BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENT OF CROP SCIENCE

EVALUATING THE PERFORMANCE OF NEW EARLY MATURING SEEDCO MAIZE HYBRID VARIETIES UNDER LOW NITROGEN CONDITIONS

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BACHELOR OF AGRICULTURAL SCIENCE HONOURS DEGREE

(CROP SCIENCE)

BY:

CHRISTINE TAFADZWA BANDA

(B202406B)

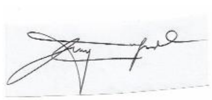
SUPERVISORS: Mr. T. Nyamugure

DECLARATION

The undersigned certify that they have read and recommended to the Department of Crop Science for acceptance, this research project entitled

Evaluating the performance of new early maturing Seed.CO maize hybrid varieties under low nitrogen conditions.

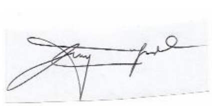
Mr T. Nyamugure (supervisor)

 **…………………………………………………**

Date 29/09/24

…………………………………………………

Mr Nyamugure (Chairperson)

 **…………………………………………………**

Date

Student Signature

 **…………………………………………………**

Date 26/06/2024

Abstract

Nitrogen being a very important nutrient for maize growth, has become a limiting factor affecting maize production across all maize growing region in Zimbabwe. Nitrogen use efficient (NUE) can be improved through several management practices, such as selecting NUE maize varieties and integrating precision agriculture technologies. This experiment aimed to evaluate the performance of maize under typical conditions faced by resource-constrained small holder famers. A total of twenty hybrids (13 experimental tests and 7 local checks) were established under low nitrogen in order to identify genotypes that can thrive in stressful nitrogen condition. The 20 hybrids were planted using the alpha lattice design, replicated 3 times with each replicate accommodating 4 incomplete blocks with 5 entries per block. Data were collected for traits such as grain yield, grain weight, ear height, moisture content, flowering, MSV and GLS. The analysis of variance (ANOVA) test conducted for grain yield, grain weight, ear height and flowering showed that there was a significant difference ($P<0.05$) compared to other measured parameters such as plant height, GLS, MSV, moisture content and number plants (which were not significant). Notably, genotypes test 6, 8, 12, 7 outperformed other hybrids including the checks 2 and 3 across all the traits important to the farmers. Hence these hybrids can be recommended for release in the market to farmers who currently rely on the underperforming local checks.

Keywords: Hybrid, NUE, Zimbabwe, small holder farmers

Acknowledgements

I express my heartfelt appreciation to the individuals who played a crucial role in helping me achieve my goal. Firstly, I am sincerely grateful to my supervisors, Dr. B. Masuka from Seed Co and Mr. Mutsengi, for their unwavering support and encouragement throughout the entirety of this project. I would also like to extend my gratitude to my dear friends, Lorraine Jere and Guerdon Muguchani, who provided laughter and companionship during this journey. Furthermore, I am profoundly thankful to my parents for their unwavering support and, above all, to the Lord God Almighty, whose divine providence made all of this possible.

DEDICATION

I dedicate this project to my mother and father.

Table of Contents

Abstract iii

Acknowledgements iv

Dedication v

Table of Contents vi

LIST OF FIGURES ix

LIST OF TABLES x

LIST OF APPENDICES xi

LIST OF ACRONYMS xii

CHAPTER ONE 1

1.0 Introduction 1

1.1 Background 1

1.2 Problem statement 2

1.3 Justification 2

1.4 Objectives and hypothesis 3

1.4.1 Main objective 3

1.4.2 Specific objectives 3

1.4.3 Hypothesis 3

CHAPTER TWO 4

2.0 Literature Review 4

2.1 Introduction to Maize Production and Variety Selection 4

2.2 Zimbabwean Communal Farmers 5

2.2.1 High Fertilizer Cost in Zimbabwe 5

2.2.2 Fertilizer Cost in Other Countries 6

2.3 Nitrogen Fertilizer 7

2.4 Nitrogen Use in Maize 7
2.4.1 Roles of Nitrogen in Maize Anthesis 8
2.4.2 Roles of Nitrogen in Silk Development 8
2.4.3 Roles of Nitrogen in Maize Ear Height 9
2.4.4 Roles of Nitrogen in Plant Height 10
2.4.5 Roles of Nitrogen in Maize Anthesis-Siliking Interval 10
2.4.6 Roles of Nitrogen on Disease Resistant Mechanisms 11
2.5 Benefits of Combining Early Maturing and Low N Tolerance Traits in a Variety 12
CHAPTER THREE 14
3.0 Materials and Methods 14
3.1 Site Description 14
3.2 Experimental Design 14
3.3 Field Management 14
3.3.1 Land Preparation and Planting 14
3.3.2 Crop Water Requirements 15
3.3.3 Weed and Pest Control 15
3.4 Data Collection 15
3.5 Data Analysis 17
CHAPTER FOUR 18
4.0 Results 18
4.1 Effect of Different Maize Genotypes on Ear Height (m). 18
4.2 Effect of Different Maize Genotypes on Days to Flowering (days) 19
4.2.1 Effect of Different Maize Genotype on Days to Anthesis 19
4.2.2 Effect of Different Genotypes on Days to Silking. 20
4.2.3 Effect of Different Genotype on Anthesis – Silking Interval 21
4.3 Effect of Different Maize Genotypes on Thousand Grain Weight. 22

4.4 Effect of Different Maize Genotypes on Grain Yield (T Ha^{-1}). 23

4.5 Analysis of Variance for Other Agronomic Traits 24

CHAPTER FIVE 25

5.0 Discussion.. 25

5.1 Effect of genotype on Ear height 25

5.2 Effects of genotype on days to anthesis.. 26

5.3 Effect of genotype on days to silking 26

5.4 Effect of genotype on anthesis-silking interval. 27

5.5 Effect of genotype on grain yield 27

5.6 Effect of genotype on plant height 28

5.7 Effect of genotype on diseases 29

CHAPTER SIX.. 30

6.1 Conclusions 30

6.2 Recommendations 30

References 32

LIST OF FIGURES

Figure4.1 Effect of genotype on ear height (m)... 18
Figure 4.2 Effect of genotype on days to anthesis.. 19
Figure 4.3 Effect of genotype on days to silking.. 20
Figure 4.4 Effect of genotype on Anthesis-silking interval... 21
Figure4.5 Effect of genotype on thousand grain weight.. 22
Figure4.6 Effect of genotype on grain yield.. 23

LIST OF TABLES

Table 1 the composition of maize grain per 100g edible portion. 4
Table 2 Trial site description. 14
Table 3 Herbicide used 15
Table 4 Description of trials recorded in the field 15
Table 5 Agronomic mean square values and significant tests for maize genotypes evaluated at KRC. 24

LIST OF APPENDICES

Appendix 1 list of genotypes used 36
Appendix 2 Analysis of variation of grain yield kg/ha 36
Appendix 3 Analysis of variation of Anthesis Silking Interval 37
Appendix 4 Analysis of variation of days to 50% anthesis 37
Appendix 5 Analysis of variation of days to 50% silking 37
Appendix 6 Analysis of variation of ear height (m) 37
Appendix 7 Analysis of variation of thousand grain weight 38
Appendix 8 Analysis of variation of grey leaf spot 38
Appendix 9 Analysis of variation of maize streak virus 38
Appendix 10 Analysis of variation of moisture % 39
Appendix 11 Analysis of variation of plant height (m) 39

LIST OF ACRONYMS

ANOVA	Analysis of variance
ASI	Anthesis-silking interval
EH	Ear height
GLS	Grey leaf spot
GY	Grain Yield
ISR	Induced systematic resistance
KRC	Kadoma research center
LSD	Least significant difference
Low N	Low nitrogen
MSV	Maize streak virus
MOI	Moisture %
NP	Number of plants
NUE	Nitrogen use efficiency
PH	Plant height
TGW	Thousand grain weight

CHAPTER ONE

1. Introduction

1.1 Background

Maize is an important cereal crop cultivated in Zimbabwe and a widely grown staple crop in Africa with more than 300 million Africans depending on it as their main food source. Since maize (*Zea mays L.*) is a globally important crop, it plays a vital role in ensuring food security particularly in Sub-Saharan Africa. Maize production is critical for supporting the livelihoods of smallholder farmers in the region. However, the productivity of maize is often constrained by various abiotic stresses, with low soil nitrogen availability being a prevalent challenge (Makumbi, *et al.*, 2018). Improving maize grain yield is important given the reliance on maize for food, feed, and fuel (Abubakar, *et al*., 2019).

Nitrogen is an essential macronutrient required for various physiological processes in plants, such as chlorophyll synthesis, protein formation, and energy production. Inadequate nitrogen supply can lead to stunted growth, reduced biomass accumulation, and significant yield losses in maize (Hirel, *et al*., 2007). This issue is particularly acute in resource-limited smallholder farming systems, where the application of nitrogen fertilizers is often limited due to financial and logistical constraints.

To address this challenge, researchers have focused on identifying and developing maize genotypes with enhanced tolerance to low nitrogen stress. Studies have revealed the existence of significant genetic variation within the maize germplasm for traits associated with NUE, including grain yield, and N-uptake under low N conditions (Makumbi, *et al*., 2018). Exploiting this genetic diversity through targeted breeding efforts can lead to the development of climate-resilient maize varieties that can thrive in nitrogen-depleted soils, thereby improving food security and supporting the livelihoods of smallholder farmers.

