BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

Effects of different plant populations on yields of two different wheat (*Triticum Aestivum L.*) varieties in Mashonaland Central.

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FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF CROP SCIENCE

RESEARCH PROJECT

DECLARATION

I, Junior Mwareka, hereby declare that this research project is a result of my original research work undertaken by myself, except where clearly and specifically acknowledged. It is being submitted for the partial fulfillment of the Bachelor of Agricultural Science Honors Degree (Crop Science). It has not been submitted before for any degree or examination at any other University.

Student name: Junior Mwareka

Signature___ ______________________________ Date: 30/06/2025

I have supervised the research project mentioned above, and I am convinced that the Research Project:

a) Can be submitted

Project Supervisor:

Signature: Date: 17/09/2025

I certify that I have checked the Research Project and I am satisfied that it conforms to the Department of Crop Science guidelines for project preparation and presentation. I therefore Authorize the student to submit this dissertation for marking.

Chairperson

____________________________Signature____________________________ Date:

Official stamp/Date received in the Department of Crop Science office

DEDICATION

To my family and Pimento farm.

ACKNOWLEDGEMENT

First and foremost, I would like to express my deepest gratitude to God for His persistent guidance, protection and the strength that enables me to successfully complete this project. I am sincerely thankful to my family, particularly my mother and my brother for their enduring support, encouragement and love throughout this journey. I would like to extend my heartfelt appreciation to Professor Mandumbu who served not only as my supervisor but also as the project coordinator for his commitment and willingness to guidance and valuable information throughout this project. I am also grateful to Mr Mutsengi my department chairperson, who provided me with valuable support and direction when I needed it the most. I would like also to thank my attachment supervisors Mr Watetepa and Mr Mlanga in their recommendation and support which lead to the success of this project. I also sincerely acknowledge Mr Shonhiwa from Pimento Farm, where I conducted my research, for his support and cooperation in providing the resources necessary for my fieldwork. Finally, I would like to thank my friends for their helpful contributions to this project.

ABSTRACT

Wheat is one of the most important cereal crops grown globally and optimizing its production is essential for improving food security. In Zimbabwe, wheat production is often constrained by sub-optimal agronomic practices including poor plant population management and inappropriate variety selection. A field study was conducted at Pimento farm in Bindura, Mashonaland Central, to evaluate the effects of different plant population rates on the growth and yield of two wheat varieties (SC Serena & SC Select).The primary objective of the study was to determine how plant population influence wheat production parameters and to identify which variety performs best under different plant population densities. A 3*2 factorial treatment structure laid in a randomized complete block design (RCBD) was used with three plant population treatments of 150, 250 and 350 plants/m^2, replicated across both wheat varieties. Data were collected on plant height, number of effective tillers, spike length, number of spikes per plant, number of spike-lets per spike and number of kernels per spike. The collected data was analysed using ANOVA with Genstat 17th edition and an LSD ($p<0.05$) was used to differentiate between statistically different means. The interaction between variety and plant population densities was significant ($p<0.05$) across all the parameters. The results showed that moderate plant population (150 and 250 plants/m^2) consistently produced better results across measured parameters where-as higher plant population (350 plants/m^2) negatively affected wheat performance due to increased competition for space, light, water and nutrients. SC Serena significantly outperformed SC Select across all plant populations, demonstrating superior adaptability, higher tillering capacity, longer spikes and greater grain yield potential. The studies outcome reinforces the importance of managing plant populations carefully and selecting high-performing wheat varieties to maximize yield.

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LIST OF ABBREVIATIONS.

ADAS: Agricultural Rural Advisory Services.

ANOVA: Analysis of Variance

FAO: Food and Agriculture Organization of the United Nations.

LSD: Least of Significance Difference.

RCBD: Randomised Complete Block Design.

S.e.d: Standard errors of differences of means

ZimStat: Zimbabwe National Statistics Agency.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND.

Wheat (*Triticum aestivum L.*) is one of the most important cereal crops grown around the world, serving as a staple food in many countries. *Triticum aestivum L.* is the predominant wheat species cultivated globally and commonly known as "bread" wheat while *Triticum durum*, often referred to as “pasta wheat”, is the second most prevalent type and thrives in Mediterranean climate (Shewry & Hey, 2015). Beyond food, wheat is also used to make alcohol, gluten, dextrose, malt, paste, and starch, among other items.

Historically, wheat has deep roots, with De Candolle (1886) suggesting that the Euphrates region, possibly extending into Syria was its original home in prehistoric times. More recent studies by Lev-Mirom and Distelfed (2023) point to South Western Asia as the likely center of wheat’s origin.

As reported by Grote et al. (2020), wheat *(Triticum aestivum, L.*) is essential for about 35% of the global population, averaging yields of 3.5 tons per hectare. However, these yields can vary significantly based on factors like farming practices (e.g fertilizer and irrigation use) and local environmental conditions (e.g climate and soil quality). Affordable staples like wheat play a vital role in supporting the livelihoods of many, especially those in low income communities (Tilman et al., 2011). Moreover, wheat is a valuable source of dietary fiber, protein, vitamins, and minerals. In terms of cultivation, wheat is typically sown at densities ranging from 150 to 400seed m^2 (Olsen et al., 2006). Godwin and Miller (2003 highlighted that the density of crops can greatly affect their yield potential. Elzinga et al. (1998) explained that farmers often assess plant population density by counting the number of plants I n specific areas, especially during early growth stages just before tillering.

In Zimbabwe plant population density plays a crucial role in wheat yields. An optimal density of 250 plants/m^2 and 150 plants/m^2 allows enough space for plants to grow without overcrowding, which enhances their growth and potential yield. Research by Chakwizira et al.(2015) indicates that lower plant densities can lead to underutilization of available resources, resulting in lower yields, whereas higher densities create competition among plants, which can hinder growth and reduce grain size.

.Mutasa et al. (2016), found that lower plant population densities often result in more tillers because there is less competition for resources. In contrast, higher densities can limit tiller production as plants focus on growing the main stem. Mlambo & Nyakudya (2018) noted that fewer tillers can decrease the number of spikes, but the spikes that do form in crowded conditions may produce more due to concentrated resources. Ultimately, finding the right balance in plant density is key: at optimal levels, wheat plants in Zimbabwe can produce a healthy number of productive tillers with well-developed spikes, maximizing grain yield (Matarira et al., 2016). However, high densities can negatively impact yield by either reducing the number of spikes or the size of grains (Chakwizira et al., 2015).

SC Select and SC Serena are two popular wheat varieties from Seed Co each with unique characteristics and responses to different planting densities. Both are medium to late maturing varieties, with SC Serena known for its resilience against diseases and adaptability to varying rainfall conditions (Africa Seedco, 2023). SC Select, is particularly drought resistant, making it suitable for drier areas. Both varieties thrive best plant populations of around 200-250 plants/m^2 (Africa SeedCo, 2023), showing high yield potential when managed properly. SC Select generally performs better in low-rainfall regions, while SC Serena excels in more favorable environments (SeedCo, n.d.).

