AN ASSESSMENT OF GENETIC ENGINEERING IN ENHANCING MAIZE PRODUCTIVITY AND ADDRESSING FOOD SECURITY CHALLENGES IN BINDURA DISTRICT, ZIMBABWE

A dissertation submitted in partial fulfilment of the requirement for the Master of Science Degree in Food Security and Sustainable Agriculture (PRODUCTION)

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DECLARATION

I hereby declare that the research project entitled "An assessment of genetic engineering in enhancing maize productivity and addressing food security in Bindura District, Zimbabwe." submitted to Bindura University of Science Education, Department of Agricultural Economics, Education and Extension is a record of an original work done by me under the guidance and supervision of Dr V Munyati and this work is submitted in partial fulfilment of the requirements for the award of a Master of Science Degree in Food Security and Sustainable Agriculture. The results embodied in this thesis have not been submitted to any University or Institute for the award of any degree of diploma.

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DEDICATION

This thesis is dedicated to my late parents (Mr and Mrs Chiwara). Your memories are always in my heart, cherishing every moment we shared and your unwavering support which shaped the person lam today. I wish you were here to see all my endeavors.

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ABSTRACT

Maize productivity in Zimbabwe remains low, with average yields of 0.8 tons/ha compared to the global average of 5.6 tons/ha. This low productivity is attributed by various factors, including pests, diseases, and climate change. Genetic engineering has been proposed as a potential solution to improve maize productivity and food security in Bindura District, Zimbabwe. This study aimed to assess the impact of genetic engineering on maize productivity and food security challenges in Bindura District, Zimbabwe, and provide evidence-based recommendations for policymakers and farmers. The study objectives were to determine the significant difference in yield output between genetically engineered maize varieties and conventional varieties, explore the knowledge and attitudes of farmers towards genetically engineered maize, assess the challenges associated with the adoption of genetically engineered maize varieties and determine the potential contribution of genetic engineering to food security in Bindura District. The theoretical framework guiding the study was from Innovation Diffusion Theory developed by Rogers (2023), which explained how new ideas, technologies, or practices are adopted and diffused within a social system. This study used a mixed-methods research approach, combining both quantitative and qualitative data collection and analysis methods. A sample of 200 maize farmers was selected for the study using Slovin's formula. Analytical tools used for the study objectives were T-test, KAP analysis, correlation analysis and ANOVA. The study established demographic characteristics which were dominated by females. The study established that genetically engineered (GE) group had a mean yield per hectare of 5.32 with a standard deviation of 2.923, while the conventional group had a mean yield per hectare of 2.58 with a standard deviation of 1.447. This farmer's response indicated that increased knowledge about genetically engineered maize can lead to a more positive attitude towards its adoption. However, some farmers view genetically engineered maize as a profit-driven technology rather than a solution to agricultural challenges. The study concluded that high input cost and market access are major challenges faced by farmers in Bindura District when adopting genetically engineered maize and positively affects adopting genetically engineered maize. The study revealed a moderate positive relationship between genetic engineering and food security variables namely food availability, resistance to pests and diseases, nutritional content and crop yield with an R value of .530. The study recommended government to provide incentives for farmers to adopt GE crops, such as subsidies or tax breaks, to encourage the transition to more productive and sustainable agricultural practices.

Key words: Genetic engineering, Maize, KAP, Convectional varieties, Food security

LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA : Analysis of Variance

FAO : Food and Agriculture Organisation

GE: Genetic Engineering

GM: Genetically Modified

GMO: Genetic Modified Organisms

SPSS : Statistical Package for Social Sciences

WHO : World Health Organisation

ZimVAC : Zimbabwe Vulnerability Assessment Committee

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CHAPTER 1
INTRODUCTION

1.1 Background of study

As the global population continues to increase, the challenge of ensuring food security become more pressing, particularly in developing countries like Zimbabwe where maize is a crucial food source, forming the backbone of the country's food security. However, the agricultural sector faces numerous challenges, including climate change, pests, diseases, and soil degradation, which significantly impact maize yields. In Bindura District, located in the Mashonaland Central Province of Zimbabwe, the agricultural landscape is characterized by smallholder farming systems that are highly vulnerable to these challenges. The district's farmers often struggle with low productivity due to factors such as inadequate access to quality seeds, limited agricultural technology, and fluctuating weather patterns, (FAO, 2022). These issues have exacerbated food insecurity, making it imperative to explore innovative solutions.

Genetic engineering offers the potential to develop maize varieties that are more resilient to environmental stresses, such as drought and pests. By incorporating specific genes that confer desirable traits, genetically modified (GM) maize can enhance yield potential and reduce the reliance on chemical pesticides. It can improve the nutritional content of maize crops, addressing common deficiencies and promoting better health in local populations, (Bernard et al, 2020). This technology not only aims to improve productivity but also seeks to ensure a stable food supply for the growing population in Bindura District.