Understanding the physiological and molecular mechanisms underlying nitrogen use efficiency in maize is important for informing breeding strategies and accelerating development of superior low-nitrogen tolerant cultivars. Evaluating the performance of diverse maize genotypes under low nitrogen conditions can provide valuable insights into the genetic and phenotypic factors contributing to nitrogen use efficiency, ultimately guiding the selection and deployment of appropriate maize varieties for resource-constrained farming system.

1.2 Problem statement

The new maize varieties were developed for low N but their performance under low N is not known.

1.3 Justification

Maize is a popular crop grown in Zimbabwe by both commercial and small-scale farmers. Due to the increase in the number of small-scale farmers who are growing maize, it has called for further research into finding and developing new seed varieties which can grow to full maturity and tolerant to low nitrogen conditions. Not all farmers are able to have high yields at the end of the growing season due to inaccessibility to nitrogen containing fertilizers. Some of these small-scale farmers have faced financial problems in trying to buy all the necessary fertilizer and other inputs to boost the growth of maize.

Efficient nitrogen uptake is crucial for promoting the growth of maize crops as it is a major nutrient in maize production. Therefore, it is essential to identify genotypes that are well-suited to low nitrogen conditions while still achieving desirable yields. This project holds significant benefits for smallholder farmers, as it enables them to determine which maize seeds are best suited to low nitrogen stress, ultimately leading to increased yields (Quan, *et al*., 2021).

However, due to increased number of farmers and increased agricultural activities it has led to major detrimental impact of nitrogen since there is extensive use of N-fertilizers (Erisman, 2013). In addition, fertilizer-derived nitrous oxide emissions into the atmosphere contribute to the depletion of the ozone layer, Nitrogen fertilizers also contribute to river eutrophication and acidification through a process known as nutrient runoff. When nitrogen fertilizers are applied to agricultural fields, not all of the nitrogen is absorbed by the plants. The excess nitrogen can leach into the soil and enter waterways as nitrate (NO_3^-). This nitrate is highly soluble in water and can easily be transported through the soil into groundwater and surface waters, such as rivers (Jyoti. T., *et al*., 2022).

1.4 Objectives and hypothesis

1.4.1 Main objective

- Evaluating the performance of new early maturing Seed Co maize hybrid varieties under low nitrogen conditions.

1.4.2 Specific objectives

1. To evaluate the effect of low nitrogen conditions on different maize genotypes on their vegetative growth stage

2. To evaluate the disease resistance on newly developed early maturing hybrid varieties

3. To evaluate the effect of low N conditions on different maize genotypes on their reproductive growth stage

4. To evaluate grain yield potential of new early maturity Seed Co maize hybrid under low N condition.

1.4.3 Hypothesis

- There is a genotypic effect on the vegetative growth stage under low N conditions.
- There is a genotypic effect on disease resistant under low N conditions.
- There is a genotypic effect on the reproductive growth stage under low N conditions
- There is a genotypic effect on yield under low N
- There is a genotypic effect on the performance of the new early maturing Seed Co maize hybrids under low N conditions

CHAPTER TWO

2.0 Literature Review

2.1 Introduction to Maize Production and Variety Selection

Maize, is an important cereal crop, it is used as both a staple food and cattle feed (Saritha, 2020). It has a lot of nutrients, the table below shows nutrient composition of white maize grain.

Table 1 the composition of maize grain per 100g edible portion.

Composition	**Per 100g of edible portion**
Carbohydrates	**71.88g**
Proteins	**8.84g**
Minerals	**1.5g**
Calcium	**10mg**
Phosphorus	**348mg**
Fibre	**2.15g**
Fats	**4.57g**

. Maize, with its high genetic production potential, it is a flexible crop that can be produced in a variety of seasons and ecosystems (Bangarwa, 2021). The choice of variety has a significant impact on crop performance, prospective yield, and resistance to biotic and abiotic stressors. The selection of maize varieties by farmers is contingent upon a number of factors, including market demand, pest and disease pressure, soil type, climate, and water availability. According to Mutanyagwa (2018), yield, farm size, household size, and agro-ecological zones all matter a lot when making this choice. Waldman (2017) emphasized the difficulty of this decision, which is influenced by perceptions of climate fluctuation, knowledge on seed performance, and the availability of seeds locally. The number of accessible maize varieties has increased thanks to developments in breeding and biotechnology, with hybrid variants becoming increasingly popular. Additionally, genetically modified maize cultivars with features like herbicide and insect resistance are being created. In a number of agricultural systems, choosing varieties with the best potential for profitability, sustainability, and maize production is crucial.

Maize farming is a major subsistence crop for small-scale farmers, providing them with self-sufficiency, income, and food security. Maize is a key cultural and social symbol in Southern Africa, and its products and meals are integral to the region's culinary and cultural heritage (Blackie, 1990). In Southern Africa, maize has long been cultivated and adapted to different agro-ecological zones, enabling communities to endure climate shocks and continue producing food in harsh conditions. Maize is critical to rural economies and lives, particularly in Africa. Blackie (2020) underlines the potential for transformational development in the maize mixed farming system, which includes chances for diversification and intensification. A vital commodity for regional commerce and integration, maize promotes economic cooperation and food security in the region. However, food security, livelihoods and regional stability may be significantly impacted by variables like pests, diseases, climate change, or agricultural policies. Consequently, the welfare of the populace and the general development of the area depend on guaranteeing sustainable maize production and resolving issues in the maize sector.

2.2 Zimbabwean Communal Farmers

Most of the communal farmers in Zimbabwe grow maize and they rely so much on this crop to feed their families. Most of these communal farming areas are located in rural part of Zimbabwe, often in less fertile regions compared to the commercial farming areas. In recent years, communal farmers have uncounted numerous difficulties, including severe droughts that have had a significant impact on them, economic instability, and limited availability of agricultural resources, extension services, and market access.

2.2.1 High Fertilizer Cost in Zimbabwe

Most of the farmers in Zimbabwe specifically the communal farmers have faced high input cost and high fertilizer cost being one of the major input with increased prices. Over the past two years farmers have struggled with high fertilizer prices, first driven by natural gas price increases which raised the cost of nitrogen production in 2021 (Chingono, 2023) .Fertilizer prices in Zimbabwe have increased significantly and also in other countries that relied on supplies from the warring Russia and Ukraine countries. The two countries are major suppliers of fertilizers, especially to African nations and the Ukraine/Russia war has seen supplies dwindling while the price of the commodity increased.

In Zimbabwe, fertilizer prices rose by about 30% for the past two years, with 50kg bag of basal fertilizer which a farmer bought for US$35 has now risen to almost US$45 and a bag of top-dressing fertilizer is now around US$60, causing viability challenges in crop production for Zimbabwean farmers, (Farmers Review Africa, 2022).

This problem however has long been there and goes way back to beyond 2002. The current war has only worsened an already existing challenge to Zimbabwean communal / resource poor farmers. The increasing cost of inputs and high transport costs make external inputs unaffordable for the smallholder farmer (Spencer, 2002). NEPAD (2006) reported a decline in inorganic fertilizer use to 8kg/ha due to such challenges, that are still there up to date.

Zimbabwe Farmers Union economist Nyasha Taderera talks about fertilizer contributing 50% towards the cost of crop production, implying that any increase in fertilizer prices significantly affects a farmer's income. Communal farmers are worse off due to high costs of fertilizers they apply below soil requirements and this seriously affects their yields and returns. Such conditions, it has been very difficult for the poor communal farmers of Zimbabwe to keep up, so they are forced to risk growing maize without fertilizers or with the little they can afford with the hope of at least getting something towards food. Some communal farmers can even gamble on growing their crop without applying fertilizers at all, due to the high costs.

2.2.2 Fertilizer Cost in Other Countries

Many African countries mostly depend on countries like Russia, Ukraine and Belarus for their fertilizer supply, however due to the occurrence of the war between Russia and Ukraine which has led to reduced supply of these fertilizers has led to shortage and price hikes with doubling of fertilizer prices between 2020 and 2022. Countries like Kenya, Uganda and Tanzania have been affected (Hassan, 2023).

2.3 Nitrogen Fertilizer

Nitrogen fertilizers are an important input in maize production, they have a major nutrient which is of paramount importance in the production of maize, thus the nitrogen nutrient. These nitrogen fertilizers when applied in correct doses during maize production they contribute towards the farmers getting high yields at the end of the growing season since yield is the major output. However, there are other benefits which are obtained from applying nitrogen fertilizers such as improved plant growth, improved grain development, increased photosynthetic capacity, increased resistance or tolerance to diseases etc. These nitrogen fertilizers are useful in every growth stage of maize.

2.4 Nitrogen Use in Maize

Nitrogen plays a crucial role in maize (*Zea mays L*) development. It is vital for processes of maize development such as the vegetative stage and reproductive stage. It also plays a crucial role in disease tolerance mechanisms, all these in turn help in optimizing yield at the end if the growing season. In maize development 50kg/ha of nitrogen is required to facilitate its growth.