1.2 PROBLEM STATEMENT.

Many challenges have been faced in wheat production leading to low yields. Plant population density is one of the primary factors which directly influence inter and intra competition for essential resources like water, light and nutrients which are drivers to potential yield. Varieties like SC Serena and SC Select are widely grown in Zimbabwe due to their high yield potential and adaptability. However, there is limited research specifically comparing how these varieties respond to different plant populations under the specific environmental and agronomic conditions. The absence of such important knowledge has made it difficult for farmers to optimize planting densities to achieve maximum yield for each variety. Therefore, this study seeks to fill this knowledge gap by conducting a comparative assessment of the yield responses of SC Serena and SC Select to varying plant populations, with the aim of providing practical, variety specific recommendations to improve wheat yield in the region.

1.3 JUSTIFICATION.

The justification for this study lies in the need to enhance wheat production in Zimbabwe, where achieving optimal yields is critical for food security and economic development. Wheat yields are highly influenced by plant population densities, which affect resource competition and crop performance (Whaley et al., 2000). SC Serena and SC Select, two widely grown wheat varieties in the region, exhibit different growth patterns and responses to environmental conditions. However, limited research exists on how different plant populations specifically affect the yields of these varieties under local conditions. This study will provide valuable insights into the optimal planting densities for each variety, helping farmers in the region improve productivity and resource use efficiency.

1.4 OBJECTIVES

1.4.1 GENERAL OBJECTIVE.

To assess the effects of different plant populations on the yield of two wheat varieties, SC Serena and SC Select

1.4.2 SPECIFIC OBJECTIVE

1. To assess how different plant population densities affect plant height, tillering and heading patterns in wheat (plant height, number of tillers, number of heads)

2. To assess how different wheat plant population densities affect grain, and spike architecture and development (number of spikelets, number of kernels, spike length).

1.5 HYPOTHESIS (ALTERNATIVE).

1. There is a significant difference in plant height, number of tillers, and number of heads of wheat under different plant population densities.
2. There is a significant difference in grain characteristics and spike architecture (number of spikelets, number of kernels, spike length) of wheat under different plant population densities.

CHAPTER 2: LITERATURE REVIEW
2.1 ORIGIN, IMPORTANCE, AND ECOLOGY OF WHEAT

Wheat (*Triticum aestivum*) is a member of the Poaceae family, which includes other grains like maize and rice. It is considered a staple crop worldwide, with its origins traced back to Southwestern Asia. De Candolle (1886) suggested that wheat originated near the Euphrates and Tigris rivers, and there are historical accounts indicating that the Aryans introduced it to India (Damania, 2016). Wheat cultivation dates back to prehistoric times, with evidence of its growth in China as early as 2700 BC (Directorate of Wheat Development, n.d.). According to Orth and Shellenberger (1988), wheat was one of the first crops to be domesticated and has served as a fundamental food source for major civilizations in Europe, West Asia, and North Africa for over 800 years. Today, it occupies more land than any other commercial crop and remains the top food grain source for humans, surpassing rice, maize, and potatoes (Investopedia, 2012). In the 2023-2024 marketing year, China was the largest wheat producer, followed by the European Union and India, with Russia being the largest exporter.

Farmers worldwide favor growing wheat due to its numerous benefits. It is packed with essential nutrients, including carbohydrates, proteins, B vitamins, iron, and zinc, all vital for maintaining good health. Fiber in wheat aids digestion, while proteins help build and repair tissues. B vitamins are crucial for energy production, and iron and zinc support the immune system. The fiber content in wheat also alleviates constipation (Shewry & Hey, 2015; Yadav et al., 2011), and the soluble fiber nourishes beneficial gut bacteria, promoting overall digestive health (Yadav et al., 2011; Reynolds and Mann, 2019). Wheat has a low glycemic index, leading to a gradual rise in blood sugar levels and potentially lowering the risk of type 2 diabetes (Jenkins et al., 2013). The Harvard T.H. Chan School of Public Health (2012) notes that premium quality wheat options are low in fat and calories, helping people feel fuller for longer.

From an agronomic perspective, wheat thrives with moderate rainfall during its critical growth stages: germination, tillering, flowering, and grain filling (EOS Crop Guide, 2023). It performs best in areas with moderate humidity, which helps reduce the risk of fungal diseases and supports pollen development and fertilization. However, lower humidity is preferred during grain filling

(EOS Crop Guide, 2023). Bayer Crop Science (2024) reports that loamy soils are ideal for wheat production, providing a balanced mix of sand, silt, and clay that ensures good drainage and nutrient availability. Wheat flourishes in slightly acidic to neutral soils, with a pH between 6.0 and 7.5.

2.2 WHEAT PRODUCTION IN ZIMBABWE

Agriculture is a vital sector in Zimbabwe, supporting about 70% of the population and contributing around 15% to the GDP. It is also responsible for 40% of export earnings and provides 63% of raw materials for agro-industry (ZimStat, 2021; FAO, 2022). As of 2023, agriculture accounted for 60-70% of income in rural areas and 10-20% in urban regions (Ministry of Lands, Agriculture, Fisheries, Water and Rural Development, 2023). Wheat is regarded as the second most important strategic food security crop in Zimbabwe, following maize (Mashingaidze et al., 2021). Its high demand, particularly for bread in urban areas, has made it a staple crop (FAO, 2022).

Wheat (*Triticum aestivum*) is typically grown in winter, despite the dry conditions during these months. To ensure successful crop development, Zimbabwean wheat farmers rely on irrigation (Nyakudya et al., 2020). According to the Agricultural Rural Advisory Services, in 2023, Mashonaland West led the country in wheat production, yielding over 138,000 tonnes at an average of 4.8 tonnes per hectare. Mashonaland East followed with 86,187 tonnes at 5.1 tonnes per hectare, and Mashonaland Central produced 85,541 tonnes at 5.3 tonnes per hectare. The Midlands and Manicaland regions also contributed significantly, with 64,364 tonnes and 60,797 tonnes, respectively. Overall, 468,000 tonnes of wheat were harvested from 90,186 hectares in 2023 (ADAS, 2023).

2.3. SPACING IN WHEAT.

Several factors influence wheat production, including pests and diseases, but plant population density is the most critical. For optimal growth and yield, the ideal plant population for wheat is between 220-250 plants per square meter (Seed Co Zimbabwe, 2021). A seeding rate of 110-125 kg/ha when drilling and 125-135 kg/ha when broadcasting is recommended to achieve this density (Seed Co Zimbabwe, 2021). Adhering to these guidelines can enhance crop tillering, spike formation, and overall yield while also helping to mitigate diseases like powdery mildew (*Blumeria graminis* f. sp. *tritici*) through good agronomic practices (Savary et al., 2019).

2.4 EFFECTS OF PLANT POPULATION ON WHEAT YIELD.

Key factors affecting wheat yield include the number of spikes per area and the number of grains per spike (Li et al., 2022). Zhang et al. (2021) found that plant population density influences grain yield by affecting the number of spikes produced. Varying seeding densities can modify yield components (Fischer, 2019).

Higher plant population densities can lead to increased competition among the plants, resulting in accelerated leaf aging and more grain abortions due to reduced spike assimilation during the filling phase (Xie et al., 2020). This competition can also hinder the plants' ability to absorb nutrients (Fischer, 2019). Although a higher seed amount may lead to more tillers, this does not fully compensate for a decrease in the number of fertile spikes per plant. Under high-density conditions, the number of grains per spike is often reduced due to the abortion of lower and upper spikelets (Xie et al., 2020). However, increasing planting density can also enhance the number of high-quality tillers, potentially boosting yield (Li et al., 2022).

