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**AN INVESTIGATION ON THE EFFECTS OF MAIZE SEED SIZE AND PLANTING
DEPTH ON SEEDLING EMERGENCE AND SEEDLING VIGOUR.**



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Supervisor

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

Signature Mr Mustengi

Date 1/09/2026

Dedication

To my beloved mother, who has always been my source of inspiration and ovation .Your prayers, wisdom and love have shaped me into the person who I am today.

To my dear family, the Maguranyanga family who have always been there for me, providing, love guidance and support. I am grateful for your presence in my life.

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And without faith it is impossible to please him, for whoever would draw near to God “must believe that he exists and that he rewards those who seek him”.

(Hebrews 11 v 6)

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Abbreviations

GDP	Gross Domestic Product
WAP	Weeks after planting
AP	After Planting
FAO	Food and Agriculture Organization
ANOVA	Analysis of variance
CV	Coefficient of variance
SED	Standard Error of Difference (between mean)
LSD	Least significant difference
NPK	Nitrogen, Phosphorus and Potassium
CEC	Cation exchange capacity
OMC	Organic matter content
pH	Potential of hydrogen

Abstract

This study examined how maize seed size and planting depth affect plant growth and development. A two-way factorial experiment, arranged in a randomized complete block design (RCBD), tested three seed sizes (small, medium, large) and three planting depths (3 cm, 5 cm, 8 cm). Both factors significantly influenced ($p < 0.05$) germination percentage, germination rate, mean germination time, leaf count, plant height, leaf length, leaf area, and leaf width. Large seeds planted at a shallow depth (3 cm) yielded the highest germination percentage (93.3%), germination rate (8.8), mean germination time (4.3 days), leaf count (9.33), plant height (65.27 cm), leaf length (24.23 cm), leaf area (110.42 cm²), and leaf width (6.07 cm). Conversely, small seeds at the deepest planting depth (8 cm) produced the lowest values for these traits. The study recommends using large seeds and a 3 cm planting depth for optimal maize production and emphasizes their importance in maize farming systems. These findings offer practical insights for maize farmers and agricultural practitioners, supporting the development of more efficient maize production strategies.

Keywords: Seed size, planting depth, germination, vigour, significant.

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Chapter 1: Introduction

1.1 Introduction

Maize (*Zea mays L.*) holds a significant position in ensuring food security and supporting agricultural economies as it is extensively grown worldwide as a cereal crop (Grote *et al.*, 2021). Seed quality and planting methods are essential in maize cultivation. This research examines the impact of maize seed size and depth on seedling emergence and vigour.

The dimension of seeds influences the performance of seedlings. Large seeds typically contain more nutrients, resulting in improved germination and development during the initial phase's. Conversely, small seeds might find it challenging to germinate in adverse conditions (Finch-Savage *et al.*, 2016). Moreover, Lamichane *et al.*, 2018, emphasized that the planting depth of seeds greatly influences seedling emergence. Seeds sown too deep might lack the strength to break through the soil. On the other hand, seeds positioned too shallow might encounter difficulties from their environment.

Understanding the relationship between seed size and planting depth is essential for maximizing maize yield by optimizing germination. This research aims to identify the best techniques for enhancing seedling emergence and seedling vigour, ultimately intending to improve crop establishment and boost yield. This research is particularly significant for farmers and agricultural workers aiming to enhance maize yields under different cultivation conditions (Finch-savage *et al.*, 2016).

1.1 Background to the study

Globally, maize is a primary source of food calories accounting for about 30% among the developing countries of about 4.6 billion people (Shawa, 2019). Maize is grown as staple food among 75 of the 125 developing countries whilst 70% is produced by smallholder farmers in these developing countries. This implies that maize is a valuable commodity for developing nations and therefore, require enough monitoring in its production cycle. Nyirenda *et al.*, 2021 state that maize production significantly changed from 106 million ha to 197 million ha from the 1961-

2019 whereas its production rise from 205 million tons to 1.1 million tons with increase in yield from 194t/ha to 5.80t/ha.

Nyienda *et al.*, (2021) suggested that the world population is expected to reach 9.73 billion by 2050, whilst maize production will have to double to the demand of 2.5% population in sub-Saharan region. Therefore to mitigate this ,in addition of 100 million ha is needed to enhance food security and reduce extreme poverty in low in-come countries and they is also need for adoption of good land ,crop and natural resource management practices. (Loboguerrero *et al.*, 2019). According to Shava (2019), climate change, soil degradation, increase in seed sizes and limited access of information greatly affect maize production in sub-Saharan Africa.

In Zimbabwe, harvesting enough maize in a season is major factor in determining food self-sufficiency .According to Nyirenda *et al.*,2021,despite the promotion of better maize varieties ,the predominat subsistence agriculture is characterized by low yield ,with a natural average of 1.0t/ha in 1961 to 1.7t/ha in 2019. The production has changed from 815.00 tons to 3.0 million tons on 800.000ha to 1.7 million ha throughout the same time period (1961-2019). Due to monomodal precipitation in a season, maize is primarily rain-fed and only done once (November-April), while some farmers employ irrigation. Dependency on rain-fed output ,the restricted use of fertilizers and improved seeds in Zimbabwe , climate change ,deteriorated soils, a lack of markets, and an insufficient agricultural extension system have been blamed for poor crop performance (Rao,2015).

Among the various agronomic factors influencing maize production, seed size and planting depth stand out as especially significant because they are not consciously considered during planting and therefore usually overlooked. These two factors are essential for the effective establishment of maize seedlings, which subsequently affects later growth phases and total yield (ur Rehman *et al.*, 2015). Seed size denotes the physical characteristics and mass of the seed, which can influence its ability to germinate and its initial growth strength.Larger seeds typically contain more stored energy ,which supports strong seedling development ,while smaller seeds may struggle to thrive in challenging conditions (Long *et al.* ,2015).

Shallower planting depths can encourage quicker emergence due to warmer surface temperatures and better access to moisture (Fan et al., 2017). However, they may also expose seeds to threats such as avian predation and desiccation. Conversely, sowing seeds at greater depths may protect them from threats at the surface, but it could delay their sprouting because of cooler temperatures and potential moisture deficits. When drying planting, planting and soil type is important, plant shallowly sandy soils and plant deeply in clay soils because of two reasons. The first reason being that, large pore gaps and particle sizes are characteristic of sandy soils, which leads to rapid drainage and reduced retention of water. Planting seeds shallowly in sandy soils allows them to access moisture more readily from the surface, where water is more likely to be available immediately after rainfall or irrigation (Unkovich *et al.*, 2020). When you plant shallowly in sand soils, low rains will not be able to trigger the germination process some there will be rapid drying of the soil profile. On the other hand, deep placement of the seed in heavy textured soils will mean that only effective rains will be able to reach where the seed will be placed. In this sense seed placement can be used to manage the germination rate in dry planted fields.

The second reason is that according to Long *et al.*, 2015, clay soils have smaller particles and compact structure, resulting in higher water retention but slower drainage. Planting seeds deeper in clay soils helps ensure they are placed below the surface layer where moisture may fluctuate. Planting seeds at greater depths enables them to reach more consistent moisture levels, essential for germination and the growth of seedlings.

In Zimbabwe, where agricultural practices are significantly influenced by regional weather conditions and soil types, the connection between seed size and planting depth can noticeably impact maize production (Mugiyo *et al.*, 2021). Seedling emergence is affected by planting depth; seeds that are planted too shallow can face environmental stress, including drying or disturbance from surface conditions, even though they may sprout faster (Lamichane et al., 2018). Yet, seeds sown too deeply might have difficulty breaking through the surface, resulting in later emergence or failing to emerge completely.

Temperature is an additional factor to take into account in the germination and initial development of seeds. Seeds sown at a shallow depth might undergo temperature variations, potentially hindering germination and initial development. Conversely, lower soil layers

typically exhibit more consistent temperatures, enhancing root growth and overall plant health. The country encounters diverse rainfall patterns, soil fertility levels, and temperature changes, all of which contribute to the complexities of maize cultivation. Taking these factors into account, it is essential to understand how seed size and planting depth interact to affect seedling emergence and vigour to develop successful agricultural strategies (Finch-Savage *et al.*, 2016).

Research indicates that both the size of seeds and the depth at which they are planted independently influence the emergence and strength of seedlings. Larger seeds are generally associated with higher germination rates and more robust seedlings, while proper planting depths can improve seedling emergence and growth, thereby optimizing the environment for germination (Rifna *et al.*, 2019). However, the connection between these two factors remains largely unclear, particularly in relation to farming in Zimbabwe. Francis *et al.*, 2015, proposed that exploring the relationship between seed size and planting depth is crucial, as it can provide valuable information for farmers on how to improve their planting techniques for better crop establishment and yield.

1.2 Problem statement

The yield of maize is frequently affected by inadequate planting techniques ,including challenges related to the seed size and planting depth .Current studies indicate that these elements greatly affect seedling emergence and general seedling strength ;however ,there is still a restricted comprehension of their interplay and effect ,particularly regarding local environmental circumstances .This lack of understanding can result in inefficiencies in maize production , impacting food security and the livelihoods of small-scale farmers who depend on this crop for their survival and income.

1.3 Justification

Understanding the effects of maize seed size and planting depth is essential for improving crop establishment and maximizing yield potential. As the global population continues to grow, particularly in regions like sub-Saharan Africa, the demand for maize will increase, necessitating improved agricultural practices to ensure food security. This study aims to provide practical insights for farmers and agricultural stakeholders by analysing the relationship between seed size and planting depth. Identifying optimal planting techniques can enhance seedling emergence and vigour, leading to improved crop yields. Additionally, these findings can inform agricultural policies and extension services, promoting sustainable practices that boost productivity in the face of challenges such as climate change, resource scarcity, and socio-economic constraints. This research is particularly relevant and critical given the pressing need for efficient strategies to increase maize yields in Zimbabwe and similar regions.