2.4.1 Roles of Nitrogen in Maize Anthesis

Anthesis is the process whereby pollen is released. The key roles of nitrogen during maize anthesis include pollen development, nitrogen is essential for the development and maturation of pollen grains in maize. Adequate nitrogen availability ensures the proper formation and viability of pollen, which is necessary for successful fertilization (Jha, 2021)

Anther development is also affected by nitrogen content. It contributes to the growth and development of the anthers, which are the male reproductive structures in maize flowers. Sufficient nitrogen supply promotes the enlargement and maturation of the anthers, enabling them to release pollen effectively (Uribelarrea, *et al*., 2002)

The nutrient has an effect on tassel development. The tassel is the male inflorescence of the maize plant, and nitrogen plays a vital role in its development. Nitrogen availability affects the size, branching, and pollen production of the tassel, which directly influences the plant's ability to fertilize the female silk (Mohamed .W, 2014)

Nitrogen remobilization can also occur within the plant especially under low N levels. During anthesis, nitrogen stored in vegetative tissues can be remobilized and transported to the developing reproductive structures, such as the tassel and developing kernels. This nitrogen remobilization supports the high nitrogen demand during the reproductive phase (Gallais, 2004).

2.4.2 Roles of Nitrogen in Silk Development

Silk Development and Emergence are influenced by the presence of Nitrogen.it is essential for the growth and development of the silk, which is the female reproductive structure in maize. Adequate nitrogen availability promotes the elongation and emergence of the silk, ensuring that it is receptive to pollen grains during anthesis (Uribelarrea, *et al.*, 2009) .

Nitrogen supply influences the duration and receptivity of the silk. Sufficient nitrogen helps maintain the silk in a receptive state for a longer period, increasing the chances of successful fertilization by pollen grains (Jha, 2021).

Kernel set and development is another parameter that can be affected by N levels. Nitrogen availability during silking influences the number of kernels set and their subsequent development.

Adequate nitrogen supply promotes the formation and growth of kernels, contributing to higher grain yield (Uribelarrea, et al., 2009).

Nitrogen can help the maize plant better withstand abiotic stresses, such as drought or heat, during the silking stage. Nitrogen-efficient plants are more resilient and can maintain silk development and receptivity under stressful conditions (Jha, 2021)

2.4.3 Roles of Nitrogen in Maize Ear Height

Nitrogen helps in plant growth and development. The nutrient that promotes overall plant growth and development in maize in nitrogen. Adequate nitrogen availability supports the elongation of the stem, which ultimately determines the placement of the ear on the plant (Trachsel, 2011).

Nitrogen affects the elongation of the internodes, which are the segments of the stem between consecutive leaves. Increased nitrogen supply can enhance internodal elongation, leading to a taller plant and a higher ear placement (Sangoi *et al*, 2002) Nitrogen is essential for the development of leaves and for the photosynthetic capacity of the plant. Improved nitrogen status can increase leaf area and chlorophyll content, enhancing the plant's ability to produce and allocate the necessary assimilates for ear development (Borras, 2003).

Nitrogen availability influences the partitioning of biomass within the maize plant. Adequate nitrogen can promote the allocation of resources towards the reproductive structures, including the developing ear, leading to a higher ear placement on the plant (Uribelarrea, *et al*., 2009).

The ear shank, which connects the ear to the stem, is an important structure that determines the final ear height. Nitrogen nutrition can affect the growth and development of the ear shank, influencing the final positioning of the ear (Borras & Otegui, 2001).

However, the response of maize ear height to nitrogen availability can be influenced by the genotype and the growing environment. Different maize cultivars may exhibit varying degrees of plasticity in their ear height in response to nitrogen supply (Sangoi *et al*., 2002).

2.4.4 Roles of Nitrogen in Plant Height

It is important for stem elongation. Nitrogen is an essential nutrient for the growth and development of the maize plant. Adequate nitrogen availability promotes cell division and expansion, leading to increased internode elongation and, consequently, taller plant stature (Borras, 2003).

Nitrogen is a key component of chlorophyll and other photosynthetic enzymes. Improved nitrogen status enhances leaf area and photosynthetic capacity, providing more assimilates for plant growth and height development (Borras & Otegui, 2001).

Nitrogen availability influences the activity of the apical meristem, which is responsible for the elongation of the stem. Adequate nitrogen promotes cell division and differentiation in the meristem, driving the upward growth of the plant (Trachsel, 2011).

Root Growth and Nutrient Uptake: Nitrogen plays a role in the development and function of the root system. Improved root growth and nutrient uptake capacity due to higher nitrogen availability can support the overall growth and height of the maize plant (Gallais, 2004).

2.4.5 Roles of Nitrogen in Maize Anthesis-Siliking Interval

The anthesis-silking interval refers to the time difference between the emergence of the male (tassels) and female (silks) reproductive structures. Nitrogen then contributes in synchronization of male and female flowering. Adequate nitrogen supply can help to ensure that the tassels and silks emerge simultaneously, thereby reducing the ASI (Otegui, 2015). According to pollen shed occurs over a 5-to-8-day period and silks are viable and receptive to pollen up to 7 to 10 days. A smaller ASI value means a greater chances of successful seed set, increased kernel number and increased yield. (Elmore, 2012). Nitrogen availability impacts the development and viability of pollen grains as well as the emergence and growth of the silks. Proper nitrogen status can support the concurrent maturation of these reproductive structures, minimizing the ASI (Uribelarrea, et *al*., 2002).

Nitrogen influences the partitioning of carbohydrates and other resources between the vegetative and reproductive structures of the maize plant. Balanced nitrogen nutrition can facilitate the allocation of resources towards the timely development of both the tassels and silks, reducing the ASI (Edmeades, *et al*., 2000).

Nitrogen availability can enhance the plant's tolerance to various abiotic stresses, such as drought, which can otherwise delay silk emergence and increase the ASI. Adequate nitrogen improves the plant's ability to maintain synchronous flowering under stress conditions (Wolfe *et al*., 1988).

The response of maize ASI to nitrogen availability can be influenced by the genotype. Different maize cultivars may exhibit varying degrees of sensitivity to nitrogen status concerning the synchronization of male and female flowering (Uribelarrea, *et al*., 2009).

2.4.6 Roles of Nitrogen on Disease Resistant Mechanisms

Nitrogen plays a crucial role in influencing the disease tolerance of maize (*Zea mays L*) plants.

Nitrogen is a key component of various biochemical compounds involved in the plant's defense against pathogens. Adequate nitrogen supply can enhance the production of phenolic compounds, phytoalexins, and other antimicrobial substances, which can improve the plant's resistance to diseases (Dordas, 2008).

Nitrogen availability affects the structural integrity of plant cell walls, which can act as physical barriers against pathogen invasion. Proper nitrogen nutrition can lead to the deposition of lignin, cellulose, and other structural components (Walter, 2007)

Nitrogen availability can enhance the plant's ability to acquire and utilize other essential nutrients, such as phosphorus and potassium, which are also important for disease resistance. Balanced nutrient status can bolster the plant's overall defense mechanisms (Dordas, 2008).

Nitrogen can play a role in triggering and maintaining the plant's systemic acquired resistance (SAR) and induced systemic resistance (ISR) pathways. These defense mechanisms can help the plant recognize and respond more effectively to pathogen attacks (Walter, 2007). When maize is supplied with sufficient N nutrient it will possess antibiosis, antixenosis and tolerance type of resistance. (Nair, 2017)

Nitrogen availability can enhance the plant's tolerance to various abiotic stresses, such as drought or extreme temperatures, which can otherwise make the plant more susceptible to disease development. Proper nitrogen nutrition can improve the plant's overall resilience (Dordas, 2008).

2.5 Benefits of Combining Early Maturing and Low N Tolerance Traits in a Variety.

Early maturing maize varieties, often referred to as early maturity maize varieties, are cultivars of maize that mature comparatively quickly. These cultivars are specially bred and chosen because they can finish the crop cycle and mature faster; on average, it takes them fewer days of about 90 to 95 days to reach physiological maturity (Bello, 2012). It has been verified that early maturing maize cultivars can assist farmers in reducing the hazards brought on by unpredictable weather. Because these cultivars develop more quickly, there is less chance of a water deficit throughout the crucial growth stages, which lowers the possibility of crop failure (Krell 2021). They can also aid in yield stabilization, especially in areas where seasonal yield volatility is significant (Fang, 2019). Early maturing cultivars are beneficial in areas that are prone to drought, irregular rainfall, or the early onset of dry periods. These types increase the likelihood of a successful harvest and lower the risk of crop failure by maturing earlier and exposing the crop to less favourable weather.

Maize varieties tolerant to low N are also very important maize cultivars, these are maize cultivar that can thrive under low nitrogen conditions. These varieties are able to grow and perform quite well in low nitrogen conditions. This trait is very important to farmers who are financially strained with limited resources. It helps these farmers to still obtain good yields at the end of the growing season.

When we combine these two in a variety(the early maturing characteristic and low nitrogen trait) , will ensure that resource strained communal farmers growing in lands that are not fertile will obtain good yields at the end of the growing season.

There is also improved adaptation to varying growing conditions, this so in that if the variety is early maturing it allows the crop to escape late season stresses like drought heat or frost which can negatively impact yield then the low N trait helps in making the crop better suited to grow in soils with limited nitrogen availability or where nitrogen fertilizer application is restricted.

There is also increased crop resilience, the combination of early maturity and low N trait can make the maize variety more resilient to various stresses such as drought, pest and disease, improving its overall performance and stability.