Fischer (2019) noted that at lower planting densities, reduced competition for water and nutrients allows for extended tillering duration, leading to more tillers and higher survival rates. This can also increase the number of spikes per plant, resulting in a greater number of grains per spike

CHAPTER 3: RESEARCH METHODOLOGY

3.1 BRIEF DESCRIPTION OF THE STUDY AREA

The study area was carried out at S/D Pimento Farm in Bindura. The farm is located along Bindura – Harare road. The geographical coordinates are S17°17'33'' latitude, E31°14'47" longitude, 1042.4m altitude, and 2m accuracy. The farm is situated in Bindura district which falls within Mashonaland Central Province. Notably, it is located in Agro-Ecological 11a and 11b, well known for its exceptional agricultural productivity and adequate rainfall. The area benefits from an average annual rainfall of 750-900mm and an average temperature of 15-25 ^{o}C. Furthermore, the farm's soil composition is predominantly clay loam. Most farmers in Bindura grow wheat in winter most probably on a commercialized scale.

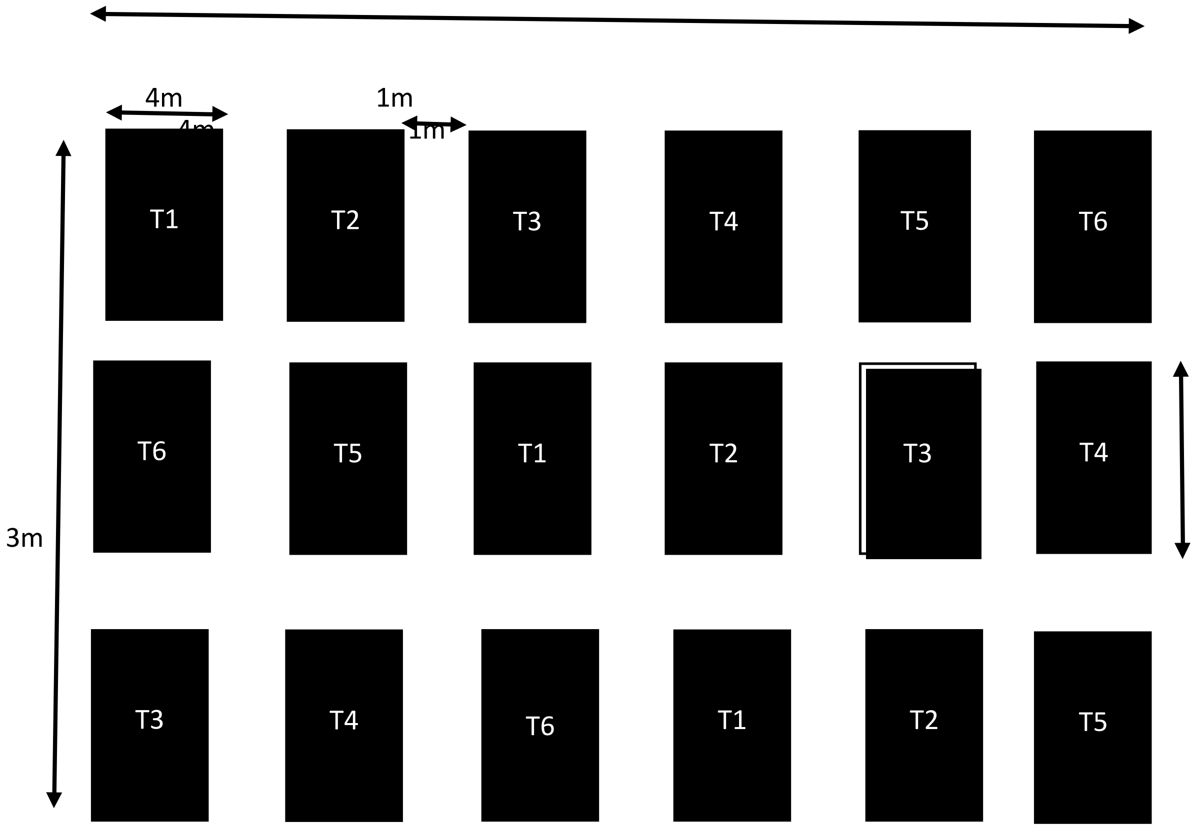
3.2 TREATMENTS AND EXPERIMENTAL DESIGN.

The research consists of 2 factors, plant population and varieties. The trial was laid as 3x2 factorial experiment laid in a Randomized Complete Block Design. The 6 treatments were used for this experiment and the treatment combination were 2 varieties and 3 levels of plant populations (Table 3.1), replicated 3 times. The 2 different wheat varieties used were SC Select and SC Serena from Seed Co and the three different plant populations were 150 plants/m^2 for low plant population, 250 plants/m for optimum plant population and 350plants/m2 for high plant population. The varieties were assigned as the main plot treatment, while 3 different levels of plant population were assigned as the sub plot treatments. The blocking factor in this experiment was the slope.

Table 3. 1 Treatments laid out in RCBD:

PLANT POPULATION (plants/m^2)	APPROXIMATE SPACING (cmxcm)	SC SERENA	SC SELECT
150 (low)	8x8	T1	T4
250 (optimum)	6x6	T2	T5
350 (high)	5x5	T3	T6

Table 3. 2: Field layout of the study.



<u>Key of the above table</u>

Length of the whole plot = 30m

Width of the whole field = 12m

Length of each plot = 4m

Length of path per each plot=1m

Width of each plot =3m

Width of path per each plot =1m

The whole area of the plot=Length * width

= 30m * 12m

= 360m

3.3 AGRONOMIC PROCEDURES

3.3.1 LAND PREPARATION

To prepare the experimental field, weeds and leftover crop residues were first cleared. Tractordrawn plow was used to perform primary tillage to a depth of 20 cm, followed by two passes with a disc harrow to create a fine, suitable seedbed. A pre-planting soil analysis was conducted, and a balanced NPK fertilizer was incorporated during the final harrowing. To ensure uniform water distribution, the land was carefully leveled. The plots were then laid out in a Randomized Complete Block Design (RCBD), with a pre-emergent herbicide applied before planting to minimize weed competition, creating an ideal environment for the wheat varieties. Each block consisted of 18 plots with six different treatments, with each plot measuring 4 m × 3 m and a 1 m pathway between them. The overall experimental area measured 30 m × 12 m.

3.3.2 VARIETIES

For this study, two wheat varieties from Seed Co: SC Serena and SC Select were used. Both varieties have high yield potentials, with SC Serena reaching up to 10.5 t/ha and SC Select up to 10.4 t/ha (SeedCo, n.d.). These are medium to late-maturing white-grain varieties, resistant to current leaf rust pathotypes. SC Select matures in 135 to 140 days, while SC Serena takes 145 to 150 days (SeedCo, n.d.). Both varieties are known for their excellent milling and baking qualities, with SC Serena having at least 12.7% protein and 30.9% gluten, and SC Select having at least 11.5% protein and 27.7% wet gluten (SeedCo, n.d.).