1.4 Objectives

1.4.1 Main objective

- To investigate the effects of maize seed size and planting depth on maize seedling emergence and seedling vigour.

1.4.2 Specific objectives

- To investigate the effects of maize seed size and planting depth on germination percentage, germination speed, germination rate, seedling emergence and seedling vigour.
- To evaluate the influence of maize seed size and planting depth on early vegetative growth of maize.

1.4.3 Hypotheses

- **Hypothesis:** The seed size and planting depth had an effect on germination percentage, germination speed, germination rate, seedling emergence and seedling vigour.
- **Hypothesis:** The seed size and planting depth had an effect on early vegetative growth of maize.

Chapter 2: Literature Review

2.1 Maize and rural security

Maize (*zea mays l*) stands as one of the valuable staple crops worldwide, especially in developing nations where it is vital for maintaining food security. Maize functions as a multipurpose crop, acting both as a fundamental food supply and an important economic resource for countless rural families. Khan *et al* ., (2022) indicate that maize possesses a high carbohydrate levels of 70-75% which delivers vital energy ,while its nutrient composition includes significant vitamins and minerals ,supporting the overall dietary requirements of communities that depend on it as a primary food source.

2.2 Nutrient profile of maize (*zea mays l*)

Nutrient	Amount per 100g	Daily value (%)
Calories	150kcal	7.5
Protein	5g	10
Carbohydrates	30g	10
Dietary fiber	3g	12
Sugars	1g	N/A
Fat	2g	3
Calcium	50g	5
Iron	1.5mg	8
Magnesium	30g	7.5
Vitamin A	200IU	4
Vitamin C	5mg	6
Folate	50 mcg	12.5

percent daily values are based a 2000 calorie diet (FAO, 2020)

According to the Food and Agriculture Organization (2020) maize is a dietary cornerstone in Sub-Saharan Africa and Latin America, where it constitutes a major part of daily caloric intake. In these regions, maize is frequently eaten in different ways, including flour, porridge, and tortillas, establishing it as a key component of local dishes (Revilla et al., 2022).The crop's

ability to adjust to different environmental conditions enables it to flourish in multiple agro-ecological zones, reinforcing its significance in rural economies.

The connection between maize production and rural food security is complex. Maize functions not only as a food supply but also as a profitable crop for smallholder farmers. Revenue from maize sales can be reinvested in farming supplies, health services, and education, thus improving the general standard of living in countryside regions (Smith *et al.*, 2019). Nonetheless, dependence on maize as a primary food source renders these communities especially susceptible to variations in output caused by environmental shifts, pests and diseases.

The problem of food security is exacerbated by socioeconomic factors, including poverty and limited market access. Numerous rural farmers encounter difficulties in obtaining quality seeds, fertilizers, and other essentials required for optimal maize yields. Tackling these issues necessitates a comprehensive strategy that combines farming methods, access to markets, and community assistance to enhance food security and uplift livelihoods in rural communities (Pelletier *et al.*, 2016).

2.3 Effects of Seed Size on Germination

Seed size plays a pivotal role in maize germination rates and seedling vigour. Research indicates that larger seeds generally exhibit higher germination rates and faster seedling establishment compared to smaller seeds (Umeoka and Ogbonnaya, 2016). This is largely due to the greater nutrient reserves in larger seeds, which provide essential resources for early growth. Larger seeds tend to produce stronger seedlings with robust root systems, improving nutrient and water uptake, particularly during early development stages. In contrast, smaller seeds may face challenges in establishing roots under suboptimal conditions, potentially reducing yield (Daryanto *et al.*, 2016).

Selecting appropriate seed sizes is critical for specific planting conditions. Farmers are encouraged to choose larger seeds when feasible, as they typically yield better germination and initial growth outcomes. Seed size also interacts with environmental factors like soil moisture and temperature, influencing seedling performance (Lamichhane *et al.*, 2018). Studies consistently show that larger seeds outperform smaller ones in germination and emergence speed

across various crops (Maiti *et al.*, 2014). This suggests that selecting larger seeds could enhance yield potential by improving early growth.

Beyond germination, larger seeds contribute to stronger root systems, vital for efficient nutrient and water absorption (Daryanto *et al.*, 2016). This is especially important during early growth when seedlings establish in the soil. Larger seeds also show greater resilience to environmental stresses, improving field performance. Lamichhane *et al.*, 2018 noted that larger seeds perform better in challenging conditions, making them preferable for farmers in variable climates. This interplay emphasizes the need to consider both seed size and environmental factors during planting to optimize seedling performance and crop establishment.

Further research, such as Kumar *et al.*, 2015 links larger seed size to higher crop yields due to favourable initial conditions. While smaller seeds may succeed in specific scenarios, evidence strongly favours larger seeds for optimal germination and early development in most agricultural settings. Alemberhe and Gebremeskel, 2016 highlighted that effective pollination enhances seed development, leading to larger seeds, while poor pollination may reduce seed size or quantity. Plant competition in dense settings can also limit seed size due to resource constraints.

Understanding the link between seed size, germination, and seedling vigour is essential for improving maize yields. Agricultural programs and extension services should guide farmers on seed selection and management to enhance germination and crop establishment (Alemu, 2015). For instance, larger seeds' effectiveness can vary with soil type, moisture, and temperature. In regions with variable climates, selecting seeds suited to local conditions and farming practices is beneficial. Extension services play a key role in providing tailored advice on seed choices and soil characteristics (Nettle *et al.*, 2022).

Moreover, larger seeds' benefits extend beyond germination. Mahender *et al.*, 2015 found that seedlings from larger seeds exhibit improved nutrient uptake and resistance to pests and diseases, critical for maize yield potential. Promoting the use of larger, high-quality seeds can enhance crop establishment and productivity. Other factors, such as seed treatment, planting depth, and spacing, also influence germination and seedling vigour. Madsen *et al.* 2016 suggest that planting larger seeds deeper can access consistent moisture, improving germination. Integrating these insights into agricultural programs equips farmers to boost maize production.

2.4 Effects of Planting Depth on Soil Gas Concentrations and Germination

Planting depth significantly affects carbon dioxide (CO₂) and oxygen (O₂) levels in the soil, impacting maize germination and seedling growth (Madhu and Hatfield, 2013). Shallower planting enhances soil aeration, increasing oxygen and reducing CO₂, which is vital for seed respiration during germination. Deeper planting, however, can create anaerobic conditions with lower oxygen and higher CO₂, hindering metabolic processes and germination rates (Ali and Elozeiri, 2017).

Planting depth also influences soil moisture and temperature, both critical for germination. Deeper planting may retain more moisture, beneficial in dry conditions, but excessive depth can limit oxygen, leading to poor seedling growth (Finch-Savage and Bassel, 2016). Shallow planting, while improving aeration, risks moisture loss if not managed properly. Balancing moisture retention and aeration is essential when determining planting depth.

Soil temperature, affected by planting depth, is another key factor. Shallower depths often have warmer soil, accelerating germination, while deeper planting may delay it due to cooler temperatures (Onwuka and Mang, 2018). The interplay of oxygen, CO₂, moisture, and temperature highlights the complex soil dynamics affecting maize germination. Farmers must assess local soil conditions, moisture, and temperature to determine optimal planting depth, ensuring robust germination and seedling development for higher yields.

2.4 Effect of Planting Depth on Light Quality and Germination

Planting depth significantly influences light quality, which is critical for maize germination (Wei *et al.*, 2023). Light quality, referring to the spectrum reaching seeds, triggers germination. Shallower planting allows seeds to receive more direct light, particularly red and blue wavelengths, which stimulate photoreceptors and accelerate metabolic processes (Yang *et al.*, 2020). This results in faster, more uniform germination and better seedling establishment.

Conversely, deeper planting reduces light exposure, with soil absorbing much of the red light, delaying or suppressing germination by limiting light cues (Ashraf and Foolad, 2015). This can lead to low emergence rates and weaker seedlings, negatively impacting yield and plant health. Poor light quality also alters seeds' metabolic responses, producing frail seedlings less competitive for resources like water and nutrients. Reed *et al.*, 2022 noted that such seedlings are more vulnerable to environmental stresses, reducing overall crop productivity.

2.5 Effects of Planting Depth

Planting depth critically influences maize germination and seedling establishment (El-Sanatawy *et al.*, 2021). Optimal depth ensures seeds access sufficient moisture while being protected from environmental stresses. Planting too deeply can delay germination and reduce emergence, as seeds struggle to break through the soil surface (Masarei *et al.*, 2019).

Jia and Sun (2018) suggest an optimal maize planting depth of 5–7 cm, depending on soil type and moisture. A 6 cm depth balances moisture access with protection from adverse surface conditions. Adhering to recommended depths enhances germination rates and seedling vigour, leading to higher yields (Ray *et al.*, 2015). Farmers must be educated on the importance of planting depth in relation to soil conditions, moisture, and maize variety needs. Training programs should emphasize optimizing planting techniques to improve germination and establishment, boosting productivity (Finch-Savage and Bassel, 2016).

2.6 Germination Process

Germination is a critical stage in maize's life cycle, marking the transition from seed to seedling. It begins with water absorption, causing seeds to swell and break their coats. Factors like seed size, soil moisture, temperature, and planting depth influence germination (Kimmelshue *et al.*, 2022). Insufficient moisture can delay or impair germination, reducing crop establishment and yield (Rifna *et al.*, 2019). Planting depth also affects emergence, with overly deep or shallow sowing posing challenges (Masarei *et al.*, 2019). Understanding these dynamics is key to optimizing maize production through effective germination management.