CHAPTER THREE

3.0 Materials and Methods

3.1 Site Description

The experiment was conducted at Seed Co Kadoma Research Station (KRC)

Table 2 Trial site description.

SITE	Kadoma Research Centre
AGRO ECOLOGICAL ZONE	III
RAINFALL	450 to 800mm
ALTITUDE(m)	1183m
GEOGRAPHICAL COORDINATES	18˚20ˈ24ˈˈS 29˚49ˈ00ˈˈE
TEMPERATURE	30˚ to 40˚
SOIL TYPE	Black clay

3.2 Experimental Design

The 20 hybrids were planted in the field using an alpha lattice design (13 experimental tests and 7 commercial / check varieties). The trial was replicated 3 times, with each replicate accommodating 4 incomplete blocks with 5 entries per block.

3.3 Field Management

3.3.1 Land Preparation and Planting

The field was ripped using a ripper, ploughed using a tractor-drawn plough to a depth of about 30cm followed by disking to break clods. Rolling was carried out to break excessive clods. A plant spacing of 50cm in-row and 75 cm inter-row was used.

3.3.2 Crop Water Requirements

The trials were rain-fed but irrigation was used at planting for emergence, Irrigation scheduling was determined by the crop water requirements as dictated by the stage of development of the crop and evapotranspiration. As a guideline, 7mm/hr. for six hours was applied after planting to facilitate germination, and a nine to 15-day irrigation cycle was administered depending on crop water needs.

3.3.3 Weed and Pest Control

Weeds were controlled using herbicides and hand weeding. Pre-emergent herbicides such as atrazine, glyphosate, and stellar star were used for chemical weed control.

Table 3 Herbicide used

Herbicide applied	Time of application	Application Rate	Weed controlled
Atrazine	Pre and early post emergence	3ltrs/ha	*Eleusine indica*, java grass, green foxtail (grassy weeds)
Glyphosate	Pre – emergence	500gm or 1 sachet in 16ltrs sprayer 2.5ltrs/ha	Blackjack, finger grass, crowfoot grass, pigweed (all grassy weeds and broadleaf weeds)
Stellar star	Post – emergence	1ltr/ha	Grass weeds (Rhodes grass, crab grass, upright star bur)

3.4 Data Collection

Data was collected for the following traits; grain yield, plant height, ear height, root lodging, stem lodging, moisture content, flowering, cob rot, plant count and grain weight.

Table 4 Description of trials recorded in the field

Agronomic trait	**Description**
Grain yield	Grain yield was recorded as shelled grain weight per plot adjusted to

	12.5% moisture (automatically adjustment factor) and converted to tonnes per hectare. A weighing wagon used to take records.
Plant height	Plant height was measured as the height between the bases of the plant to the insertion of the first tassel branch of the same plant and was measured after the soft dough stage. A measuring rule was used. (cm)
Ear height	Measured as height between the bases of a plant to the insertion of the top ear of the same plant. measuring rule used, measurement recorded in cm
Flowering (Days to mid-pollen days to mid-silk)	As soon as the plants starts flowering records are taken every day for every plot. For days to mid-pollen, it is when we have a physical count of plant which would have shed its pollen, when 50% of the plant per plot have shed its pollen, we record the day it would have reached 50%. For days to mid-silk, we do the same as of pollen just that in this case we check the plants that would have produced silk, if the plot would have reached 50%, we record the date in a gadget.
Moisture content	Percent water content of grain is measured at harvest. A weighing wagon was used as it records the grain yield it would simultaneously record moisture content
Thousand grain weight(TGW)	A scale was used to measure the total weight of a sample containing a thousand grains, then the weight of the seed sample was divided by the

number of seeds in a sample then multiply the results by 1000 to obtain the TGW.

3.5 Data Analysis

GenStat Eighteenth Edition (Payne R W *et al*., 2019) was used for the analysis of data. The Least Significant Difference (LSD) ($p<0.05$) was used to separate means where there was significant difference.

CHAPTER FOUR

4.0 Results

4.1 Effects of Different Maize Genotypes on Ear Height (m).

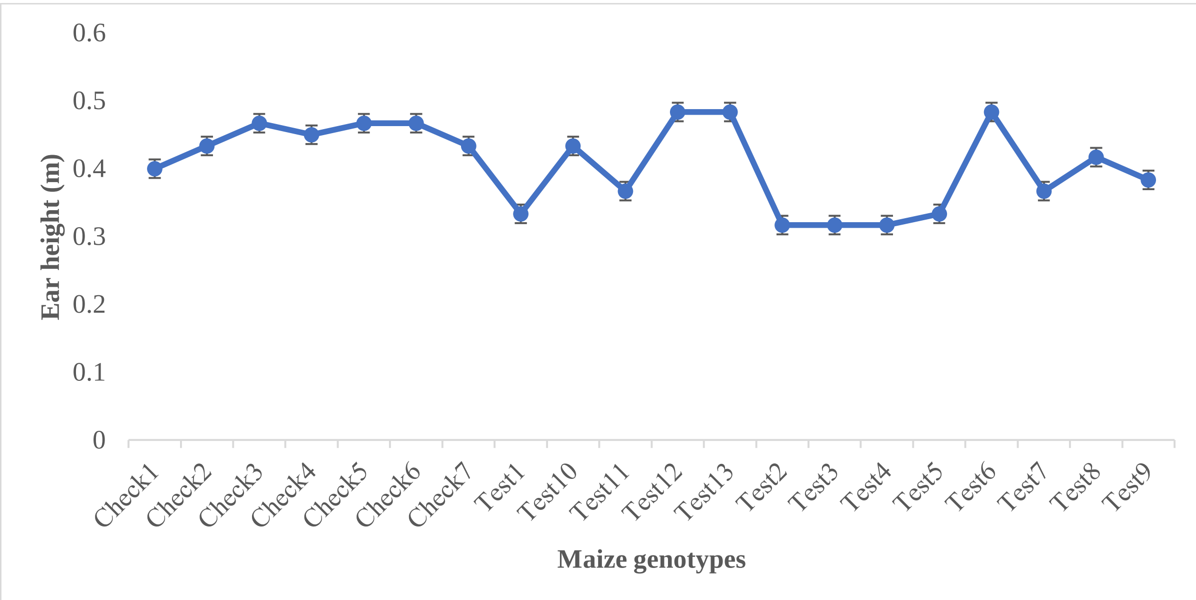


Figure4.1 Effect of genotype on ear height (m)

There was a significant difference ($p<0.05$) on ear height of all maize genotypes evaluated. Genotypes Test 6, Test12 and Test 13 had the same good score of 0.48m in terms of optimal ear height followed by genotype Check3, check 5 and Check 6 with the same score of 0.47m. Amongst other genotypes tested. The least performing genotypes were Test 2, Test 3, Test 4 and Test 5 with the same score of 0.32m, they the lowest ear height.

4.2 Effects of Different Maize Genotypes on Days to Flowering (days)

The analysis of variance for the days to flowering traits such as days to anthesis, days to silking and anthesis-silking interval were recorded and presented in Figure 4.2, Figure 4.3 and Figure 4.4 respectively. There were highly genotypic significant difference ($p<0.001$) for traits such days to anthesis, days to silking and anthesis-silking interval mind the line spacing here.

4.2.1 Effects of Different Maize Genotype on Days to Anthesis

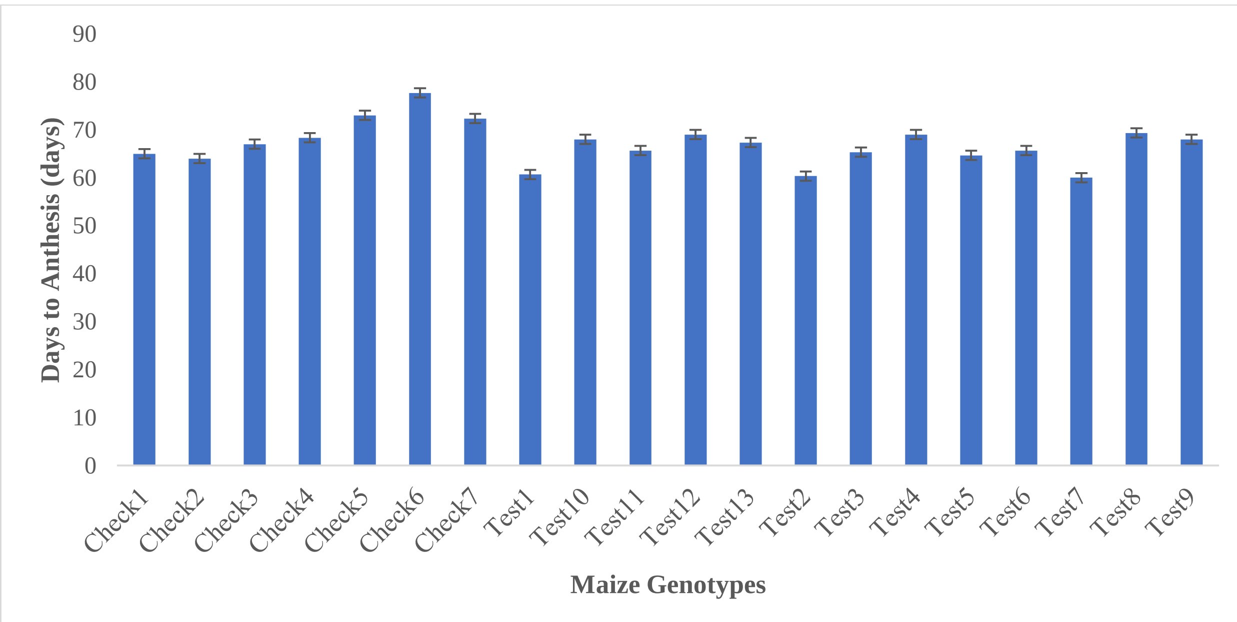


Figure 4.2 Effect of genotype on days to anthesis.