Farmers in Bindura District are accustomed to certain maize seed varieties which, in the face of climate change are becoming susceptible and vulnerable to weather fluctuations, new emerging pests and diseases, affecting productivity, increasing vulnerability to poverty, food and nutrition insecurity. The majority of the farmers are aware and are now using improved maize seed, as revealed by Chikobvu *et al* (2024). Although the general adoption rate recorded is high in Bindura District, farmers are still inclined to certain maize varieties which breeders are trying to phase out replacing with new ones, better fighters contented with prevailing weather patterns. These old varieties have been established to suit certain conditions and have deteriorated and become more susceptible to new virulent pests and diseases as well as to moisture stress. According to the SeedCo Farmers guide (2022), it is advisable not to rely on only one variety but to grow a selection of the best varieties suitable to the farm conditions. The use of certified seed ensures that the seed is of the highest quality in-terms of genetic purity, germination and vigour.

It is a tendency of farmers to recycle maize seed when they fail to get the one they are familiar with. Oluwayemisi (2023) state that, recycled seeds are susceptible to pests and diseases and their degree of drought tolerance is very low affecting productivity. Commercial farmers rapidly adopt maize hybrids and adoption is slower in the communal sector, (Ayeiko, *et al*, 2022). Seed houses are increasing, offering the best performing maize seed varieties, which see many outlets, agro-dealers or stores stocked with genetically improved maize seeds. Despite the availability of various high performed new genetically modified maize seed varieties on market, the adoption of these new varieties remains a challenge especially in the smallholder sector. Farmers tend to be reluctant to accept new genetically modified maize seed varieties on the market due to social and ethic factors, which obstruct them from trying new maize varieties and biased to growing one selection they have been cultivating over ages and periods.

As Zimbabwe continues to grapple with food security challenges, understanding the role of genetic engineering in maize production becomes increasingly critical for policymakers, researchers, consumers and farmers. This study aims to investigate the role of genetic engineering on maize productivity and its potential to address food security issues in Bindura District, thereby contributing to the broader discourse on agricultural innovation in Zimbabwe.

1.2 Problem statement

Maize is a staple crop in Zimbabwe, accounting for approximately 50% of the country's caloric intake (FAO, 2020). However, maize productivity in Zimbabwe remains low, with average yields of 0.8 tons/ha compared to the global average of 5.6 tons/ha (World Bank, 2022). This low productivity is attributed by various factors, including pests, diseases, and climate change. Genetic engineering has been proposed as a potential solution to improve maize productivity and food security. In Bindura District, Zimbabwe, 70% of farmers report struggling to meet their household food needs due to low maize yields (ZIMSTAT, 2020).

The use of genetically engineered maize has been shown to increase yields by 45-65% and reduce pesticide use by 30-50% in other countries (Klumper & Qaim, 2024). However, the adoption of genetically engineered maize in Zimbabwe is limited due to concerns about its safety, efficacy, and regulatory frameworks. This study aims to assess the impact of genetic engineering on maize productivity and food security challenges in Bindura District, Zimbabwe, and provide evidence-based recommendations for policymakers and farmers.

1.3 Objectives of study

1.3.1 Main objective

The main objective of the research was to compare the yield output of genetically engineered maize varieties with conventional varieties in Bindura District.

1.3.2 Specific objectives

1. To determine the significant difference in yield output between genetically engineered maize varieties and conventional varieties in Bindura District.

2. To explore the knowledge and attitudes of farmers towards genetically engineered maize in Bindura District.

3. To assess the challenges associated with the adoption of genetically engineered maize varieties in Bindura District.

4. To determine the potential contribution of genetic engineering to food security in Bindura District.

1.4 Research questions

1. Is there a significant difference in yield output between genetically engineered maize varieties and conventional varieties in Bindura District?

2. What are the perceptions and attitudes of farmers towards genetically engineered maize in Bindura District?

3. What are the major challenges faced by farmers in Bindura District when adopting genetically engineered maize?

4. How does genetic engineering contribute to food security in Bindura District, Zimbabwe?

1.5 Hypothesis

1.5.1 Hypothesis 1

The research study hypothesized that genetic engineering in maize crops in Bindura District, Zimbabwe, significantly enhances maize productivity and resilience against environmental stresses thereby contributing to improved food security among smallholder farmers. The hypothesized factors were yield and food security outcomes of genetically engineered maize varieties with conventional varieties. The Household Food Insecurity Access Scale variables were hypothesized representing the apparent universal domains of the food insecurity experience in terms of occurrence and the frequency of each indicator

Hypothesis 2

The study hypothesized that farmers in Bindura District have positive perceptions and attitudes towards genetically engineered maize and these perceptions are influenced by factors such as knowledge, educational level and exposure to information about genetic engineering. This hypothesis was tested through surveys, interviews and focus groups with farmers in Bindura District exploring their perceptions, attitudes and concerns about genetically engineered maize.

1.6 Motivation of the study

Zimbabwe has faced significant challenges related to food security, particularly in remote areas like Bindura District. With a growing population and changing climate conditions, traditional agricultural practices may not suffice to meet the increasing food demands. According to

ZIMSTAT, 2025, Zimbabwe's current population is approximately 16.9 million and 65% of the people are living below the poverty line. The World Food Programme (2024), noted that Zimbabwe is a land locked and low-income food deficit country in the Southern Africa. In the same vain WFP reported in 2024 that, more than 10million people in Zimbabwe face food insecurity at the peak of the lean season as poor rains and erratic weather patterns have a negative impact on crop harvests. Under nutrition rates are considered high especially in rural districts like Bindura where diets lack diversity, maize being the main staple food and lack of essential nutrients. Genetic engineering offers innovative solutions to improve crop yields and resilience against pests and diseases, which are crucial for ensuring food availability.