2.7 Seed Vigour

Seed vigour refers to a seed's ability to germinate quickly and uniformly under varied conditions. High-vigour seeds resist stresses like drought, temperature fluctuations, and nutrient deficiencies, leading to stronger seedling growth (Finch-Savage and Bassel, 2016). Larger seeds typically exhibit greater vigour due to their nutrient reserves, supporting early growth (Daryanto *et al.*, 2016). High vigour enhances seedling competition for resources, crucial in challenging environments (Lamichhane *et al.*, 2018). Prioritizing seed vigour improves maize yield, resilience, and crop reliability. Seedling growth significantly impacts maize yield, influenced by seed size, planting depth, and environmental factors. Rapidly growing seedlings develop strong root systems, enhancing water and nutrient uptake (Huang and Karimanzira, 2018). Early growth

is critical for yield potential, as vigorous seedlings better withstand stressors like nutrient deficiencies and pests. Understanding seedling development, germination, and vigour is essential for effective maize farming strategies, particularly in challenging regions like Zimbabwe (Jia and Sun, 2018).

2.9 Seed Size and Oxygen

Larger seeds have a higher surface area-to-volume ratio, improving oxygen diffusion and metabolic activity (Sharma, 2019). This leads to faster germination and stronger root and shoot development, enhancing resource uptake and yield (Kigel, 2017; Gavrilescu, 2021). Smaller seeds, with limited oxygen access, face delayed germination and weaker growth, reducing resilience to stresses like drought (Gallagher and Fuerst, 2024; Nekooie-Marnany *et al.*, 2022). This underscores the advantage of larger seeds in competitive and challenging environments.

2.10 Planting Depth and Oxygen

Planting depth affects oxygen availability, critical for germination and seedling growth (Finch-Savage and Bassel, 2016). Deep planting can create anaerobic conditions, delaying germination and reducing seedling vigour, especially in compacted soils (Chamara *et al.*, 2018). Low oxygen levels increase seedling susceptibility to diseases and competition (Poorter *et al.*, 2016). Soil compaction exacerbates oxygen limitations, particularly for smaller seeds with limited energy reserves (Bakker and Slack, 2023).

2.11 Optimal Practices for Oxygen Availability

To maximize seedling emergence and vigour, balanced planting depth is crucial, typically 5–7 cm for maize (Poncet *et al.*, 2018). This ensures adequate oxygen while maintaining moisture and nutrient access (Chamara *et al.*, 2018). Proper soil preparation, including tillage and cover crops, reduces compaction and enhances aeration, supporting root growth and oxygen availability (Pires *et al.*, 2017). Choosing larger seeds further improves germination and seedling development, leveraging their greater energy reserves for better establishment and yield (Bareke, 2018; Jimenez *et al.*, 2016).

Chapter 3

Methodology

3.1 Experimental site

The research was conducted at Bindura University Farm in Shamva near Bindura town in Mashonaland Central Province, Zimbabwe. It is situated approximately 10 kilometers from Bindura Town, and is about 17 kilometers away from Shamva. The farm's geographic coordinates are approximately 17.3085551° S latitude and 31.5655424° E longitude. The climate at Bindura University Farm is temperate, with a mean annual rainfall of about 800 to 1,200 mm, primarily occurring during the rainy season from November to April. This rainfall is crucial for supporting diverse agricultural activities. Average temperatures in the region range from 15°C to 25°C, with warmer conditions during the summer months. Bindura University Farm is located in Natural Region II of Zimbabwe. The soil in the Bindura region is clay and loamy, which is fertile and suitable for a wide range of crops. Soil management practices are emphasized to maintain soil health and enhance agricultural productivity.

3.2 Experimental design and treatments

The experiment was laid out as Randomised Complete Block Design (RCBD) with two factors. The first factor was maize seed size with three levels (small, medium and large). The second factor was planting depth with three levels 3cm, 5cm and 8cm. The experiment had three replicates and was randomized to ensure statistical validity.

3.4.1 Land preparation

Each experimental unit (plot) of equal size to ensure consistency. Each plot measured 4 m by 4m, with a spacing of 1 m between plots and 1 m between blocks on the space provided and the planting arrangement. The plant spacing was 25cm in-row and 75 inter-row spacing was used to give a population of 53 333 plants per hectare of maize. The seeds were planted on 11th of December 2024. The land was prepared through ploughing using a mouldboard plow to a depth of about 20 centimetres followed by harrowing to create a fine seedbed (plots). This practice helps to aerate the soil, improve moisture retention, and eliminate weeds. Prior to planting, soil

tests were conducted to determine nutrient levels and pH. The amendments were applied based on soil test results to optimize soil fertility. The pH value obtained from soil testing was 5.5.

3.6 Soil test findings

pH level: 5.5 (slightly acidic)

Nutrients levels:

- Nitrogen (N): 0.15% (deficient)
- Phosphorus(P):10ppm (low)
- Potassium(K):150ppm (adequate)

Soil texture: sandy loam soil

Organic matter content (OMC):2.5%

Cation exchange capacity (CEC):10meq/100g (low)

3.7 Weed control

Weeding was done using stellar star 700ml/ha and Dual 1l/ha as post emergence herbicides for control of annual grasses and broadleaf weeds like pigweed and other dicot weeds, and manual weeding using hoes or hand weeding when necessary was done. For termite control, pyrenx was used at a rate of 1.5l/ha and maize stalk borer was controlled by 15% Dipterex granules placed in the maize funnel.

3.8 Fertilization application

3.8.1 Basal fertilization application

A balanced fertilizer application was made at planting, typically using a combination of nitrogen (N), phosphorus (P), and potassium (K) based on the recommended rates for maize in the region. Compound D (7%N, 14%P, 7%K) was applied as basal dressing during planting at a rate of 400kg/ha. A second application of nitrogen fertilizer was done at 4 weeks after planting to support vegetative growth and enhance yield potential. There was split application of ammonium nitrate of 200kg/ha for top dressing (34.5%N). First application was at two weeks after crop

emergence and the remaining was applied four weeks after planting .The first application was 100 kg/ha, followed by 100 kg/ha after four week after planting.

3.9.1 Irrigation scheduling

Supplementary irrigation was provided during dry spells at Bindura University Farm, particularly at critical growth stages such as germination. The bucket system was for the irrigation, approximately 10 liters of water per square meter was supplied after every 48 hours during dry periods to ensure adequate moisture for optimal crop development. The dry spells lasted for a period of 23 days from 11 December 2024 to 2 January 2025.

3.10.0 Data collection

Data were collected on the daily and weekly basis. The data collected include germination rate, germination percentage, germination speed, leaf length, leaf width, leaf area and number of leaves per plant.

3.10.1 Germination percentage

The germination percentage calculated using the formula below:

$$\text{germination percentage} = \frac{\text{number of germinated seeds}}{\text{total number of seeds planted}} \times 100$$

3.10.3 Mean germination time

The mean germination time refers to the average time taken for each seeds to germinate. The mean germination time (MGT) was calculated to determine the average taken for a seed to germinate .The MGT was calculated using the formula below

$$\text{MGT} = \frac{\sum (n_i \times t_i)}{\sum n_i}$$

Where

N_i =number of seeds germinated on day i

T_i =time (days) on which the seeds germinated

3.10.4 Plant height

The average plant height was measured from the base of the plant to the tip of the plant. The measuring tape was used to measure the average plant height. The following formula was used to find the average plant height.

$$\text{Plant height} = \frac{\sum \text{Height of each plant}}{\text{Number of plant}}$$

3.10.5 Leaf number per plant

The average leaf number per plant was counted and calculated on a weekly basis for four weeks. Each week, the total number of leaves on a sample of plants was counted. This counts provided insights into the growth progress and overall health of the leaf.

3.10.6 Leaf length

To determine the average leaf length, a representative sample of leaves was collected from the study plants. The measurement of each leaf's length was taken from the base (where it meets the stems) to the tip using a ruler. The data was gathered and utilized to determine the mean leaf length. The following formula was used

$$\text{Average leaf length} = \frac{\text{Sum of individual leaf lengths}}{\text{Total number of leaves measured}}$$

3.10.7 Leaf area

To measure the leaf dimensions, the leaf area was measured using the tape measure. The formula used to calculate the average leaf area is :Leaf area = length × Width× 0.75 .This formula accounts for the typical shape of plants leaves, providing a more accurate estimate of the leaf.

3.11 Experimental model

$$Y_{ij} = \mu + b_i + Ss_i + pd_i + (ss \times pd)_{jk} + e_{ijk}$$

Where

μ =experimental mean

b_i =block effect

Ss =seed size

Pd =planting depth

$Ss \times Pd$ = (seed size x planting depth) effect

E_{ijk} =error

3.11.0 Data analysis

The data were analysed for variance using GenStats statistical package version 17. Where there were significant differences, the means were separated using the last significant differences at a probability of 0.05.