The graph showed the effects of maize genotype on days to anthesis, it showed that test 7 had the least days which means it was the earliest with 60 days. Test 1 and 2 followed at 62 days. Test 5, 6, 3 performed the same as of check 1 and 2. Test 4, 8 12 were very late.

4.2.2 Effects of Different Genotypes on Days to Silking.

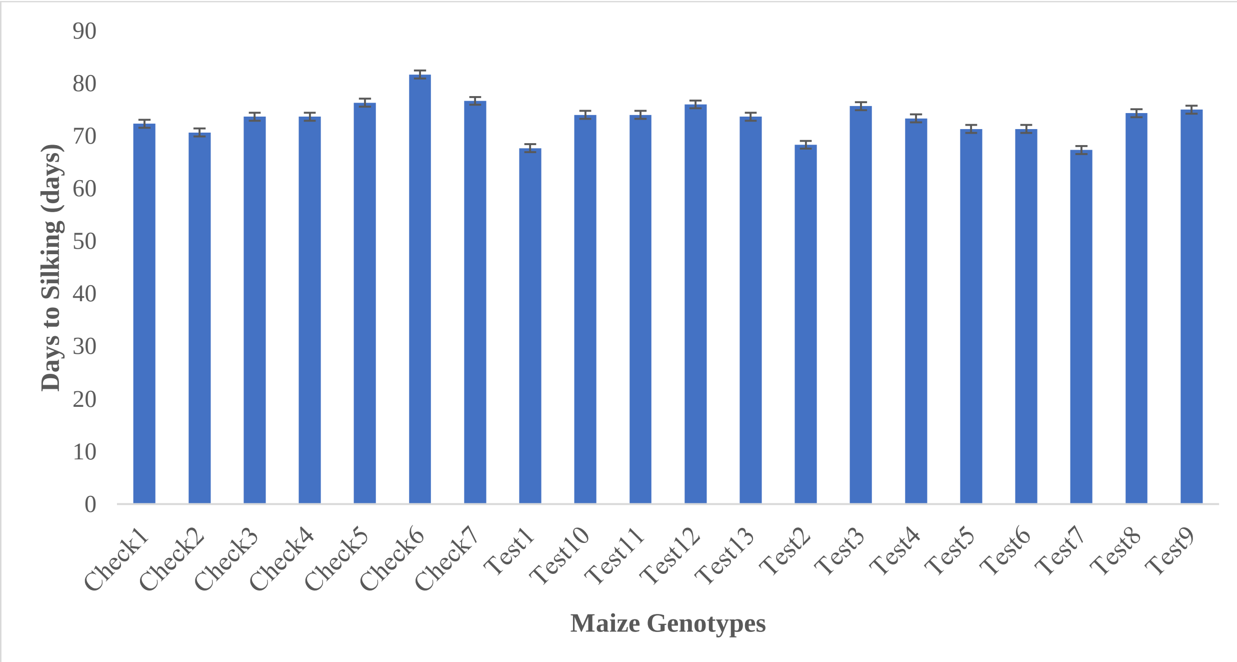


Figure 4.3 Effect of genotype on days to silking.

Genotype had a significant effect on days to silking ($p<0.05$). The ANOVA showed that Genotype 7, 1, 2 had the earliest days to silking (day 67). Test 5 and 6 performed the same as local check 2 (day 70). Then test 4, 11, 13 also had the same performance with that of check 3 and 4 with 73 days. Test 9, 3, and 12 showed the highest number of days to silking of 75 days.

4.2.3 Effects of Different Genotype on Anthesis – Silking Interval

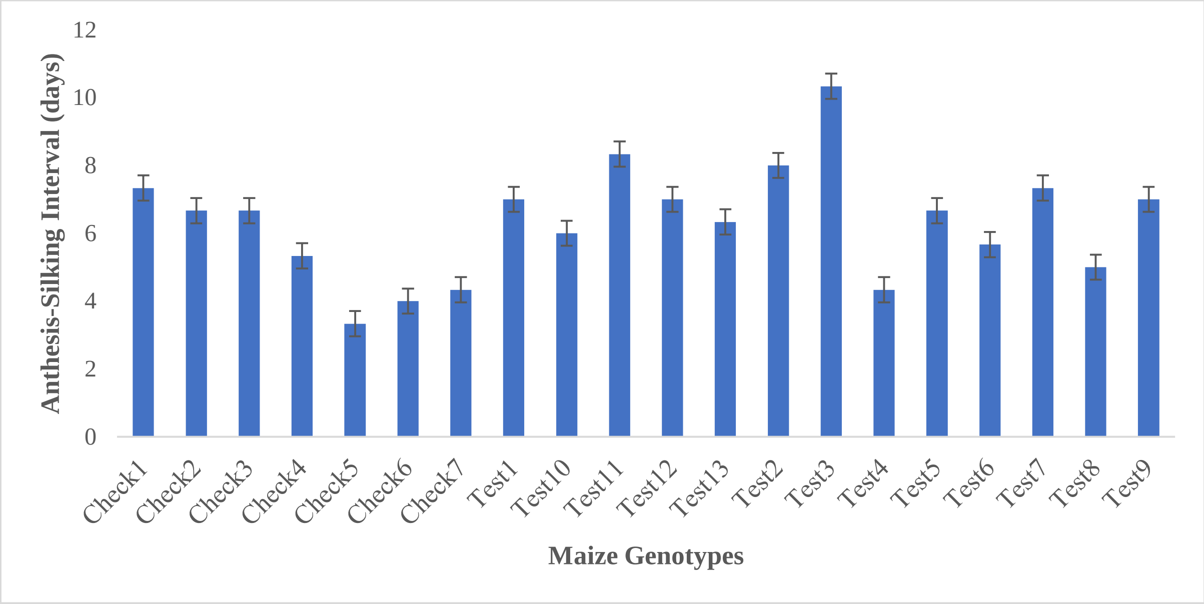


Figure 4.4 Effect of genotype on Anthesis-silking interval

Genotype had an effect on the anthesis-silking interval ($p<0.05$). The graph presented that Genotype Test 4 had the least number of days of anthesis-silking interval of 4 days same with that of commercial check 5 and 6. Test 8 and check 4 had the same number of days of 5 days. Genotype test 3 had the highest number of days which were 11 days.

4.3 Effects of Different Maize Genotypes on Thousand Grain Weight.

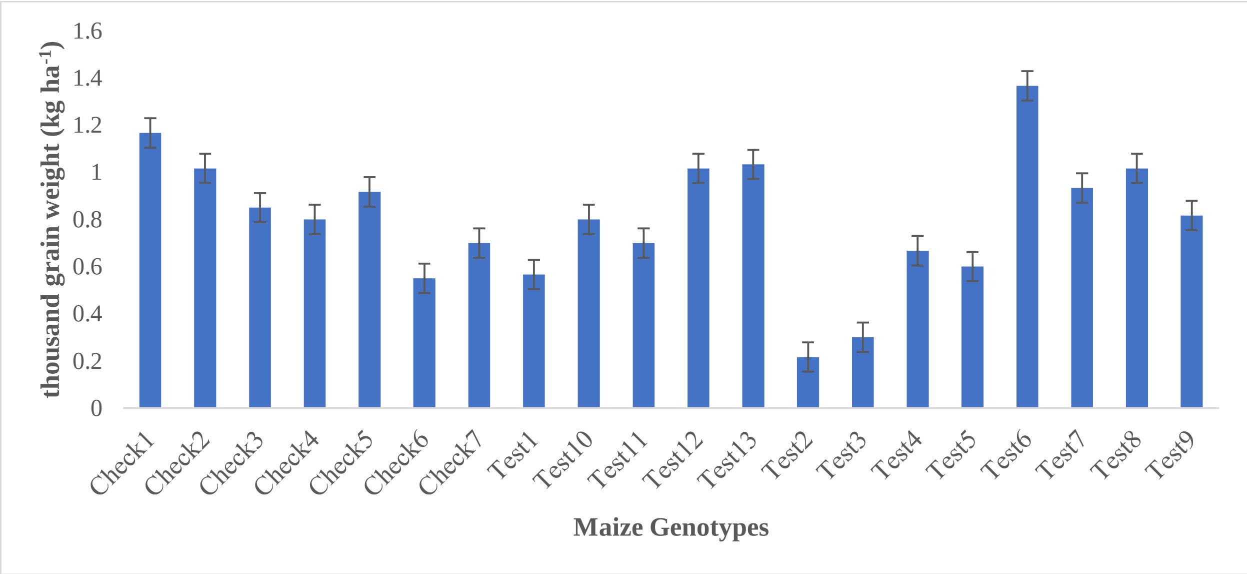


Figure4.5 Effect of genotype on thousand grain weight

Variety had an effect on thousand grain weight ($p<0.05$). Test 6 showing a significant difference against check 1. Test 8, 7, 13, 12 had almost the same performance with that of local check 2 and 5. Test 9, 10, 11 almost had the same weight with that of check 5. Test 2 and 3 performed badly. Genotype test 6 had the highest weight of 1.4 kg/ha and test 2 and 3 with the least weight of 0.2kg/ha and 0.3 kg/ha respectively.