3.3.3 IRRIGATION AND FERTILISATION.

To maintain consistent water availability and nutrient supply, irrigation and fertilization were carefully managed throughout the experiment. Water was sourced from the Mazowe River, and a sprinkler irrigation system was used to ensure uniform water distribution, reducing stress on the plants. Compound D was applied as a basal fertilizer at a rate of 450-600 kg, and the soil pH was maintained between 5.5 and 6.5 for optimal growth.

3.3.4 WEED, PEST AND DISEASES MANAGEMENT

Weed competition was managed using both pre-emergence and post-emergence herbicides.

Glyphosate was applied right after planting as a pre-emergent herbicide, followed by Dicamba to control weeds after they emerged. Pest management strategies were also implemented, using plastic whistles and scarecrows to deter quelea birds. Additionally, we sprayed the crops with tebuconazole to protect against diseases like yellow rust and powdery mildew.

3.4 AGRONOMIC DATA COLLECTED

From agronomic data collected yield of the grain and other major yield components were measured. These comprise the plant height, number of tillers, number of spikes or heads, number of kernels or grains, number of spike-lets, and spike length per selected plants were considered as parameters to study the effects of different plant populations on the yield of two different wheat (*Triticum Aestivum. L*) varieties. The yield components measured are listed in table 3.3 below:

Table 3. 3Parameters measured and their description.

Parameter	**description**
Plant height	The height of the plant was recorded by measuring the plants using a tape measure from the surface of the soil to the tip of the spike at physiological maturity. Five plants were selected randomly per each plot and the average was recorded.
Number of effective tillers	The number of effective tillers was recorded in each plot at physiological maturity. The use of hands was done to easily count the number of tillers per plant. Five plants were selected randomly per each plot and the average was recorded.
Spike length	The spike length was measured using a tape measure at physiological maturity. Five plants were selected randomly per each plot and the average was recorded.

Number of spikes or heads	The spikes or heads were counted using hands. Five plants were selected randomly per each plot, and then the average was recorded.
Number of spike-lets	Five plants were selected randomly in each plot to count the number of spike-lets. This was done using hands. Then the average was calculated from the five plants.
Number of kernels per spike	The grains of selected plants per plot were selected and separated from their spikes. Then the number of grains was calculated. The results were averaged on to per-spike basis.

3.4DATA ANALYSIS.

The data collected was analyzed using analysis of variance (ANOVA) to assess how different plant populations affected the yield performance of the wheat varieties. This analysis was performed using GenStat (17th edition), with tests conducted at a significance level of $p < 0.05$. Means of significant treatment difference were separated using Standard errors of differences of means (S.e.d)

CHAPTER 4: RESULTS

4.1 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE PLANT HEIGHT (IN CM) AT PHYSIOLOGICAL MATURITY.

There was a high significance ($p<0.05$) on the average plant height on variety, plant population, and their interaction. Fig 4.1 shows that plant height increases with an increase in plant population density for both SC Serena and SC Select. However, SC Serena persistently recorded taller plants compared to SC Select in all the plant populations. The tallest plants were recorded at 350 plants/m^2 whilst the shortest plants were recorded at 150 plants/m^2. At 150 plants/m^2 and 250 plants/m^2 population density, the difference in plant height between the two varieties is statistically significant while at 350 plants/m^2 plant population density, the difference in plant height between the two varieties is not statistically significant.

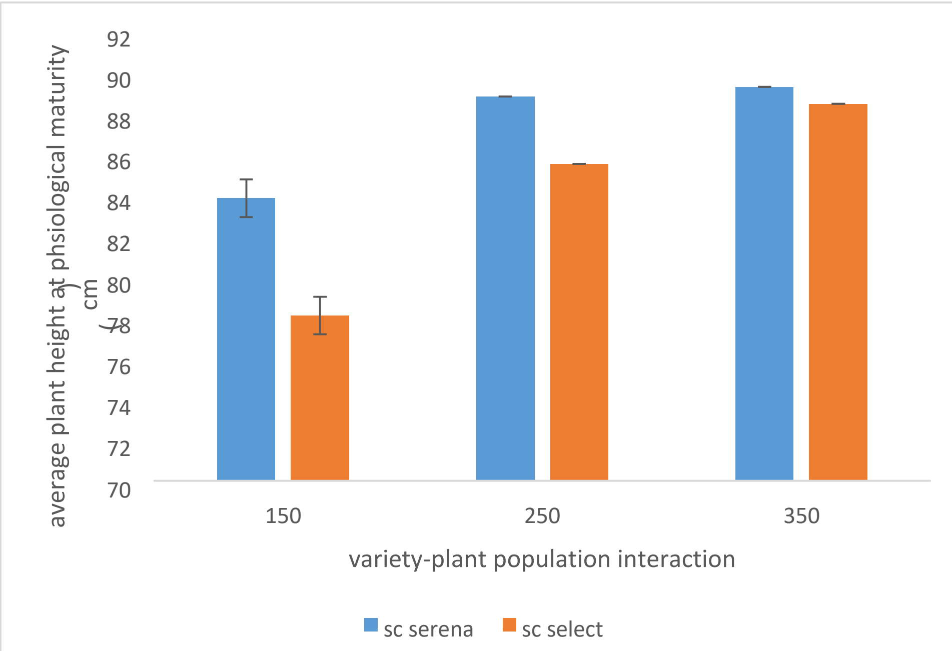


FIGURE 4. 1 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE PLANT HEIGHT (IN CM) AT PHSYIOLOGICAL MATURITY

4.2 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF EFFECTIVE TILLERS.

There was a high significance ($p<0.05$) on the average number of effective tillers on plant population and their interaction. The results shows higher significant on plant population (<0.001) and very slight significant of (0.049) on their interaction. There were no significant on variety (0.008). Figure 4.2 shows that there was a decrease in the average number of effective tillers with an increased plant population. The highest number of tillers was recorded at 150 plants/m^2. At 350 plants/m^2 plant population, there was a sharp decline on the number of tillers per plant for both varieties. SC Serena showed a slightly higher number of tillers compared to SC Select.

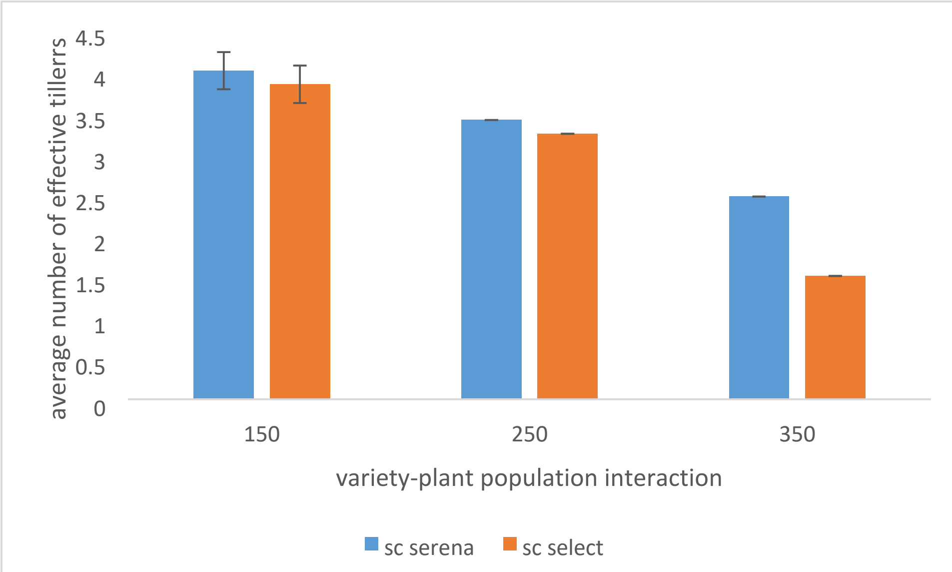


FIGURE 4. 2 EFFECTS OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF EFFECTIVE TILLERS PER PLANT

4.3 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE SPIKE LENGTH (IN CM).