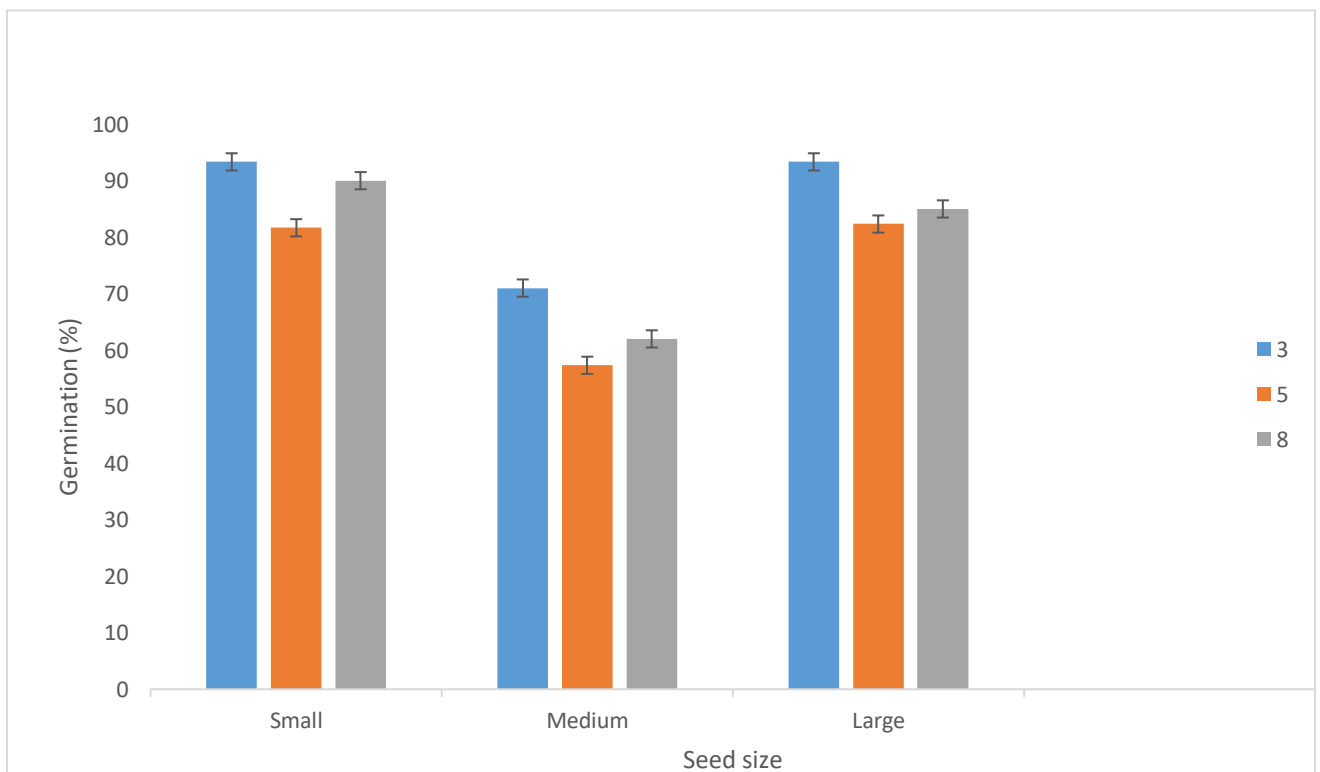
Chapter 4

4.0 Results

4.1: Effects of seed size and planting depth on germination percentage

There was a significant interaction between seed size and planting depth on germination percentage at $p < 0.05$. The highest value was observed for medium seed size planted at a depth of 5 cm, while the lowest was recorded for small seed size planted at 8 cm Figure 4.1.

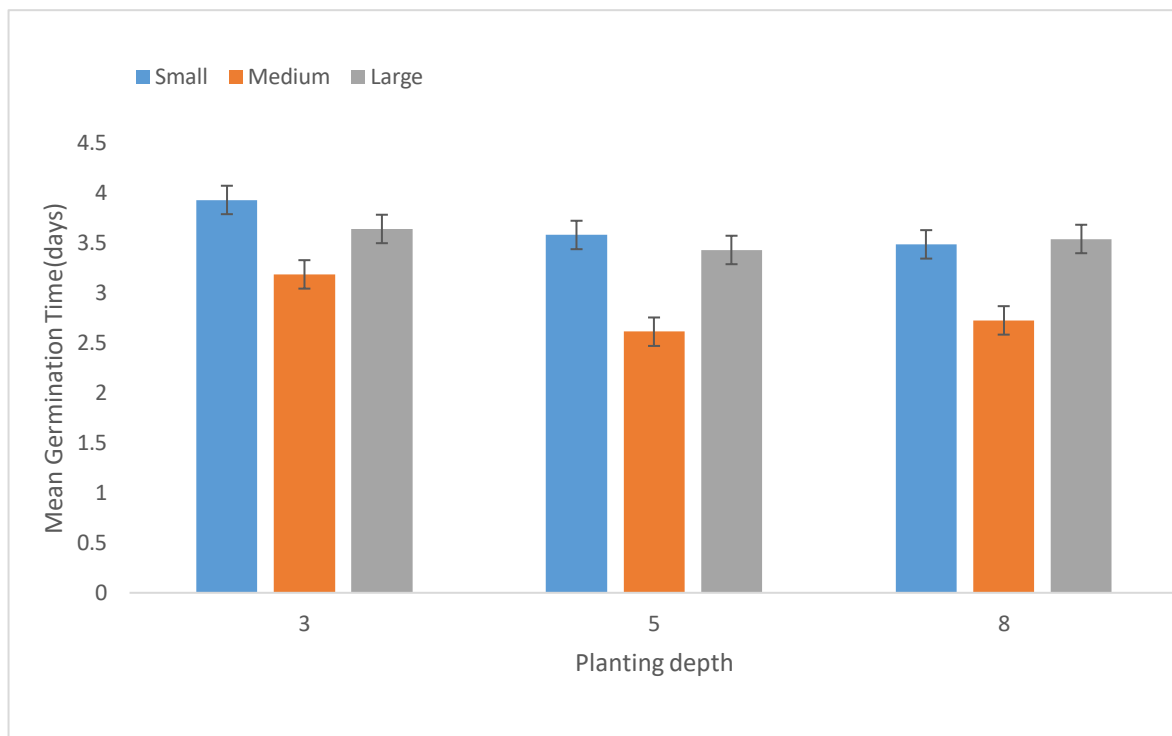
Figure 4.1 Effects of seed size and planting depth on germination percentage



4.2: Effects of seed and planting on mean germination time

There was a significant interaction between seed size and planting depth on mean germination time at $p < 0.001$. Seeds planted at a depth of 8 cm exhibited the longest germination time, whereas the shortest was noted for medium seed size planted at 3 cm depth.

Figure 4.2 Effects of seed size and planting on mean germination time



4.3:1 Effects of seed size and planting depth on germination rate at 72 hours

Table 4.3.1 Effects of seed size and planting depth on germination rate at 72 hours

Treatments	Germination rate at 72 hours
LARGE X 3	12.67 ^a
SMALL X 8	12.67 ^a
LARGE X 5	12 ^a
SMALL X 3	9.67 ^b
LARGE X 8	9.33 ^b
SMALL X 5	8 ^b
MEDIUM X 3	5.67 ^c
MEDIUM X 8	5.67 ^c
MEDIUM X 5	5 ^c
p-value	<0.001
lsd	1.6790
Cv%	10.9
SED	0.797

Based on the range test at $p \leq 0.05$, means for factors sharing the same letter(s) are not substantially different from each other.

At 72 hours there was an interaction between seed size and planting on germination rate ($p < 0.001$). The germination rate peaked with large seeds at a depth of 3 cm and 8 cm, both recording a rate of 12.67. The lowest rate was observed for medium seeds at 5 cm, which showed a value of 5c Table 4.3.1.

4.3.2 Effects of seed size and planting on germination rate at 96 hours

Table 4.3.2 Effects of seed size and planting depth on germination rate at 96 hours

Treatment	Germination rate at 96 hours
SMALL X 8	25.67 ^a
LARGE X 3	22.67 ^b
SMALL X 3	19 ^c
LARGE X 5	18.69 ^c
LARGE X 3	17 ^d
SMALL X 5	15.33 ^e
MEDIUM X 3	14.67 ^f
MEDIUM X 8	11.33 ^g
MEDIUM X 5	9.67 ^h
CV	5.4
LSD	1.606
SED	0.758
P-VALUE	<0.001

Based on the range test at $p \leq 0.05$, means for factors sharing the same letter(s) are not substantially different from each other.

At 96 hours there was an interaction between seed size and planting on germination rate ($p < 0.001$). The highest germination rate was again recorded for small seeds at a depth of 8 cm, achieving 25.67a. The lowest was for medium seeds at a depth of 5 cm, which had a rate of 9.67h Table 4.3.2.

4.3.3 Effects of seed size and planting depth on germination rate at 120 hours

Table 4.3.3 Effects of seed size and planting depth on germination rate at 120 hours

Treatment	Germination rate at 120 hours
SMALL X 8	30.33 ^a
SMALL X 3	30 ^a
LARGE X 3	29 ^{ab}
SMALL X 5	24 ^b
LARGE X 5	24 ^b
LARGE X 8	22.67 ^c
SMALL X 3	19 ^d
SMALL X 8	19 ^d
SMALL X 5	15.33 ^e
CV %	3.4
LSD	1.394
SED	0.657
P-VALUE	<0.001

Based on the range test at $p \leq 0.05$, means for factors sharing the same letter(s) are not substantially different from each other.

At 120 hours there was an interaction between seed size and planting on germination rate ($p < 0.001$). The large seeds at a depth of 3 cm and small seeds at a depth of 3 cm both reached a high of 30.33a. The lowest rate remained with small seeds at a depth of 5 cm, recording 15.33e Table 4.3.3.

4.3.4 Effects of seed size and planting on germination rate at 144 hours

Table 4.3.4 Effects of seed size and planting depth on germination rate at 144 hours

Treatment	Germination rate at 144 hours
LARGE X 3	33.67 ^a
SMALL X 3	33.33 ^b
SMALL X 8	32.33 ^c
LARGE X 8	30.67 ^d
LARGE X 5	29.67 ^e
SMALL X 5	29.33 ^e
MEDIUM X 3	25.67 ^f
MEDIUM X 8	22.33 ^g
MEDIUM X 5	20.67 ^h
LSD	1.301
SED	0.614
CV%	2.6
P-VALUE	<0.001

Based on the range test at $p \leq 0.05$, means for factors sharing the same letter(s) are not substantially different from each other.

