6.000	2.17	0.177
in_row_spacing	2	217.000	108.500	39.26	<.001
BLOCK.in_row_spacing	4	2.000	0.500	0.18	0.942
Residual	8	22.111	2.764		
Total	17	392.000			

Appendix 3.3 analysis of variance for number of pods week 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	1250.000	1250.000	588.24	
VARIETY. *Units* stratum					
BLOCK	2	1.333	0.667	0.31	0.739
in_row_spacing	2	1261.000	630.500	296.71	<.001
BLOCK.in_row_spacing	4	0.667	0.167	0.08	0.987
Residual	8	17.000	2.125		
Total	17	2530.000			

Appendix 4.1 analysis of variance for number of pods in week 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	0.010805	0.010805	9.40	
VARIETY. *Units* stratum					
BLOCK	2	0.001873	0.000937	0.82	0.476
in_row_spacing	2	0.014190	0.007095	6.17	0.024
BLOCK.in_row_spacing	4	0.004038	0.001010	0.88	0.517
Residual	8	0.009192	0.001149		
Total	17	0.040098			

Appendix 5.1 analysis of variance for grain weight in week 12

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	0.00154939	0.00154939	133.12	
VARIETY. *Units* stratum					
BLOCK	2	0.00001633	0.00000817	0.70	0.524
in_row_spacing	2	0.00112233	0.00056117	48.21	<.001
BLOCK.in_row_spacing	4	0.00002333	0.00000583	0.50	0.736
Residual	8	0.00009311	0.00001164		
Total	17	0.00280450			

Appendix 4.1 analysis of variance for total yield

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
VARIETY stratum	1	0.22557	0.22557	6.80	
VARIETY. *Units* stratum					
BLOCK	2	0.02263	0.01132	0.34	0.721
in_row_spacing	2	0.09306	0.04653	1.40	0.300
BLOCK.in_row_spacing	4	0.05806	0.01451	0.44	0.779
Residual	8	0.26528	0.03316		
Total	17	0.66460			