4.4 Effects of Different Maize Genotypes on Grain Yield (T Ha^{-1}).

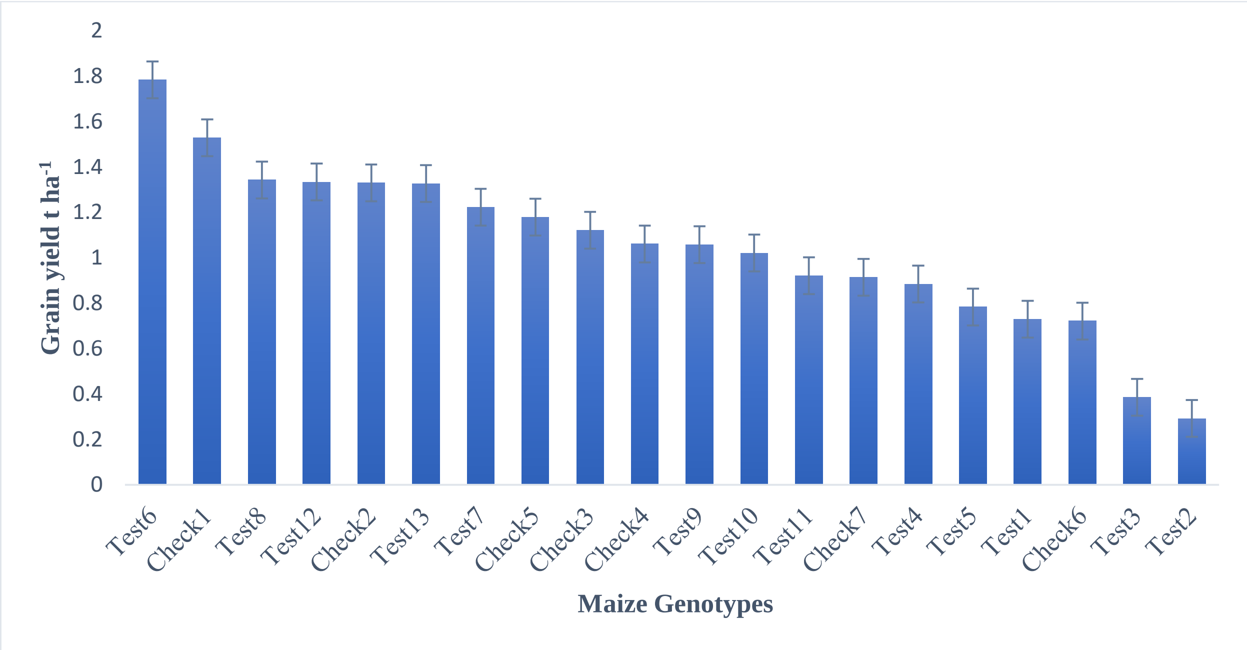


Figure4.6 Effect of genotype on grain yield

The variety had an effect on grain yield ($p<0.05$). Test 6 yielded the highest (1.8t/ha) with a significant difference against check1. Test 8, 12,13,7 also performed very well with almost the yield as of check 2. Test 9, 10, 11 performed the same with check 4. However test 2 and 3 performed badly yielding the least with 0.3kg/ha and 0.4kg/ha respectively.

4.5 Analysis of Variance for Other Agronomic Traits

There was no significant difference (p>0.05) for other agronomic traits which are grey leaf spot (GLS), maize streak virus (MSV), number of plants (NP), plant height (PH), and moisture % (MOI)

Table 5 Agronomic mean square values and significant tests for maize genotypes evaluated at KRC.

Change	D.F.	GLS	MSV	NP	PH	MOI
Rep	2	0.05^{ns}	0.07^{ns}	12.82^{ns}	0.20***	0.18^{ns}
Block	3	0.06^{ns}	0.02^{ns}	5.89^{ns}	0.05^{ns}	1.01^{ns}
Rep.Block	6	0.36^{ns}	0.02^{ns}	14.17*	0.06*	5.37^{ns}
Genotypes	19	0.41^{ns}	0.03^{ns}	6.83^{ns}	0.04^{ns}	1.49^{ns}
Residual	29	0.25	0.03	4.41	0.02	4.70
Total	59	0.30	0.03	6.54	0.04	3.39
Mean		2.35	1.03	39.03	1.53	14.31
P value		0.12	0.6	0.14	0.12	0.79
SE		0.41	0.15	1.72	0.12	1.77
$LSD_{0.05}$		0.84	0.31	3.51	0.25	3.62
CV%		21.44	18.06	5.38	9.80	15.15

NB: LSD-least significant difference at 5%; CV-coefficient of variation; SE-standard error; *,**,*** indicates significant at p≤0.05, p≤0.01 and p≤0.001 respectively; DF-degrees of freedom; MOI-moisture content (%), PH-plant height (cm); ; GLS-grey leaf spot (%); MSV-maize streak virus (%); NP-number of plants

CHAPTER FIVE

5.0 Discussion

Nitrogen plays a crucial role as a vital nutrient in the growth and maturation if maize plants. It has a significant impact on the outcome of experiments and the interpretation of results. Understanding and also in evaluating of the different maize parameters helps to determine the suitable maize hybrids that performs well in areas of low N. It also helps in developing management practices that optimize yield and quality of maize under different growing conditions.

5.1 Effect of genotype on Ear height

There was a significant difference on the ear height of the planted experimental maize hybrid and local checks. Maize ear height is an important agronomic trait that directly affects nutrient utilization efficiency, lodging resistance and ultimately maize yield (Smith, 2020). Lower maize ear height helps the plant to be resistant to lodging and increase ear height can contribute to greater lodging risk especially under nutrient deficient condition like low N (Moreno, et al., 2018) . In the case were the ear height of the maize genotype under low N is at optimal height (optimal ear height 0.4m to 0.5m) (Han, 2023), if exposed to areas of strong wind, heavy rains or there environmental factors the maize will be able to resist to lodging (Wang, X., 2021). From the results obtained it showed that most of the genotypes planted had optimal ear height, test 2, 3 and 4 had the lowest ear height of 0.32m. Test 5 and test 1 also followed with a low ear height of 0.33m. However test 6, 13, and 12 showed optimal ear height of 0.5m. Ear height helps to optimize grain yield in that optimal EH under low N ensures that there is increased absorption of nutrients from the soil and allocate the limited resources to grain production rather than excessive vegetative growth (Wang, X., 2021). Also low ear position reduce leverage effect on the stalk making the plant more stable. However EH significantly impact the grain yield since optimal positioned ears tend to produce more kernels per ear contributing overall yield (Sangoi, 2001). EH may ensure that the leaves around the ear , which are crucial for photosynthesis receive adequate sunlight, this is important in that in the case were the N levels are low the plant will need to maximize photosynthesis to compansate to reduced nutrient available.

5.2 Effects of genotype on days to anthesis

A significant difference in days to anthesis of the planted genotypes was noticed, with test 7 having the least number of days to anthesis which were 60 days, followed by test 1 and 2 with 61 days. Anthesis is crucial for pollination and once missed they have an impact on the overall yield. Days to anthesis timing and duration can be determined by factors such as temperature, light and humidity. According to (Zhao, 2019) the earlier flowering maize plants were able to complete key reproductive process like pollination and grain filling before nitrogen deficiency became too severe. In contrast late flowering genotypes experienced greater yield reductions under the low nitrogen conditions. According to (Beck. D., 2003) reduced leaf area development, altered stem elongation and hormonal imbalances are the key physiological factors that brings about the differences in days to anthesis under low nitrogen conditions.

5.3 Effect of genotype on days to silking

The maize genotype had an effect on days to silking under low nitrogen conditions. It is observed that genotypes with earlier silking days (shorted days to silking) generally produced higher yields compared to those which produce silks late (Banziger, 1999). According to (Moose, *et al.*, 2004), the genotypes with earlier silking dates produced high yield compared to the late silking genotypes. The genotype that took longer to reach silking exhibited greater yield reduction under low N environments. This is \,;mostly likely because of the prolonged vegetative phase depleting the limited soil nitrogen before the critical reproductive stage. From the results obtained they showed that genotype test 1 and 7 had the least days to silking of 67 days. Test 2 followed with 68 days. Genotype test 12 was the one with the most number of days to silking of 76 days same as that of check 5 (late silking). Under low nitrogen conditions for the early maturing hybrid maize genotypes, 55 to 60 days are the ideal number of days to silking, the genotypes found within this range would normally have the increased yields compared to those which would have produced their silks late (Edmeades, et al., 1995). Physiologically the reduced leaf area and hormonal imbalances affects the number of days to silking of maize genotypes under low nitrogen conditions (Banziger, 1999).