There was a high significance ($p<0.05$) on the average spike length on variety, plant population, and their interaction. The results in figure 4.3 shows that spike length decreased with an increase in plant population density for both SC Serena and SC Select. The longest spikes were recorded at 150 plants/m^{2}whilst the shortest spike length was recorded at 350plants/m^2. SC Serena constantly produced slightly longer spikes than SC Select. The difference in fig 4.3 were not statistically significant at 150plants/m^2 and 250plants/m^2 plant population densities and this suggest that both SC Serena and SC Select responded similarly in terms of spike length under different plant densities.

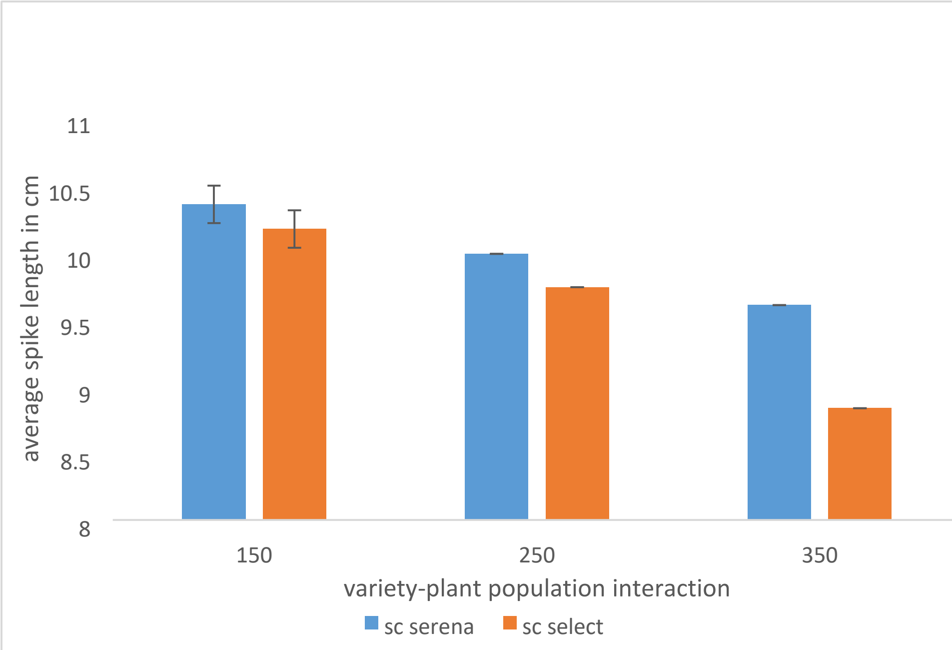


FIGURE 4. 3 EFFECT OF VARIETY AND PLANT POPULATION ON AVERAGE SPIKE LENGTH

4.4 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF SPIKES OR HEADS PER PLANT.

There was a significance (<0.05) on the average number of spikes or heads on variety, plant populations, and their interaction. Fig 4.4 shows that the average number of spikes decreases with increased plant population. Both varieties produced more spikes at 150 plants/m^2 and fewer spikes at 350 plants/m^2. SC Serena keeps on producing the highest average number of spikes or heads as compared to SC Select across all plant populations.

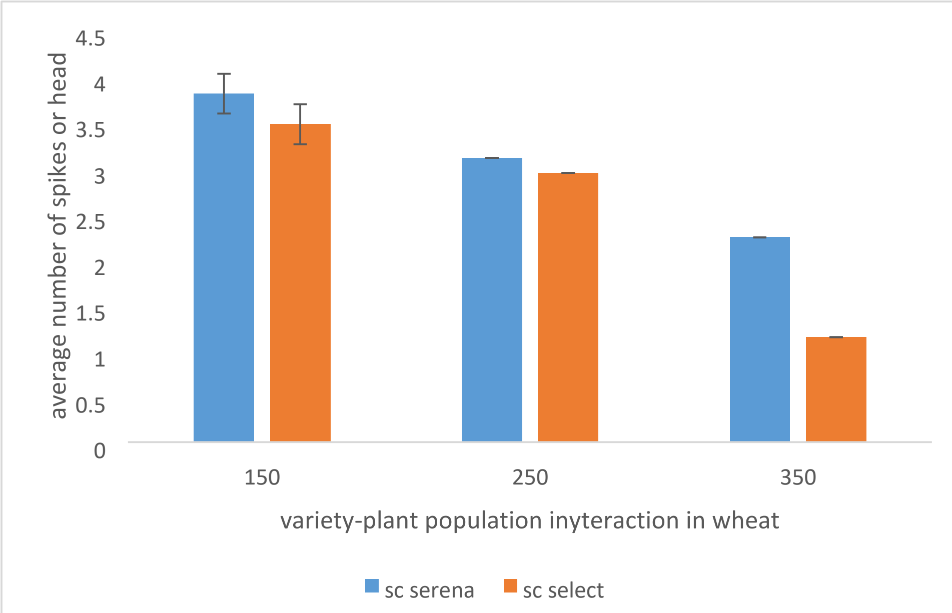


FIGURE 4. 4 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF SPIKES PER PLANT.

4.5 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF SPIKELETS.

There was a significance (<0.05) on the average number of spike-lets in variety, plant population, and their interaction, with a higher significance ($p<0.01$) on variety and plant population and a slight significance on the interaction ($p=0.047$). Fig 4.5 shows a slight decrease in number of spike-lets per spike with an increase in plant population density. SC Serena consistently produced more spike-lets compared to SC Select across all plant population densities.

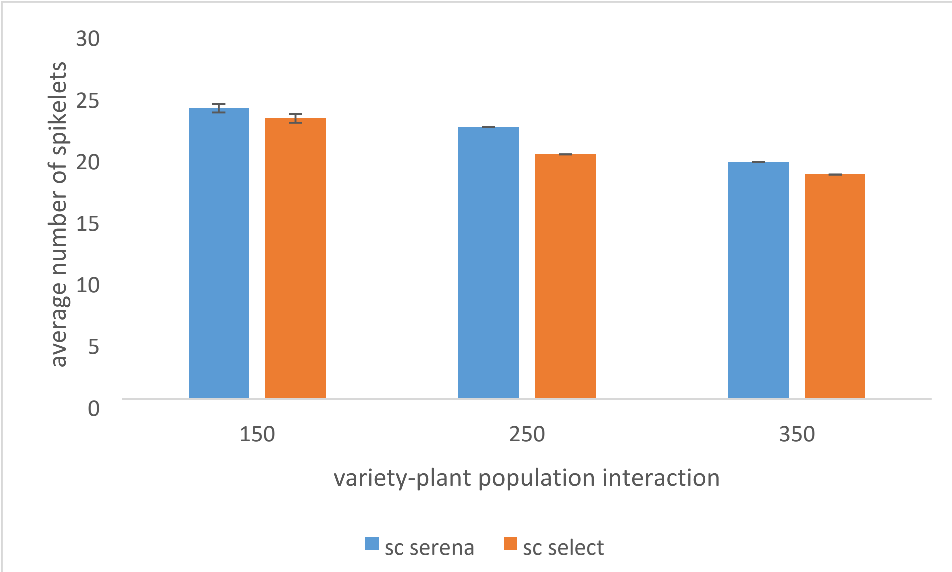


FIGURE 4. 5 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF SPIKE-LETS PER SPIKE

4.6 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF KERNELS PER SPIKE.