At 144 hours there was an interaction between seed size and planting on germination rate ($p < 0.001$). The highest germination rate was observed for large seeds at a depth of 3 cm, achieving 33.67, while the lowest was for medium seeds at a depth of 5 cm, with a rate of 20.67

Table 4.3.4.

4.4:1 Effects of seed size and planting depth on average leaf number per plant at 1 week after planting

Table 4.4.1 Effects of seed size and planting depth on average leaf number per plant at 1 week after planting

Treatment	Number of leaves per at 1 week after planting
LARGE X 3	2.667 ^a
LARGE X 5	2 ^{ab}
MEDIUM X 3	2 ^{ab}
MEDIUM X 5	2 ^{ab}
SMALL X 3	2 ^{ab}
SMALL X 5	1.333 ^b
SMALL X 8	1.333 ^b
MEDIUM X 8	1 ^c
LARGE X 8	1 ^c
CV%	19.2
SED	0.2664
LSD	0.5648
P-VALUE	<0.001

Based on the range test at $p \leq 0.05$, the means for factors sharing the same letter(s) are not substantially different from each other.

There was a significant interaction between seed size and planting depth ($P < 0.001$) on the number of leaves among treatments. The large seed size at 3 cm had the highest number of leaves at 2.667, followed by large seed size at 5 cm (2). The lowest counts were observed in large seed size at 8 cm (1) Table 4.4.1.

4.4.2 Effect of seed size and planting depth on average leaf number per plant at 2 weeks after planting

Table 4.4.2 Effects of seed size and planting depth on average leaf number per plant at 2 weeks after planting

Treatment	Number of leaves per at 2 weeks after planting
LARGE X 3	5.667 ^a
LARGE X 5	5 ^b
MEDIUM X 3	5 ^b
SMALL X 3	4.333 ^c
MEDIUM X 5	4 ^d
LARGE X 8	4 ^d
MEDIUM X 8	3 ^e
SMALL X 5	3 ^e
SMALL X 8	2 ^f
CV%	6.6
SED	0.2152
LSD	0.4561
P-VALUE	<0.001

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on number of leaves ($p < 0.005$). The large seed size at 3 cm had the highest number (5.667), followed by medium seed size at 3 cm (5). The lowest was the small seed size at 8 cm (2) Table 4.42.

4.4.3 Effect of seed size and planting depth on average leaf number per plant at 3 weeks after planting

Table 4.4.3 Effects of seed size and planting on average leaf number per plant at 3 weeks after planting

Treatment	Number of leaves per at 3 weeks after planting
LARGE X 3	8 ^a
LARGE X 5	7 ^b
MEDIUM X 3	7 ^b
LARGE X 8	6.667 ^c
MEDIUM X 5	6 ^d
SMALL X 3	6 ^d
SMALL X 5	5 ^e
MEDIUM X 8	5 ^e
SMALL X 8	4 ^f
Cv%	3.2
SED	0.1571
LSD	0.3331
P-VALUE	<0.001

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on leaf number per plant at 3 weeks ($p < 0.005$). The large seed size at 3 cm produced the highest (8), followed by medium seed size at 5 cm (6). The lowest was small seed size at 8 cm (4) Table 4.4.3.

4.4.4 Effect of seed size and planting depth on leaf number per plant at 4 weeks after planting

Table 4.4.4 Effects of seed size and planting depth on average leaf number per plant at 4 weeks after planting

Treatment	Number of leaves per at 4 weeks after planting
LARGE X 3	9.333 ^a
MEDIUM X 3	9 ^{ab}
LARGE X 5	8.667 ^{ab}
MEDIUM X 5	8 ^c
SMALL X 3	8 ^c
SMALL X 5	7 ^d
LARGE X 8	6.667 ^e
MEDIUM X 8	6 ^f
SMALL X 8	5 ^g
CV%	4
SED	0.2485
LSD	0.5267
P-VALUE	<0.001

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on leaf number per plant in all treatments at 4 weeks after planting ($p < 0.001$). The large seed size at 3 cm had the highest count of 9.333, followed by medium seed size at 3 cm (8). The lowest was small seed size at 8 cm (5) Table 4.4.4.

4.5:1 Effects of seed size and planting on average plant height at

Table 4.5.1 Effects of seed size and planting depth on average plant height at 1 week after planting

Treatment	Plant height at 1 weeks after planting
LARGE X 3	13.933 ^a
LARGE X 5	13.267 ^{ab}
MEDIUM X 3	12.100 ^{ab}
LARGE X 8	11.333 ^b
MEDIUM X 8	10.233 ^c
MEDIUM X 5	10.900 ^c
SMALL X 3	9.867 ^d
SMALL X 5	9.200 ^d
SMALL X 8	8.167 ^e
CV %	1.4
LSD	0.2644
P-VALUE	P<0.001
SED	0.1247

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was significant difference ($P < 0.005$) in plant height among treatments. The large seed size at 3 cm had the highest height at 13.933, followed by large seed size at 5 cm (13.267). The lowest was small seed size at 8 cm (8.167) Table 4.5.1.

4.5.2 Effects of seed size and planting depth on average plant height at 2 week after planting

Table 4.5.2 Effects of seed size and planting depth on average plant height at 2 weeks after planting

Treatment	Plant height at 2weeks after planting
LARGE X 3	35.267 ^a
LARGE X 5	32.267 ^b
LARGE X 8	29.800 ^c
MEDIUM X 3	28.233 ^d
MEDIUM X 5	25.167 ^e
SMALL X 3	24.867 ^f
MEDIUM X 5	23.133 ^g
SMALL X 5	22.133 ^h
SMALL X 8	20.167 ⁱ
CV %	0.2
LSD	0.1148
P-VALUE	<0.001
SED	0.0541

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was significant difference ($p < 0.005$) in plant height. The large seed size at 3 cm reached the highest height of 35.267, followed by large seed size at 5 cm (32.267). The lowest was small seed size at 8 cm (20.167) Table 4.5.1.

4.5.3 Effects of seed size and planting depth on average plant height at 3 week after planting

There was a significant difference ($p < 0.005$) in plant height. The large seed size at 3 cm had the highest height of 50.367, followed by large seed size at 5 cm (48.333). The lowest was small seed size at 8 cm (35.233) Table 4.5.3.

Table 4.5.3 Effects of seed size and planting depth on average plant height at 3 weeks after planting

According to the range test at ≤ 0.05 , the means for factors that are followed by the same letter(s) are not substantially different from one another.

Treatment	Plant height at 3 weeks after planting
LARGE X 3	50.367 ^a
LARGE X 5	48.333 ^b
LARGE X 8	45.567 ^c
MEDIUM X 3	45.100 ^c
MEDIUM X 5	41.800 ^d
MEDIUM X 8	40.567 ^e
SMALL X 3	40.267 ^e
SMALL X 5	37.500 ^f
SMALL X 8	35.233 ^g
CV%	0.4
SED	0.1264
LSD	0.2680
P-VALUE	<0.001

4.5.4 Effects of seed size and planting depth on average plant height at 4 week after planting

Table 4.5.4 Effects of seed size and planting depth on average plant height at 4 weeks after planting

Treatment	Plant height at 4 weeks after planting
LARGE X 3	65.267 ^a
LARGE X 5	62.100 ^{ab}
LARGE X 8	60.700 ^{ab}
MEDIUM X 3	59.933 ^b
MEDIUM X 5	57.367 ^c
SMALL X 3	55.367 ^c
MEDIUM X 8	55.233 ^c
SMALL X 5	52.463 ^d
SMALL X 8	50.367 ^e
CV%	0.1
SED	0.0430
LSD	0.0912
P-VALUE	<0.001

According to the range test at ≤ 0.05 , the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant difference ($p < 0.005$) in plant height. The large seed size at 3 cm achieved the highest height of 65.267, followed by large seed size at 5 cm (62.100). The lowest was small seed size at 8 cm (50.367) Table 4.5.4.

4.6:1 Effects of seed size and planting depth on average leaf length at 1 week after planting

Table 4.6.1 Effects of seed size and planting depth on average leaf length at 1 week after planting

Treatment	Leaf length at 1 week after planting
LARGE X 3	6.833 ^a
LARGE X 5	6.367 ^{ab}
MEDIUM X 3	6.300 ^{ab}
LARGE X 8	5.167 ^b
SMALL X 3	5.067 ^b
MEDIUM X 5	4.833 ^c
MEDIUM X 8	4.233 ^c
SMALL X 5	3.900 ^d
SMALL X 8	2.700 ^e
CV%	0.9
SED	0.0645
LSD	0.1786
P-VALUE	<0.001

According to the range test at ≤ 0.05 , the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant difference ($p < 0.005$) in leaf length among treatments. The large seed size at 3 cm had the highest leaf length of 6.833, followed by large seed size at 5 cm (6.367). The lowest was small seed size at 8 cm (2.700) Table 4.6.1.

4.6:2 Effects of seed size and planting depth on average leaf length at 2 week after planting

Table 4.6.2 Effects of seed size and planting depth on average leaf length at 2 weeks after planting

Treatment	Leaf length at 2 weeks after planting
LARGE X 3	15.167 ^a
LARGE X 5	14.900 ^b
LARGE X 8	12.900 ^c
MEDIUM X 3	11.733 ^d
MEDIUM X 5	11.267 ^d
MEDIUM X 8	10.133 ^e
SMALL X 3	9.933 ^f
SMALL X 5	9.067 ^f
SMALL X 8	8.233 ^g
CV%	0.9
SED	0.0843
LSD	0.1786
P-VALUE	<0.001

According to the range test at ≤ 0.05 , the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on leaf length ($P < 0.005$). The large seed size at 3 cm showed the highest length of 15.167, followed large seed size at 5 cm (14.900). The lowest was small seed size at 8 cm (8.233) Table 4.6.2.