5.4 Effect of genotype on anthesis-silking interval.

According to (Lima, 2022) anthesis- silking interval is the period between pollen shed and silking, hence delayed silking relative to pollen shed is a good indicator of response to abiotic stresses in maize. ASI is affected by nitrogen availability and this in turn helps to assess the utility of ASI to indirectly predict grain yield (GY). The shorter the ASI the better. Effective pollination depends on the timing and synchronization of tassel and silk emergence. The supply of nitrogen can affect how silk and tassel growth are coordinated. Sufficient nitrogen availability encourages tassels and silks to emerge on time, guaranteeing the best possible overlap between pollen shed and silk receptivity a crucial aspect of successful fertilization and pollination. (Wilson, 2022) In the case of low nitrogen condition the planted genotypes showed test 4 ,8, 6 had the least number for ASI of 4, 5 and 6 days respectively and test 3 with the highest number of 11 days . Pollen shed occurs over a 5 to 8 day period the tassel releases pollen. When the pollen shed it remains viable for a short period of time ranging from 30 mis to 24 hour (Liang, *et al.*, 2023) and silks are viable and receptive to pollen for up to 7 to 10 days. So when we have many day in between anthesis and silking it reduces the chances of an effective pollination and fertilization of the plant hence reduction of the GY. In this research we were also evaluating on the genotype which are early maturing and from the results obtained we have test 1 and 2 which produce their pollen and silks earlier and have ASI of 7 days which makes the early maturing hybrids. In the case of short season environment they can thrive and perform well. These test out performed the commercial check 1

5.5 Effect of genotype on grain yield

There existed a notable disparity in the grain yield among the various maize genotypes that were cultivated. Grain yield is an important factor to farmers since at the end of the growing season one expects high yields so in the case of resource strained farmers they tend to benefit from growing these high yielding varieties under low N conditions. Grain yield is a parameter which is influence by other agronomic traits. These parameter will have a positive correlation for them to ensure that there are high yields.

Days to anthesis, days to silking and ear height have an impact on the overall yield at the end of the growing season. Ear height is possitively correlated to days to silking and anthesis in that taller maize plant with higher ear placement tend to have delayed silking emergence and polle shed, this relationship is however driven by the additional time required for taller plant to accumulate sufficient biomass and reach reproductive maturity. The shorter the days to anthesis and silking are generally desirable, as they indicate ealier maturity and a longer grain fill period. The optimal ear height balances the benefits of improved light interception and ease of harvest while minimizing the risk of lodging. The coordinated timing of anthesis and silking is crucial for successful pollination and kernel set, which in turn diectly impact grain yield. (Delucchi, 1991).

For maize genotypes to exhibit high yields under low nitrogen the maize plant height is not supposed to be very tall rather under low N conditions the plant height is reduced to around 1.5 to 1.9m optimal height (Chen, 2020). From the results obtained it showed that all genotypes had an optimal plant height under the low N condition with genotypes having their plant height ranging from least height of 1.4m to the highest which is 1.8m.

The maize genotype with the highest grain yield was test 6 with 1.8t/ha it also had great values on other agronomic traits which contributed to its overall yield. It had 6 days of the anthesis silking interval which shows that pollination with these few days was very effective. It also had optimal ear height under low nitrogen of 0.5m and also an optimal plant height of 1.5m which ensure high yields under low nitrogen condtion

These maize genotypes which had high yields showed that in areas of short growing seasons they perform well since these hybrids are early maturing. This also implies that before the harsh conditions strike for example high temperature or before the rains which are required for plant growth stop the maize variety would have received adequate rains enough forits growth hence it performs well. These varieties are well suited to farmers staying in such areas.

5.6 Effect of genotype on plant height

Plant height in maize is an important agronomic trait because it is highly heritable (Peiffer *et al*., 2014), easy to measure, and influences the stalk lodging (Li *et al.*, 2007). Previous research has shown that plant height correlates highly with biomass or grain yield, so it is used for estimating biomass (Salas Fernandez *et al*., 2009; Han et al., 2019) and grain yield. There was no significant difference between the genotypes planted ($P>0.05$) and the plant height of the planted maize hybrids showed that there were not tall. According to Abubakar (2022) morphologically, early maize varieties are generally shorter in height (185-190 cm), early maturing maize hybrids are generally shorter in height due to the genetic selection for faster development and earlier maturity. The height of a maize plant is determined by the number and length of the internodes, which are the segments between the joints of the stem. In early maturing varieties, the growth period is reduced, which means there is less time for the plant to develop tall stalks. This is a result of breeding efforts that focus on creating plants that can complete their life cycle more quickly to avoid environmental stresses or to fit into certain cropping systems where shorter plants are preferred. Additionally in areas with low soil nitrogen, which is a common constraint in sub-Saharan Africa, early maturing hybrids are bred to perform well under these conditions, which may also contribute to their shorter stature.

5.7 Effect of genotype on diseases

The planted genotypes were not susceptible to diseases, there were resistant to maize streak virus and grey leaf spot. There was no significant difference of the planted maize hybrids. Maize planted with insufficient nitrogen tends to be weak and can be attacked by various diseases if not properly managed but from the genotypes planted they were resistant, this showed that the genotypes planted can tolerate the low nitrogen stress, this will allow them to maintain better overall health and resilience against the diseases even under low nitrogen. It can also be that the lines had genetic resistance.

CHAPTER SIX

6.1 Conclusions

Genotype had no effect on vegetative stage, the plant height of the planted genotypes did not vary.

Genotype had an effect on the reproductive growth stage. It had an effect on the ear height, days to anthesis, days to silking and anthesis silking interval. Genotype test 6 and 13 had optimal ear height under low nitrogen conditions. Test 2 and 3 had the lowest EH. The genotypes with the optimal EH can contribute to the development of climate resilient maize variety that can thrive in resource constrained farming system. Genotype test 6 and 13 had number of days of ASI which were within the range of effective pollination. Test 3 was the top worst performer, it had the highest number of ASI of 11 days. It was followed by test 2, 9 and 11 which had ASI of 8 days.

Genotype also had an effect on grain yield with test 6 and 13 with the highest grain yield of 1.8kg/ha and 1.3kg /ha respectively. Since grain yield is influenced by different agronomic traits these test showed great performance of the tested traits and they had increased yield under low nitrogen. Test 2 and 3 had the least grain yield of 0.29kg/ha and 0.39kg/ha respectively.

6.2 Recommendations

Genotypes 6 and 13 are fit to be released to the farmers who are currently growing the commercial checks that were out performed by the genotypes under low N. The small scale farmers who are financially constrained can now grow these varieties as they perform well under low conditions.

Also the farmers in areas of short growing seasons can opt for these early maturing varieties as they grow fast

The genotypes test 3 and 2 performed badly therefore it is recommended that the genotypes can be discarded.

There is need to carry out more researches so as to come up with competitive potential replacements for the worst performers like genotype 2 and 3.

More test and trials to be carried out for these genotypes under different ecological regions and also in areas of different soil types.

References

- Abubakar, A., Manga, A. A., Kamara, A. Y. & Tofa, A. L., 2019. Physiological evaluation of maize hybrids under low nitrogen. *Advances in Agriculture*, x(1155).

- Banziger, M., Edmeade, G.O &Lafitte, H.R., 1999. Selection for drought tolerence increases maize across a range of nitrogen loevels.. *Crop Science,* IV(39), pp. 1035-1040.

- Beck, D., Betran, F.J., Ribaut, J.M, 2003. Genetic diversity, specific combining ability, and heterosis in tropical maize under stress and non stress environments. *Crop Science,* iii(43), pp. 797-806.

- Bello, O. A. S., 2012. Evaluation of Early and Late/ Intermediate Maize Varieties for Grain Yield Potential and Adaptation to a Southern Guinea S. *International Journal of Plant Research,* II(2), pp. 14-21.

- Borras, L., 2003. Seed dry weight response to source - sink manipulations in wheat maize and soyabeans: a quantitative reappraisal.. *Field Crop Research,* II-III(86), pp. 131-146.

- Borras, L. & Otegui, M. R., 2001. Maize kernel weight response to post flowering source sink ratio. *Crop Science,* VI(41), pp. 1816-1822.

- Chen, B., 2020. Genotypic variation in maize plant height under low nitrogen availability. *plant and soil,* 1(450), pp. 209-221.

- Chingono, N., 2023. *Zimbabwe suspends import tax on fertilizer as El Nino looms,* Harare: The Reuters daily briefing newsletter.

- Cicchino, M. E., 2010. Heat stress in field growth maize: responce of physiological determinants of grain yield.. *Crop Science,* iv(50), pp. 1438-1448.

- Delucchi, C., 1991. Relationship between agronomic traits and grain yield in Argentine maize hybrids. *Maydica,* iii(36), pp. 349-354.

- Dordas, C., 2008. Role of nutrients in controlling plant diseases in sustainable agriculture. *Agronomy for sustainable development,* i(28), pp. 33-46.

- Edmeades, G. 0., Lafitte, H. R. & Banziger, M., 1995. *Drought and nitrogen stress tolerance evaluation intropical maize,* s.l.: CIMMYT.

- Edmeades, G., Chapman, S. C., Lafitte, H. R. & Banziger, M., 2000. Selection improves drought tolerance in tropical maize populations:l.Grain in biomass, grain yield, and harvest index. *Crop Science,* iv(40), pp. 1044-1051.

- Elmore, R. W., 2012. *Stress, Anthesis-Silk Interval and Corn Yield Potential,* s.l.: IOWA STATE UNIVERSITY.

- Erisman, J., 2013. consequence of human modification of the global nitrogen cycle. *philosophical transactions of the Royal SocietY B: Biological science,* 368(1621).