There was an extreme significance ($p<0.05$) on the average number of kernels per spike for all the factors.. Figure 4.6 illustrates a clear trend, as the plant population increases from 150 plants/m^2 to 350 plants/m ^{2} number of kernels per spike decreases steadily for both varieties. The most number of kernels was recorded at 150 plants/m^2 whereas the fewer number of kernels was recorded at 350 plants/m^2. SC Serena constantly produces a higher number of kernels per spike than SC Select.

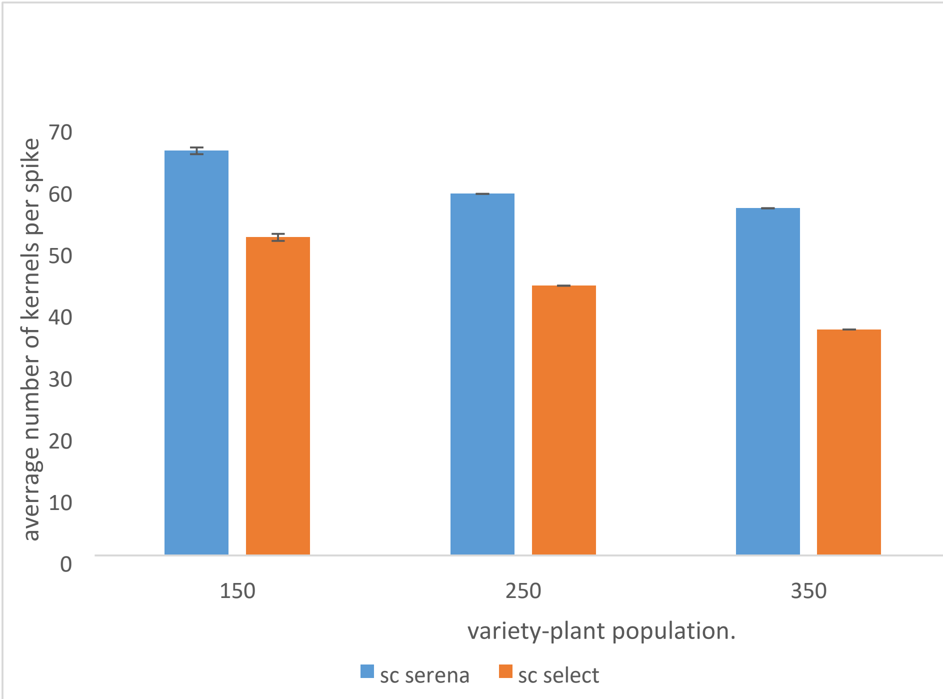


FIGURE 4. 6 EFFCET OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF KERNELS PER SPIKE

CHAPTER 5: DISCUSSION

5.1 AVERAGE PLANT HEIGHT AT PHYSIOLOGICAL MATURITY

The differences in average plant height between SC Serena and SC Select can be attributed to their unique genetic traits and growth patterns. SC Serena, being a medium to late-maturing variety, benefits from a longer vegetative phase, allowing it to accumulate more biomass and grow taller compared to early-maturing varieties like SC Select, which matures slightly earlier (135 to 140 days versus SC Serena's 145 to 150 days). This slight early maturation may limit SC Select's maximum height potential (Khan et al., 2014; Mumtaj et al., 2015).

When planted at a density of 350 plants/m², both varieties showed increased height as a response to competition for light. In such crowded conditions, plants compete intensely for available sunlight, prompting a phenomenon called etiolation, where they grow taller to capture more light. This can lead to taller, sometimes spindly stems. Tuba et al. (2024) noted that shading can promote plant height. Additionally, higher densities can cause plants to allocate more resources to stem elongation rather than to other yield components like tillering or grain filling (Feng et al., 2024). At lower densities (250 and 150 plants/m²), plants have more room to grow without overcrowding, which supports healthier development.

The Interaction between variety and plant population density was significant, indicating that plant height responses varied between the two varieties. This suggests that genetic factors such as growth vigor and tillering ability influence how each variety expresses height under different densities. SC Serena exhibited a more pronounced height increase with higher densities compared to SC Select, likely due to its stronger response to etiolation. This highlights the importance of selecting both the appropriate variety and plant population density to optimize wheat production, ensuring a balance between height, lodging resistance, and yield potential.

5.2 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF EFFECTIVE TILLERS.

As plant population density increased, the average number of effective tillers per plant decreased. At lower densities, plants have better access to essential resources like water, nutrients, and sunlight, which supports the development of more tillers. Arduini et al. (2006) found that reducing seed rates lowers the competition among plants, allowing for increased tillering due to better resource access. However, at higher densities, the competition forces plants to focus on the main stem's growth, reducing the number of tillers.

While higher densities might initially yield more total tillers due to the increased number of plants, many of those tillers may not be productive in competitive environments, thus lowering the effective tiller count per plant (Zhang et al., 2016). The concept of "high-quality" tillers comes into play here; even if the overall number of tillers is lower at higher densities, the remaining effective tillers can contribute significantly to yield.

The lack of significant differences between SC Serena and SC Select suggests both varieties have similar tillering potential under high competition. Any minor differences observed may stem from natural variability or environmental factors rather than true genetic superiority. Thus, plant spacing seems to play a more crucial role in tiller development than the variety itself in this context.

5.3 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE SPIKE LENGTH (IN CM).

The average spike length decreased with increasing plant population due to heightened competition for resources. As plants compete more intensely, they tend to allocate nutrients to survival and stem growth rather than to spike development. Higher densities lead to fewer spikes per plant due to this intraspecific competition, where plants struggle for limited resources.

Chakwizira et al. (2015) noted that increased density typically reduces individual plant components like spike length. In contrast, at lower densities (150 plants/m^2), plants have more space and access to nutrients, allowing for longer, healthier spikes. SC Serena's genetic makeup enables it to produce more spikes than SC Select, likely due to superior resource allocation for spike growth, even under moderate stress (Luo et al., 2020).

At higher densities, the upper leaves can shade lower parts of the plant, reducing light penetration to developing spikes. Less light means reduced photosynthetic efficiency, which in turn limits energy available for spike development (Zhang et al., 2016). Water competition also plays a role, as shared soil moisture can become depleted during critical growth stages. Yang et al. (2019) highlighted that water stress during spike elongation can lead to smaller spikes, as plants prioritize the survival of the main stem over reproductive structures.

5.4 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF SPIKES OR HEADS PER PLANT.