4.6:3 Effects of seed size and planting depth on average leaf length at 3 week after planting

Table 4.6.3 Effects of seed size and planting depth on average leaf length at 3 weeks after planting

Treatment	Leaf length at 3 weeks after planting
LARGE X 3	18.367 ^a
LARGE X 5	16.533 ^b
MEDIUM X 3	16.267 ^c
LARGE X 8	16.233 ^c
SMALL X 3	15.100 ^d
MEDIUM X 5	14.733 ^e
MEDIUM X 8	14.367 ^e
SMALL X 5	14.233 ^e
SMALL X 8	12.867 ^f
CV%	0.7
SED	0.0844
LSD	0.1790
P-VALUE	<0.001

According to the range test at ≤ 0.05 , the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on leaf length at 3 weeks after planting ($p < 0.005$). The large seed size at 3 cm maintained the highest at 18.367, followed by large seed size at 5 cm (16.533). The lowest was small seed size at 8 cm (12.867) Table 4.6.3.

4.6:4 Effects of seed size and planting depth on average leaf length at 4 week after planting

Table 4.6.4 Effects of seed size and planting depth on average leaf length at 4 weeks after planting

Treatment	Leaf length at 4 weeks after planting
LARGE X 3	24.233 ^a
MEDIUM X 3	22.233 ^{ab}
LARGE X 5	22.200 ^b
MEDIUM X 5	20.233 ^{ab}
SMALL X 3	20.167 ^c
LARGE X 8	20.167 ^c
MEDIUM X 8	18.267 ^d
SMALL X 5	18.433 ^d
SMALL X 8	16.333 ^e
CV%	0.3
SED	0.0916
LSD	0.1942
P-VALUE	<0.001

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on average leaf length at 4 weeks after planting ($p < 0.005$). The large seed size at 3 cm had the highest length of 24.233, followed by medium seed size at 3 cm (22.233). The lowest was small seed size at 8 cm (16.333)

Table 4.6.4.

4.7.1 Effects of seed size and planting depth on average leaf area at 1 week after planting

Table 4.7.1 Effects of seed size and planting depth on average leaf area at 1 week after planting

Treatment	Leaf area at 1 weeks after planting
LARGE X 3	6.833 ^a
LARGE X 5	6.367 ^{ab}
MEDIUM X 3	6.300 ^{ab}
LARGE X 8	5.167 ^b
SMALL X 3	5.067 ^c
MEDIUM X 5	4.833 ^d
MEDIUM X 8	4.233 ^e
SMALL X 5	3.900 ^f
SMALL X 8	2.700 ^g
CV%	0.7
LSD	0.1786
SED	0.0843
P-VALUE	<0.001

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on average leaf area at 1 week after planting in all treatments ($p < 0.005$). The large seed size at 3 cm had the highest leaf area of 6.833, followed by large seed size at 5 cm (6.367). The lowest was small seed size at 8 cm (2.700) Table 4.7.1.

4.7.2 Effects of seed size and planting depth on average leaf area at 2 week after planting

Table 4.7.2 Effects of seed size and planting depth on average leaf area at 2 weeks after planting

Treatment	Leaf area at 2 weeks after planting
LARGE X 3	15.167 ^a
LARGE X 5	14.100 ^{ab}
LARGE X 8	12.900 ^b
MEDIUM X 3	11.733 ^c
MEDIUM X 5	11.267 ^c
MEDIUM X 8	10.133 ^d
SMALL X 3	9.933 ^e
SMALL X 5	9.067 ^e
SMALL X 8	8.833 ^f
CV%	0.9
LSD	0.1786
SED	0.0843
P-VALUE	<0.001

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between ($p < 0.005$) seed size and planting depth on average leaf area at 2 weeks after planting. The large seed size at 3 cm had the highest leaf area of 15.167, followed by large seed size at 5 cm (14.100). The lowest was small seed size at 8 cm (8.833) Table 4.7.2.

4.7.3 Effects of seed size and planting depth on average leaf area at 3 week after planting

Table 4.7.3 Effects of seed size and planting depth on average leaf area at 3 weeks after planting

Treatment	Leaf area at 3 weeks after planting
LARGE X 3	18.367 ^a
LARGE X 5	16.533 ^{ab}
MEDIUM X 3	16.267 ^{ab}
LARGE X 8	16.233 ^b
SMALL X 3	15.100 ^c
MEDIUM X 5	14.733 ^c
MEDIUM X 8	14.367 ^d
SMALL X 5	14.233 ^d
SMALL X 8	12.867 ^e
CV %	0.9
SED	0.0844
LSD	0.1790
P-VALUE	<0.001

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on average leaf area at 3 weeks after a planting ($p < 0.005$). The large seed size at 3 cm show the highest leaf area at 18.367, followed by large seed size at 5 cm (16.533). The lowest was small seed size at 8 cm (12.867) Table 4.7.3.

4.7.4 Effects of seed size and planting depth on average leaf area at 4 week after planting

Table 4.7.4 Effects of seed size and planting depth on average leaf area at 4 weeks after planting

Treatment	Leaf area at 4 weeks after planting
LARGE X 3	24.233 ^a
MEDIUM X 3	22.233 ^{ab}
LARGE X 5	22.200 ^{ab}
MEDIUM X5	20.233 ^b
LARGE X 8	20.167 ^c
SMALL X 3	20.167 ^c
SMALL X 5	18.433 ^d
MEDIUM X 8	18.267 ^d
SMALL X 8	16.333 ^e
CV%	0.3
SED	0.0550
LSD	0.11166
P-VALUE	<0.001

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on leaf area in all treatments ($p < 0.001$) at 4 weeks after planting. The large seed size at 3 cm achieved the highest leaf area of 24.233, followed by medium seed size at 3 cm (22.233). The lowest was small seed size at 8 cm (16.333) Table 4.7.4.

4.8.1 Effects of seed size and planting depth on leaf width at 1 week after planting

Table 4.8.1 Effects of seed size and planting depth on average leaf width at 1 week after planting

Treatment	Leaf width at 1 week after planting
LARGE X 3	2.967 ^a
LARGE X 5	2.833 ^{ab}
MEDIUM X 3	2.667 ^{ab}
LARGE X 8	2.467 ^b
MEDIUM X 5	2.100 ^c
SMALL X 3	2.000 ^c
MEDIUM X 8	1.867 ^d
SMALL X 5	1.600 ^e
SMALL X 8	1.233 ^f
CV%	5.1
SED	0.0916
LSD	0.1942
P-VALUE	<0.001

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on leaf width ($p < 0.005$) at 1 week after planting. The large seed size at 3 cm had the highest width of 2.967, followed by large seed size at 5 cm (2.833). The lowest was small seed size at 8 cm (1.233) Table 4.8.1.

4.8.2 Effects of seed size and planting depth on average leaf width at 2 week after planting

Table 4.8.2 Effects of seed size and planting on average leaf width at 2 weeks after planting

Treatment	Leaf width at 2 weeks after planting
LARGE X 3	4.167 ^a
LARGE X 5	3.800 ^{ab}
LARGE X 8	3.467 ^{ab}
MEDIUM X 3	3.467 ^{ab}
SMALL X 3	3.333 ^c
MEDIUM X 5	3.133 ^c
MEDIUM X 8	2.667 ^d
SMALL X 5	2.567 ^e
SMALL X 8	2.033 ^f
CV%	2.4
SED	0.0614
LSD	0.1301
P-VALUE	<0.001

According to the range test at ≤ 0.05 , the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting on leaf width ($p < 0.005$) at 2 weeks after planting. The large seed size at 3 cm showed the highest width at 4.167, followed by medium seed size at 3 cm (3.800). The lowest was small seed size at 8 cm (2.033) Table 4.8.2.

4.8.3 Effects of seed size and planting depth on average leaf width at 3 week after planting

Table 4.8.3 Effects of seed size and planting depth on average leaf width at 3 weeks after planting

Treatment	Leaf width at 3 weeks after planting
LARGE X 3	5.133 ^a
MEDIUM X 3	4.567 ^{ab}
LARGE X 5	4.533 ^{ab}
LARGE X 8	4.200 ^c
SMALL X 3	4.100 ^d
MEDIUM X 5	4.100 ^d
MEDIUM X 8	3.900 ^e
SMALL X 5	3.500 ^f
SMALL X 8	3.133 ^g
CV%	1.3
SED	0.0427
LSD	0.0905
P-VALUE	<0.001

According to the range test at $p \leq 0.05$, the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on leaf width ($p < 0.005$) at 3 weeks after planting. The large seed size at 3 cm maintained the highest width of 5.133, followed by medium seed size at 3 cm (4.567). The lowest was small seed size at 8 cm (3.133) Table 4.8.3.

4.8.4 Effects of seed size and planting depth on average leaf width at 4 week after planting

Table 4.8.4 Effects of seed size and planting depth on average leaf width at 4 weeks after planting

Treatment	Leaf width at 4 weeks after planting
LARGE X 3	6.067 ^a
MEDIUM X 3	5.567 ^{ab}
LARGE X 5	5.533 ^{ab}
MEDIUM X 5	5.133 ^c
SMALL X 3	5.100 ^c
LARGE X 8	5.033 ^d
MEDIUM X 8	4.833 ^e
SMALL X 5	4.500 ^f
SMALL X 8	4 ^g
CV%	1.8
SED	0.0768
LSD	0.1628
P-VALUE	<0.001

According to the range test at ≤ 0.05 , the means for factors that are followed by the same letter(s) are not substantially different from one another.

There was a significant interaction between seed size and planting depth on average leaf width ($p < 0.005$) at 4 weeks after planting. The large seed size at 3 cm maintained the highest width of 6.067, followed by medium seed size at 3 cm (5.567). The lowest was small seed size at 8 cm (4.000) Table 4.8.4.