- Gallais, A. B., 2004. An approach to the genetics of nitrogen use efficiency in maize. *Journal of Experimental Botany,* 396(55), pp. 295-306.

- Han, 2023. Maize Ear Height and Ear -Plant Height Ratio Estimation with LiDAR Data and Vertical Leaf Area Profile. *Remote Sensing,* 15(4).

- Hassan, M., 2023. *One Year Later Somalia Still Feeling Effects of Ukraine War.* [Online] Available at: http://www.voanews.com/a/one-year-later-somalia-still-feeling-effects-of-ukraine-war-/6977881.html
  [Accessed 12 April 2023].

- Hirel, B., Gouis, L., Ney, B. & Gallias, A., 2007. The challenge of improving nitrogen use efficiency in crop plants: towards a more central role for genetic variability and quantitative genetics within integrated approaches.. *journal of experimental batany,* 9(58), pp. 2369-2387.

- Jha, U., 2021. Nitrogen Use Efficiency in maize; Genetic Architecture, Physiological mechanism, and strategies for improvement. *The Crop Journal,* i(9), pp. 27-24.

- Jyoti. T., Shahzad, A. & Moksh, M., 2022. Nitrogenous Fertilizers: impact on environment sustainability, mitigation strategies and challenges. *International Journal of Environmental Science and Technology,* Volume 19, pp. 11649-11672.

- Liang, Y., Wang, X. & Zhang, J., 2023. Factors influencing the longevity of maize pollen and its implications for crop pollination. *Plant and Soil,* i-ii(478), pp. 123-138.
- Lima, D. C., 2022. utility of anthesis - silking interval information to predict grain yield under water aand nitrogen limited conditions. pp. 151 - 163.
- Makumbi, D., Diallo, A., Kanampiu, F. & Karaya, H., 2018. Genotypic response of tropical maize landraces to drought stress, biomass and associated traits.. *crop science,* 2(58), pp. 689-700.
- Mohamed .W, 2014. Effect of Diffent Nitrogen Source on Tasseling, Silking, Maturing and Grain yield of Hybrid Maize. *Agricultural Plant Science,* 1(32), pp. 56-61.
- Moose, S., Dudley, J. W. & Rocheford, T. R., 2004. Maize selectioction passes the century mark: a unique resource for 21st century genomic. *Trends in plant science,* vii(9), pp. 358-364.
- Moreno, A., Logica, P. & Braganca, H., 2018. Maize lodging: Causes, measerements and assessment. *trends in Agricultural Science,* i(2), pp. 12-17.
- Nair, R., 2017. Plant nutrient management for enhanced insect pest resistance. *Agronomy,* iv(7), p. 72.
- Otegui, M. &. M. S., 2015. Kernel set and flower synchrony within the ear of maize: l.Sowing date effect. *Crop Science,* ii(37), pp. 441-447.
- Quan, Z. et al., 2021. Fate and Use Efficiency of Nitrogen Fertilizer in Maize Cropping System and Their Responses to Technologies and Management Practices. *A Global Analysis of Field 15N Tracer Studies', Earths future,* 9(5).
- Sangoi, L., 2001. Understanding plant density effects on maize growth and development : an important issue to maximize grain yield. *Ciecia Rural,* i(31), pp. 159-168.
- Smith, J., 2020. Genetic regulations of maize ear placement: Implications for yield and harvest efficiency.. *the journal for Agricutural Science,* 3(155), pp. 401 - 411.

- Trachsel, S., 2011. Vegetative growth processes during the flowering period in maize. *Crop Science,* iv(51), pp. 1692-1703.
- Uribelarrea, M., Echarte, L. & Andrade, F. H., 2009. Kernel number determination in Argentinean maize hybrid released between 1965 and 2007. *Field crop research,* II(114), pp. 147-154.
- Uribelarrea, M., Otegui, M. E. & Westgate, M. E., 2002. Pollen production, pollination dynamics and kernel set in maize. *Crop Science,* vi(42), pp. 1910-1918.
- Walter, D., 2007. Influence of nutrition on disease development caused by fungal pathogens; implications for plant diesease control. *Annals of applied biology,* iii(151), pp. 307-324.
- Wang, X., 2021. Genotypic variation in optimal maize ear height under low nitrogen availability.. *Filed crops research,* Volume 260.
- Zhao, X., 2019. Influence of flowering time on grain yield of maize genotypes under limited nitrogen availability. *Agronomy journal,* iv(111), pp. 1928-1937.

APPENDICES

Appendix 1

List of genotypes used

GENOTYPE
CHECK 1
CHECK 2
CHECK 3
CHECK 4
CHECK 5
CHECK 6
CHECK 7
TEST 1
TEST 2
TEST 3
TEST 4
TEST 5
TEST 6
TEST 7
TEST 8
TEST 9
TEST 10
TEST 11
TEST 12
TEST 13

Appendix 2 Analysis of variation of grain yield kg/ha

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ REP_NO	2	1.5515	0.7757	6.79	0.004
+ BLOCK_NO	3	0.7613	0.2538	2.22	0.107
+ REP_NO.BLOCK_NO	6	4.9178	0.8196	7.17	<.001
+ DESIGNATION	19	4.7336	0.2491	2.18	0.028
Residual	29	3.3148	0.1143		
Total	59	15.2791	0.2590		

Appendix 3 Analysis of variation of Anthesis Silking Interval

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ REP_NO	2	23.969	11.984	4.90	0.017
+ BLOCK_NO	3	11.320	3.773	1.54	0.232
+ REP_NO.BLOCK_NO	6	55.363	9.227	3.77	0.010
+ DESIGNATION	19	78.558	4.135	1.69	0.118
Residual	22	53.809	2.446		
Total	52	223.019	4.289		

Appendix 4 Analysis of variation of days to 50% anthesis

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ REP_NO	2	17.4333	8.7167	8.98	<.001
+ BLOCK_NO	3	177.5167	59.1722	60.94	<.001
+ REP_NO.BLOCK_NO	6	107.2333	17.8722	18.41	<.001
+ DESIGNATION	19	790.6422	41.6127	42.86	<.001
Residual	29	28.1578	0.9710		
Total	59	1120.9833	18.9997		

Appendix 5 Analysis of variation of days to 50% silking

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ REP_NO	2	37.217	18.608	5.93	0.009
+ BLOCK_NO	3	76.915	25.638	8.18	<.001
+ REP_NO.BLOCK_NO	6	56.385	9.398	3.00	0.027
+ DESIGNATION	19	440.503	23.184	7.39	<.001
Residual	22	68.981	3.135		
Total	52	680.000	13.077		

Appendix 6 Analysis of variation of ear height (m)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ REP_NO	2	0.025000	0.012500	3.01	0.065
+ BLOCK_NO	3	0.034458	0.011486	2.77	0.059
+ REP_NO.BLOCK_NO	6	0.077667	0.012944	3.12	0.017
+ DESIGNATION	19	0.181716	0.009564	2.31	0.021
Residual	29	0.120284	0.004148		

Total	59	0.439125	0.007443		

Appendix 7 Analysis of variation of thousand grain weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ REP_NO	2	0.89808	0.44904	6.77	0.004
+ BLOCK_NO	3	0.45683	0.15228	2.30	0.099
+ REP_NO.BLOCK_NO	6	2.90792	0.48465	7.31	<.001
+ DESIGNATION	19	2.75350	0.14492	2.18	0.028
Residual	29	1.92350	0.06633		
Total	59	8.93983	0.15152		

Appendix 8 Analysis of variation of grey leaf spot

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ REP_NO	2	0.1000	0.0500	0.20	0.822
+ BLOCK_NO	3	0.1833	0.0611	0.24	0.867
+ REP_NO.BLOCK_NO	6	2.1667	0.3611	1.42	0.240
+ DESIGNATION	19	7.8382	0.4125	1.63	0.116
Residual	29	7.3618	0.2539		
Total	59	17.6500	0.2992		

Appendix 9 Analysis of variation of maize streak virus

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ REP_NO	2	0.13333	0.06667	1.91	0.166
+ BLOCK_NO	3	0.06667	0.02222	0.64	0.596
+ REP_NO.BLOCK_NO	6	0.13333	0.02222	0.64	0.699
+ DESIGNATION	19	0.59031	0.03107	0.89	0.595
Residual	29	1.00969	0.03482		
Total	59	1.93333	0.03277		

Appendix 10 Analysis of variation of moisture %

Sourses of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
+ REP_NO	2	3.712	1.856	0.23	0.792
+ BLOCK_NO	3	5.030	1.677	0.21	0.887
+ REP_NO.BLOCK_NO	6	57.273	9.546	1.21	0.331
+ DESIGNATION	19	105.768	5.567	0.70	0.785
Residual	29	229.240	7.905		
Total	59	401.023	6.797		

Appendix 11 Analysis of variation of plant height (m)

Sources of variation	d.f.	s.s.	m.s.	v.r.	F pr.
+ REP_NO	2	0.40508	0.20254	8.98	<.001
+ BLOCK_NO	3	0.14483	0.04828	2.14	0.117
+ REP_NO.BLOCK_NO	6	0.35392	0.05899	2.62	0.038
+ DESIGNATION	19	0.69206	0.03642	1.62	0.119
Residual	29	0.65394	0.02255		
Total	59	2.24983	0.03813		