The average number of spikes per plant decreased as plant population density increased due to intensified competition for resources. At higher densities, this competition suppresses tiller formation, resulting in fewer spikes (Yang et al., 2019). Conversely, at lower densities, each plant enjoys more space and resources to grow additional tillers, which can develop into productive spikes (Zhang et al., 2016).

At a density of 150 plants/m², both varieties showed higher spike production, with SC Serena consistently producing more spikes. This indicates SC Serena's superior genetic potential for maintaining effective tillers that develop into spikes, even when faced with varying densities. Li et al. (2022) noted that wheat varieties with strong genetic adaptability can sustain spike production by effectively utilizing available nutrients and space. SC Serena's advantage may stem from better root development, allowing for more efficient resource acquisition (Ma et al., 2015).

At higher densities (350 plants/m²), plants tend to prioritize vertical growth over lateral tillering, resulting in fewer spikes. High-density planting also alters hormonal balances within the plants. Liu et al. (2022) reported that changes in hormones under crowded conditions could lead to premature senescence of tillers and spike abortion. Overall, SC Serena outperformed SC Select across all densities in terms of spike length, indicating its genetic advantages in resource competition.

5.5 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF SPIKELETS.

As plant population density increased, the average number of spike-lets per plant decreased. At lower densities (150 plants/m²), individual wheat plants have more access to important resources like water, sunlight, and nutrients, which allows them to invest more energy into developing robust spikes with numerous spike-lets. Adequate spacing reduces competition, enabling each plant to reach its genetic potential for spikelet formation (Mutasa et al., 2016). SC Serena has shown advantages in making the most of these favorable conditions, likely due to its stronger genetic capacity for spike development.

As competition increases at higher densities, plants experience shading, which decreases their photosynthetic rates and limits energy available for spikelet development (Luo et al., 2020). Additionally, competition for soil nutrients like nitrogen becomes more severe, and nutrient stress can hinder spikelet formation as plants prioritize survival over reproductive growth (Yang et al., 2019).

Hormonal balance within the plants may also play a role in reducing the average number of spike-lets. Hormones such as cytokinins and auxins regulate spikelet production. Under lowdensity conditions, these hormones promote the development of multiple spike-lets. However, in crowded conditions, hormonal signals may shift to favor stem elongation and the maintenance of fewer reproductive units (Zhang et al., 2016).

Notably, SC Serena consistently produced more spike-lets per spike than SC Select, indicating its better genetic capacity for supporting spikelet development even under stress (Matarira et al., 2016). SC Serena may possess deeper root systems that allow it to maintain reproductive growth despite resource competition, while SC Select appears more sensitive to crowding, which limits its spikelet production.

5.6 EFFECT OF VARIETY AND PLANT POPULATION ON THE AVERAGE NUMBER OF KERNELS PER SPIKE.

The number of kernels per spike decreased as plant population density increased, likely due to physiological, environmental, and genetic factors that hinder the plants' ability to fully develop grains in crowded conditions. Under optimal conditions with sufficient water, space, and light at lower densities, wheat plants can direct more energy toward reproductive development, resulting in better grain filling and more kernels per spike. Reduced competition in these environments allows for stronger photosynthetic activity and efficient nutrient transport to the spikes, maximizing kernel maturation (Zhang et al., 2016). SC Serena's superior performance in the average number of kernels across all densities suggests it is better at distributing assimilates to reproductive tissues, enhancing grain production.

As plant density rises to 350 plants/m², the competition for limited resources increases significantly. High-density planting leads to more shading, which reduces sunlight reaching lower leaves and diminishes overall photosynthetic efficiency (Luo et al., 2020). The reduction in photosynthesis limits the energy available for grain filling, adversely affecting kernel development. Additionally, higher densities create more competition for essential soil nutrients like nitrogen, which is crucial for spike and grain development. Limited nitrogen availability can lead to incomplete grain filling and kernel abortion, where some kernels do not develop properly (Zhang et al., 2016).

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS.

6.1 COCLUSIONS.

This study explored how different plant populations affect the yield of two wheat varieties by examining six key parameters. It was clear that the interaction between plant population and variety selection played a significant role in the performance of the wheat. Specifically, factors such as plant height, effective tiller count, spike length, number of spikes (or heads) per plant, number of spike-lets, and kernels per spike were all influenced by this interaction.

Lower plant densities (150 plants/m²) produced the best results for effective tillers, spike length, number of spikes, spike-lets, and kernels per spike. However, the tallest plants were noted at higher densities (350 plants/m²). Throughout the study, SC Serena consistently outperformed SC Select, demonstrating its ability to achieve greater height, more tillers, longer spikes, and a higher number of kernels per plant. SC Serena also showed better adaptability and performance across varying plant densities compared to SC Select. Overall, these findings highlighted that plant population density significantly affects competition for essential resources like water, nutrients, and light, directly impacting wheat yield components.

6.2 RECOMMENDATIONS.

Based on the results of this study, farmers are encouraged to use lower (150 plants/m²) to moderate (250 plants/m²) plant populations for wheat cultivation, as these densities have shown the best outcomes in terms of growth, spike development, and overall grain yield. Additionally, it is advisable for farmers to choose the SC Serena variety, given its exceptional performance compared to SC Select across all measured parameters.

Farmers should avoid planting at higher densities (350 plants/m²), as this can hinder plant development and negatively affect yield. For those with limited access to irrigation and fertilizers, lower plant populations are particularly beneficial, as they reduce competition and allow each plant to maximize the use of available resources.

Bibliography

ADAS. (2023). *Zimbabwe wheat production statistics.* Agricultural Rural Advisory Services.

Africa, S. (2023). *High-yielding white grain wheat variety*. Retrieved from SeedCo Africa: https://www.seedcoafrica.com/wheat/wh203

Arduini, I. M. (2006). Grain yield and dry matter and nitrogen acccumlation and remobilization in durum wheat as affected by variety and seeding rate. *European Journal of Agronomy*.

Chakwizira, E. M. (2015). Effects of plant population density on wheat yield and yield compobnents in Zimbabwe.

Damania, A. (2016). The Ancient "Khapli" Wheat: Is it Under-utilized? *Asian Agri-History*. de

Candolle, A. (1886). *Origin of Cultivated Plants.* Newyork: D. Appleton and Company.

Development, D. o. (n.d.). Crop description. *wheat development PDF*.

Elzinga, C. S. (1998). *Measuring and Monitoring Plant populations.* U.S: Department of Agriculture, Forest Service, Rocky Mountain Research Station.

FAO. (2022). Zimbawe Agricultural Sector Overview. *Food and Agriculture Organization of the United Nations*.

Feng S, S. C. (2024). Optimizing Wheat Planting Density By Adjusting Population Structure and Stabilizing Stem Strength to Achieve High and Stable Yields . *Agronomy*.

Fischer, R. (2019). Wheat physiology: A review of recent development. *Field crops research*.

Godwin, R. J. (2003). Areview of the technology for mapping within field variability. *Biosystems Ebgineering*.

Grote, E. F. (2020). Food security and the dynamics of wheat and maize value in Africa and Asia. *Frontiers in Sustainable Food Systems, Volume 4*.

Guide, E. C. (2023). Wheat Growth stages and optimal environmental conditions.

Health, H. T. (2012). Whole grains and health: Fiber and Glycemic.

Investopedia. (2012). *Top Agricultural Producing countries.* Retrieved from Investopedia.