Chapter 5

Discussion of Results

The results of this study provide significant insights into the effects of maize seed size and planting depth on various growth parameters, including germination percentage, mean germination time, germination rate, number of leaves per plant, plant height, leaf length, leaf area, and leaf width.

5.1 Germination Percentage

The germination percentage was significantly influenced by both seed size and planting depth. Larger seeds planted at a shallower depth (3 cm) exhibited the highest germination percentage, indicating that seed size plays a crucial role in successful germination. This finding aligns with existing literature, which suggests that larger seeds contain more nutrients, thereby enhancing their ability to germinate effectively. Penfield, 2017 state that the increased nutrient reserves in larger seeds may provide the necessary energy for breaking dormancy and supporting the initial growth of the seedling. Conversely, smaller seeds planted at greater depths (8 cm) showed lower germination rates, highlighting the importance of optimal planting depth in ensuring seedling establishment. Seeds planted too deep may struggle to emerge due to insufficient energy reserves and delayed exposure to favorable environmental conditions (Fenner, 2017).

5.2 Mean Germination Time

Mean germination time varied significantly with different combinations of seed size and planting depth. Seeds planted at a depth of 3 cm germinated more quickly, supporting the notion that shallower planting can lead to faster emergence due to improved access to heat and moisture. Egley, (2017), suggested that the shallow depths typically offer warmer soil temperatures, which can accelerate metabolic processes necessary for germination. The results suggest that while larger seeds tend to germinate faster, planting depth substantially impacts how quickly germination occurs. This underscores the need for farmers to consider both seed size and planting depth when planning their planting strategies to optimize crop establishment.

5.3 Germination Rate

The germination rate was highest for large seeds at 3 cm and lowest for small seeds at 8 cm. This trend indicates a clear interaction between seed size and planting depth, where optimal conditions for larger seeds significantly enhance their germination rate. A higher germination rate is crucial for achieving uniform crop stands, which can lead to more efficient resource utilization throughout the growing season. The findings suggest that farmers should prioritize larger seeds, especially when planting at shallower depths, to achieve higher germination rates, ultimately leading to better crop establishment and resilience against environmental stresses (Reed *et al.*, 2022).

5.4 Number of Leaves per Plant

The number of leaves per plant was positively correlated with seed size and negatively correlated with planting depth (Umeoka and Ogbonnaya, 2016). Larger seeds consistently produced more leaves, indicating better seedling vigor. This can be attributed to the enhanced nutrient reserves present in larger seeds, which facilitate early growth and leaf development. A higher leaf count is crucial for maximizing photosynthetic capacity and overall plant health. The results highlight the significance of selecting appropriate seed sizes to maximize leaf production, which is vital for overall plant health and productivity. Additionally, a greater number of leaves can improve the plant's ability to capture sunlight, which is essential for photosynthesis and growth.

5.5 Plant Height

Plant height was significantly affected by the interaction between seed size and planting depth. The tallest plants were those grown from large seeds at a depth of 3 cm, reinforcing the notion that optimal planting conditions enhance initial growth. Taller plants generally have better access to sunlight, which can further enhance photosynthesis and growth rates. This result is particularly important as plant height is often a predictor of overall yield potential. Therefore, farmers should be encouraged to adopt practices that favor larger seeds planted at shallower depths to maximize plant height and, consequently, yield (Liu *et al.*, 2018). Moreover, taller plants often exhibit improved competitive ability against weeds, further supporting crop establishment.

5.6 Leaf Length

Similar trends were observed in leaf length, where larger seeds resulted in longer leaves when planted at optimal depths. The findings suggest that both seed size and planting depth play critical roles in determining leaf development, which is essential for photosynthesis and overall plant vigor. Chen *et al.*, 2017 suggested that the longer leaves can increase the surface area available for light capture, thereby enhancing the plant's ability to produce energy. Farmers can enhance maize production by ensuring that larger seeds are used in conjunction with the recommended planting depth. Additionally, longer leaves may contribute to improved water use efficiency, allowing plants to thrive in varying moisture conditions.

5.7 Leaf Area

Leaf area, a crucial determinant of photosynthetic capacity, was significantly influenced by both seed size and planting depth. Larger seeds produced a greater leaf area, particularly at shallower depths, emphasizing the importance of both factors in plant growth. This result underscores the role of adequate leaf area in maximizing light capture and enhancing photosynthesis, ultimately contributing to higher yields (Croce *et al.*, 2024). A larger leaf area can also improve the plant's ability to intercept sunlight, leading to increased biomass accumulation. The findings suggest that managing seed size and planting depth effectively can lead to more robust leaf development, which is essential for achieving optimal crop performance.

5.8 Leaf Width

According to Umeoka and Ogbonnaya, (2016) leaf area and leaf width followed same patterns, with larger seeds at shallower planting depths resulting in wider leaves. This finding further highlights the importance of selecting appropriate seed sizes and planting depths to optimize leaf morphology, which is essential for efficient resource utilization. The greater leaf width observed in larger seeds under optimal conditions suggests a better capacity for photosynthesis and nutrient uptake. Wider leaves can enhance the plant's ability to capture sunlight, which is crucial for energy production. Furthermore, the increased leaf width may improve the plant's tolerance to environmental stresses, such as drought, by promoting better water retention.

Chapter 6

Conclusion and Recommendations

6.1 Conclusion

This study highlights the significant influence of maize seed size and planting depth on seedling emergence and plant vigour. The findings show that larger seeds consistently outperform smaller ones in key growth metrics, including germination percentage, germination rate, mean germination time, leaf count, plant height, leaf length, leaf area, and leaf width. Large seeds planted at a 3 cm depth achieved the highest germination percentage (93.3%) and germination rate (8.8), alongside superior early growth characteristics, such as leaf count (9.33), plant height (65.27 cm), leaf length (24.23 cm), leaf area (110.42 cm²), and leaf width (6.07 cm). This combination of seed size and planting depth optimizes seedling emergence and enhances overall plant health and vigour. In contrast, small seeds planted at an 8 cm depth showed the lowest performance across these metrics, underscoring the challenges of using smaller seeds and deeper planting. Deeply planted seeds may face difficulties emerging due to limited energy reserves, delayed access to favourable environmental conditions, and potential moisture shortages. These findings emphasize the need to carefully select seed size and planting depth to maximize maize yield and ensure successful crop establishment. The study also indicates that the interaction between seed size and planting depth is critical for refining agricultural practices. Farmers should be informed about the advantages of using larger seeds and shallower planting depths, particularly in areas with variable environmental conditions, to optimize growth outcomes. For optimal maize production, the study recommends planting large seeds at a 3 cm depth to improve seedling establishment, enhance crop performance, and increase yields. Adopting these practices can improve resource efficiency and resilience to environmental stresses, supporting food security in maize-dependent regions. Future research should investigate the long-term impacts of these practices across diverse soil types and moisture conditions to further optimize maize production strategies. Additionally, exploring the economic benefits of using larger seeds and optimal planting depths could provide farmers with valuable insights to boost productivity and livelihoods.

6.2 Recommendations

Based on my research into the effects of maize seed size and planting depth on seedling emergence and vigour, I advise farmers to prioritize larger maize seeds, especially when planting at a 3 cm depth. This combination yields the highest germination percentage, germination rate, and superior plant growth metrics, such as leaf count, plant height, leaf length, leaf area, and leaf width. I recommend that farmers adjust their planting methods to use larger seeds at shallower depths to optimize germination and early seedling development. Additionally, proper soil preparation and nutrient management are essential to support the growth of these larger seeds. I also suggest that agricultural extension services educate farmers on selecting appropriate seed sizes and planting depths based on their local environmental conditions. Adopting these practices can significantly improve maize crop establishment, increase yields, and enhance food security in regions where maize is a staple crop. Further research should investigate the long-term effects of these practices across different soil types and moisture levels to optimize maize production strategies. By implementing these recommendations, farmers can achieve greater resource efficiency and resilience to environmental stresses, ultimately improving their livelihoods.

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APPENDIX

ANOVA TABLES

Analysis of variance for germination percentage

Variate: %Germination

Source	d.f.	s.s.	m.s.	v.r.
Rep	2	76.281	38.140	10.91
seed_size ignoring planting_depth	2	3292.504	1646.252	471.12
seed_size eliminating planting_depth	2	3291.856	1645.928	471.03
planting_depth ignoring seed_size	2	602.085	301.042	86.15
planting_depth eliminating seed_size	2	601.436	300.718	86.06
seed_size.planting_depth	4	32.218	8.055	2.31
Residual	14	48.921	3.494	
Total	24	4051.360	168.807	

F pr.
0.001
< 0.001
< 0.001
< 0.001
< 0.001
< 0.001
0.109

Analysis of variance for mean germination time

Variate: % MGT

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.03221	0.01610	0.53	
Rep.*Units* stratum					
seed_size	2	3.53023	1.76511	58.22	<.001
planting_depth	2	0.76934	0.38467	12.69	<.001
seed_size.planting_depth	4	0.17777	0.04444	1.47	0.259
Residual	16	0.48513	0.03032		
Total	26	4.99467			

Analysis of variance for germination rate at 72 hours

Variate: %72_hours

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2.7407	1.3704	1.44	
Rep.*Units* stratum					
seed_size	2	173.8519	86.9259	91.15	<.001
planting_depth	2	5.4074	2.7037	2.83	0.088
seed_size.planting_depth					
	4	47.7037	11.9259	12.50	<.001
Residual	16	15.2593	0.9537		
Total	26	244.9630			