Jenkins, D. e. (2013). Glycemic index and health outcomes: systemic review. *American Journal of Clinical Nutrition*.

Khan N, K. M. (2014). Effect of maturity date on cultivar variation and association for growth duration characters and grain yield in bread wheat. *Pakistan Journal of Agriculture Research.*

Lev-Mirom, Y. &. (2023). Where was wheat domesticated? *Nature plants*.

Li, H. G. (2022). Effects of plant density on tiller occurence and grain yield in winter wheat. *Agronomy Journal*.

Li, X. w. (2022). Effects of plant densityy on tillering, grain number, and yield components in wheat. *Journal of Integrative Agriculture*.

Liu, T. W. (2022). Plant hormone regulation of tiller growth and development in wheat. *Journal of Plant Growth Regulation*.

Luo, C. Z. (2020). Allometric relationship and yield formation in response to planting density under ridge-furrow plastic mulching in rainfed wheat. *Field Crops Research*.

Ma, Y. G. (2015). Tiller Development and contribution to yield in wheat as affected by planting density. *Crop Science*.

Mashingaidze, N. C. (2021). Wheat production trends and challenges in Zimbabwe. *African Journal of Agriculture Research*, 155-162.

Matarira, C. e. (2016). Wheat yield response to planting density in Zimbabwe. *Agronomy Journal*.

Ministry of Lands, A. F. (2023). *Annual Agriculture Sector Performance Report.* Government of Zimbabwe.

Mlambo, P. &. (2018). Water Use Efficiency and Plant Population Density in Zimbabwean Wheat Production. *Journal of Water and Irrigation Management*.

mumtaj, M. A. (2015). Evaluation Of Growth and Yield Attributes of Different Wheat Genotypes Sown Under Various Planting Times. *Journal of Biology, Agriculture and Healthcare, 5 (19),85.*

Mutasa, M. e. (2016). Wheat yield response to planting density in Zimbabwe. *Avronomy Journal*, 45-51.

Nyakudya, I. C. (2020). Irrigation management in Zimbabwe: opportunities for smallholder wheat production. *Irrigation and Drainage Systems*.

Olsen, J. K. (2006). Influence of sowing density and spatial pattern of spring wheat (Triticum aestivum) on the supression of different weed species. *Weed Biology and Management*, 165-173.

Orth, R. &. (1988). Origin, production and utilization of wheat. *Wheat Chem. Technol*.

Reynolds, A. &. (2019). Carbohydrates quality and human health:dietary fiber effects. *Nutrition Reviews*.

Savary, S. W. (2019). The global burden of pathogens and pests and pests on major food crops. *Nature Ecology & Evolution*.

Science, B. C. (2024). Soil and nutrient management for spring wheat.

SeedCo, A. (n.d.). *Wheat Production Guide:SC Select & SC Serena*. Retrieved from SeedCO Africa.

Shewry, P. &. (2015). The contribution of wheat to to human diet and health. In J. Cherry, *Wheat Science and Trade* (pp. 1-20). New Jersey, USA: Wiley Blackwell.

Tilman, D. B. (2011). Global Food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences.*

Tuba, U. A. (2024). Efffect Of Plant Density and Shading Application on yield and Yield Components in Faba Bean. *MAS JOURNAL OF APPLIED SCIENECS.*

Whaley, J. S. (2000). The physiological response of winter wheat to reductions in plant density. *Annals of Applied Biology*.

Xie, Q. M. (2020). Effects of plant population density on yield components and competitive ability. *European Journal of Agronomy*.

Yadav, P. Y. (2011). Carbohydrates quality and human health: dietary fiber effects. . *Nutrition Reviews*.

Yang, D. C. (2019). Optimizing plant density and nitrogen application to manipulate tiller growth and increase grain yield and nitrogen-use efficiency in winter wheat. *PeerJ*.

Yang, D. C. (2019). Optimizing plant density and nitrogen applicationto manipulate tiller growth and increase grain yield and nitrogen use efficiency in winter wheat. *PeerJ 7*.

Zhang, Y. D. (2016). Effects of plant density on grain yield, protein size distribution, and breadmaking quality of winter wheat grown under two nitrogen fertilisation rates. *European Journal of Agronomy*, 1-10.

Zhang, Y. F. (2021). The impact of plant density on plant growth and yield. *Agronomy*.

Zimbabwe, S. (2021). Wheat Growers Guide. *Zimbabwe edition: plant population and disease management Seed Co Zimbabwe*.

ZimStat. (2021). Zimbabwe Agricultural Livelihoods Survey. *Zimbabwe National Statistics Agency*.

APPENDICES

Appendix 1: ANALYSIS OF VARIATE

1.1 VARIATE: AVERAGE PLANT HEIGHT AT PHYSIOLOGICAL MATURITY.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	7.381	3.691	2.90	
block.*Units* stratum					
variety	1	48.676	48.676	38.25	<.001
plant_population	2	206.541	103.271	81.15	<.001
variety.plant_population	2	18.008	9.004	7.08	0.012
Residual	10	12.726	1.273		
Total	17	293.331			

1.2 VARIATE: AVERAGE NUMBER OF EFFECTIVE TILLERS.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	2.06778	1.03389	13.39	
block.*Units* stratum					
variety	1	0.84500	0.84500	10.94	0.008
plant_population	2	11.75111	5.87556	76.09	<.001
variety.plant_population	2	0.64000	0.32000	4.14	0.049
Residual	10	0.77222	0.07722		
Total	17	16.07611			

1.3 VARIATE: AVERAGE SPIKE LENGTH.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.11194	0.05597	1.90	
block.*Units* stratum					
variety	1	0.72000	0.72000	24.43	<.001
plant_population	2	3.31361	1.65681	56.22	<.001
variety.plant_population	2	0.30583	0.15292	5.19	0.028
Residual	10	0.29472	0.02947		

1.4 VARIATE: AVERAGE NUMBER OF SPIKES PER PLANT.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.13471	0.06736	0.95	
block.*Units* stratum					
variety	1	1.25876	1.25876	17.71	0.002
plant_population	2	11.85081	5.92541	83.38	<.001
variety.plant_population	2	0.73008	0.36504	5.14	0.029
Residual	10	0.71062	0.07106		
Total	17	14.68498			

1.5: VARIATE: AVERAGE NUMBER OF SPIKELETS

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	0.6553	0.3276	1.81	
block.*Units* stratum					
variety	1	9.4612	9.4612	52.28	<.001
plant_population	2	56.1369	28.0685	155.10	<.001
variety.plant_population	2	1.5325	0.7663	4.23	0.047
Residual	10	1.8097	0.1810		
Total	17	69.5957			

1.6 VARIATE: AVERAGE NUMBER OF KERNELS.

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
block stratum	2	13.3811	6.6906	13.96	
block.*Units* stratum					
variety	1	1180.9800	1180.9800	2464.37	<.001
plant_population	2	447.6411	223.8206	467.05	<.001
variety.plant_population	2	27.6033	13.8017	28.80	<.001
Residual	10	4.7922	0.4792		
Total	17	1674.3978			

APPENDIX 2: FIELD PHOTOGRAPHS. ***2.1***
SOME OF THE MATERIALS USED

2.2 PICTURES BELOW SOME OF THE PARAMETERS BEING STUDIED