Analysis of variance for germination rate at 96 hours

Variate: %96_hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	2.8889	1.4444	1.68	
Rep.*Units* stratum					
seed_size	2	369.5556	184.7778	214.58	<.001
planting_depth	2	90.8889	45.4444	52.77	<.001
seed_size.planting_depth					
	4	163.5556	40.8889	47.48	<.001
Residual	16	13.7778	0.8611		
Total	26	640.6667			

Analysis of variance for germination rate at 120 hours

Variate: %120hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	5.6296	2.8148	4.34	
Rep.*Units* stratum					
seed_size	2	511.6296	255.8148	394.69	<.001
planting_depth	2	108.7407	54.3704	83.89	<.001
seed_size.planting_depth					
	4	61.2593	15.3148	23.63	<.001
Residual	16	10.3704	0.6481		
Total	26	697.6296			

Analysis of variance for germination rate at 144 hours

Variate: %144hrs

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.9630	0.4815	0.85	
Rep.*Units* stratum					
seed_size	2	445.4074	222.7037	394.30	<.001
planting_depth	2	84.9630	42.4815	75.21	<.001
seed_size.planting_depth	4	5.9259	1.4815	2.62	0.074
Residual	16	9.0370	0.5648		
Total	26	546.2963			

Analysis of variance for average number of leaves per plant at week 1
Variate: week1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.2963	0.1481	1.39	
Rep.*Units* stratum					
seed_size	2	0.5185	0.2593	2.43	0.119
planting_depth	2	5.6296	2.8148	26.43	<.001
seed_size.planting_depth	4	1.4815	0.3704	3.48	0.032
Residual	16	1.7037	0.1065		
Total	26	9.6296			

Analysis of variance for average number of leaves per plant at week 2
Variate: week2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.22222	0.11111	1.60	
Rep.*Units* stratum					
seed_size	2	14.22222	7.11111	102.40	<.001
planting_depth	2	18.00000	9.00000	129.60	<.001
seed_size.planting_depth	4	0.44444	0.11111	1.60	0.223
Residual	16	1.11111	0.06944		
Total	26	34.00000			

Analysis of variance for average number of leaves per plant at week 3
Variate: week_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.07407	0.03704	1.00	
Rep.*Units* stratum					
seed_size	2	22.29630	11.14815	301.00	<.001
planting_depth	2	14.29630	7.14815	193.00	<.001
seed_size.planting_depth	4	0.59259	0.14815	4.00	0.020
Residual	16	0.59259	0.03704		
Total	26	37.85185			

Analysis of variance for average number of leaves per plant at week 4
Variate: week_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.51852	0.25926	2.80	
Rep.*Units* stratum					
seed_size	2	11.18519	5.59259	60.40	<.001
planting_depth	2	39.40741	19.70370	212.80	<.001
seed_size.planting_depth	4	0.14815	0.03704	0.40	0.806
Residual	16	1.48148	0.09259		
Total	26	52.74074			

Analysis of variance for average plant height at week 1
Variate: week1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.2963	0.1481	1.39	
Rep.*Units* stratum					
seed_size	2	0.5185	0.2593	2.43	0.119
planting_depth	2	5.6296	2.8148	26.43	<.001
seed_size.planting_depth	4	1.4815	0.3704	3.48	0.032
Residual	16	1.7037	0.1065		
Total	26	9.6296			

Analysis of variance for average plant height at week 2
Variate: Week_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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Rep stratum	2	0.002963	0.001481	0.34	
Rep.*Units* stratum					
seed_size	2	476.800741	238.400370	54204.72	<.001
planting_depth	2	117.442963	58.721481	13351.41	<.001
seed_size.planting_depth	4	0.503704	0.125926	28.63	<.001
Residual	16	0.070370	0.004398		
Total	26	594.820741			

Analysis of variance for average plant height at week 3
Variate: Week_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.35630	0.17815	7.43	
Rep.*Units* stratum					
seed_size	2	480.62296	240.31148	10020.71	<.001
planting_depth	2	103.45407	51.72704	2156.96	<.001
seed_size.planting_depth	4	2.34370	0.58593	24.43	<.001
Residual	16	0.38370	0.02398		
Total	26	587.16074			

Analysis of variance for average plant height at week 4
Variate: Week_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.35630	0.17815	7.43	
Rep.*Units* stratum					
seed_size	2	480.62296	240.31148	10020.71	<.001
planting_depth	2	103.45407	51.72704	2156.96	<.001
seed_size.planting_depth	4	2.34370	0.58593	24.43	<.001
Residual	16	0.38370	0.02398		
Total	26	587.16074			

Analysis of variance for average length at week 1
Variate: Week_1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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Rep stratum	2	0.02667	0.01333	0.57	
Rep.*Units* stratum					
seed_size	2	63.92667	31.96333	1369.86	<.001
planting_depth	2	19.21556	9.60778	411.76	<.001
seed_size.planting_depth	4	1.49778	0.37444	16.05	<.001
Residual	16	0.37333	0.02333		

Total 26 85.04000

Analysis of variance for average leaf length at week 1
Variate: Week_1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.020000	0.010000	1.60	
Rep.*Units* stratum					
seed_size	2	22.526667	11.263333	1802.13	<.001
planting_depth	2	18.606667	9.303333	1488.53	<.001
seed_size.planting_depth	4	1.013333	0.253333	40.53	<.001
Residual 16	0.100000	0.006250			
Total 26	42.266667				

Analysis of variance for average leaf length at week 2
Variate: Week_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.03630	0.01815	1.70	
Rep.*Units* stratum					
seed_size	2	113.13852	56.56926	5312.59	<.001
planting_depth	2	15.59185	7.79593	732.14	<.001
seed_size.planting_depth	4	0.52148	0.13037	12.24	<.001
Residual	16	0.17037	0.01065		
Total	26	129.45852			

Analysis of variance for average leaf length at week 3
Variate: Week_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.28222	0.14111	13.19	

Rep.*Units* stratum					
seed_size	2	41.02889	20.51444	1918.23	<.001
planting_depth	2	20.44222	10.22111	955.74	<.001
seed_size.planting_depth	4	1.26222	0.31556	29.51	<.001
Residual	16	0.17111	0.01069		
Total	26	63.18667			

Analysis of variance for average leaf length at week 4

Variate: Week_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.000741	0.000370	0.08	
Rep.*Units* stratum					
seed_size	2	68.056296	34.028148	7500.08	<.001
planting_depth	2	70.427407	35.213704	7761.39	<.001
seed_size.planting_depth	4	0.090370	0.022593	4.98	0.008
Residual	16	0.072593	0.004537		
Total	26	138.647407			

Analysis of variance average leaf area at week 1

Variate: Week_1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.9812	0.4906	2.53	
Rep.*Units* stratum					
seed_size	2	276.6992	138.3496	713.29	<.001
planting_depth	2	152.1428	76.0714	392.20	<.001
seed_size.planting_depth	4	9.7701	2.4425	12.59	<.001
Residual	16	3.1034	0.1940		
Total	26	442.6967			

Analysis of variance for average leaf area at week 2

Variate: Week_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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Rep stratum	2	2.308	1.154	1.09	
Rep.*Units* stratum					
seed_size	2	2336.578	1168.289	1103.72	<.001
planting_depth	2	593.109	296.554	280.17	<.001
seed_size.planting_depth	4	8.777	2.194	2.07	0.132
Residual	16	16.936	1.058		
Total	26	2957.708			

Analysis of variance for average leaf area at week 3

Variate: Week_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	15.1938	7.5969	15.78	
Rep.*Units* stratum					
seed_size	2	2055.9105	1027.9552	2135.70	<.001
planting_depth	2	1279.8785	639.9393	1329.55	<.001
seed_size.planting_depth	4	40.9388	10.2347	21.26	<.001
Residual	16	7.7011	0.4813		
Total	26	3399.6227			

Analysis of variance for average leaf area at week 4

Variate: Week_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	15.030	7.515	3.48	
Rep.*Units* stratum					
seed_size	2	4122.203	2061.102	953.80	<.001
planting_depth	2	3970.949	1985.474	918.80	<.001
seed_size.planting_depth	4	45.236	11.309	5.23	0.007
Residual	16	34.575	2.161		
Total	26	8187.993			

Analysis of variance for average leaf width at week 1

Variate: Week_1

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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Rep stratum	2	0.05852	0.02926	2.32	
Rep.*Units* stratum					
seed_size	2	5.89852	2.94926	234.21	<.001
planting_depth	2	2.13852	1.06926	84.91	<.001
seed_size.planting_depth	4	0.16148	0.04037	3.21	0.041
Residual	16	0.20148	0.01259		
Total	26	8.45852			

Analysis of variance for average leaf width at week 2
Variate: Week_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.002963	0.001481	0.26	
Rep.*Units* stratum					
seed_size	2	6.240741	3.120370	552.46	<.001
planting_depth	2	3.922963	1.961481	347.28	<.001
seed_size.planting_depth	4	0.343704	0.085926	15.21	<.001
Residual	16	0.090370	0.005648		

Total 26 10.600741

Analysis of variance for average leaf width at week 3
Variate: Week_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.082963	0.041481	15.19	
Rep.*Units* stratum					
seed_size	2	4.956296	2.478148	907.25	<.001
planting_depth	2	3.391852	1.695926	620.88	<.001
seed_size.planting_depth	4	0.081481	0.020370	7.46	0.001
Residual	16	0.043704	0.002731		

Total 26 8.556296

Analysis of variance for average leaf width at week 4

Variate: Week_4

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	2	0.038519	0.019259	2.18	
Rep.*Units* stratum					
seed_size	2	4.716296	2.358148	266.68	<.001
planting_depth	2	4.120741	2.060370	233.01	<.001

seed_size.planting_depth		4	0.117037	0.029259	3.31	0.037
Residual		16	0.141481	0.008843		
Total	26		9.134074			