The impacts of climate change, such as droughts and erratic rainfall patterns, pose significant risks to maize production. Bryman. 2023 suggested that genetic engineering can develop maize varieties that are more tolerant to these adverse conditions, thereby ensuring consistent yields even in challenging environments. This aspect is particularly relevant for Bindura District, where climate variability is a pressing concern. By assessing the potential of genetic engineering, this study seeks to highlight the importance of adopting modern agricultural technologies to enhance productivity, sustainability in maize farming and effective use of genetically modified organisms (GMOs) in Zimbabwe.

1.7 Justification

Considering the above circumstances, the research aims to bring out the inherent understanding on the role of genetic engineering in improving maize productivity and food security in Bindura District. By exploring genetic engineering, this study aims to identify how genetically modified (GM) maize can withstand adverse environmental conditions, thereby increasing yields and ensuring a stable food supply for the local population.

The study seeks to improve the understanding of smallholder farmers in Bindura, who rely on maize as their primary source of income and sustenance. Enhanced productivity can also contribute to rural development and poverty alleviation. The findings can inform policymakers, agricultural extension officers, and local communities about the potential benefits and challenges of adopting genetically engineered crops. It can promote informed decision-making regarding agricultural practices and food security strategies. Above all the research study will contribute to the body of knowledge and will be used as the basis for other research work to be done in related fields.

1.8 Scope of the study

This study is limited to Bindura District which may not be a representative of other regions or countries. The findings may not be generalizable to other contexts due to differences in climate, soil, and socio-economic conditions. The study also focused specifically on maize production in Bindura District, Zimbabwe, and presented data collected from local maize farmers, agricultural experts, and relevant stakeholders. It does not cover other crops or regions outside Bindura.

1.8.1 Limitations

The study had some household interviews and accuracy of the information therefore varied from household to household, depending on attitude, literacy levels and understanding between the interviewer and the interviewee. Limitations were also encountered on budget, where requirements like transport costs and stationary for questionnaires were very high in terms of costs, due to the prevailing current economic crisis that the country is facing. Smallholder maize farmers rely on normal rain season for farming. This means that growing maize is seasonal so the study was conducted only during the rainy season.

1.9 Outline of the thesis

The study was organized into 6 chapters. Chapter 1 (Introduction) comprised of the background of the study, problem statement, objectives, research questions, hypothesis, motivation of the study, justification, scope of the study, limitations and outline of the thesis. Chapter 2 (Literature Review) included the introduction, conceptual framework and summary of literature. Chapter 4 and 5 (Results): illustrating two different developed research manuscripts for the study each comprising of an abstract, introduction, materials and methods, description of the study area, sampling procedure, data collection and analysis procedure, challenges encountered during data collection, results and discussion of results, recommendations, conclusion and references. Lastly Chapter 6, (Summary, conclusion and Recommendation) which included the introduction, research summary, conclusion, policy implications and recommendations, areas for further research, references and appendices.

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CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The literature review in this chapter aims to provide a comprehensive overview of the existing research on genetic engineering in maize production, with a specific focus on its potential to enhance productivity and address food security challenges in the Bindura District of Zimbabwe. The chapter will define key terms, identify literature gaps, and discuss the theoretical and conceptual frameworks guiding the study. It will also examine empirical studies on genetically engineered maize, comparing its performance to conventional maize seeds. By synthesizing the findings of previous studies, this chapter will provide a foundation for understanding the role of genetic engineering in improving maize productivity and food security in Bindura and potentially Zimbabwe.

2.2 Definition of key terms

2.2.1 Genetic Engineering

Different authorities and institutions define this term differently but generally all point to one common criterion that this technology has significant implications particularly in enhancing crop productivity and addressing food security. Mlambo and McCaeter, (2020) defined genetic engineering as the integration of alien genes into an organism using techniques such as recombinant DNA technology. This process allows for the modification of specific traits in plants, animals, or microorganisms to achieve desired outcomes, such as increased resistance to pests or improved nutritional content.

Furthermore the Food and Agriculture Organization (FAO, 2021) noted that genetic engineering encompasses a range of techniques that enable the transfer of genes between organisms, which can lead to the development of crops with enhanced traits, such as drought tolerance and pest resistance. This definition emphasizes the technological aspect of genetic engineering as a tool for improving agricultural productivity. Additionally, Moyo et al, (2022) contended that this method that allows for the precise alteration of plant genomes to improve yield, quality, and resilience against environmental stresses. This definition highlights the practical applications of GE in crop improvement, particularly in staple crops like maize, which is crucial for food security in regions like Bindura.

Jones, (2022), viewed through the lens of biosafety and ethical considerations and suggested that genetic engineering not only involves the technical aspects of gene modification but also the assessment of potential risks associated with the release of genetically modified organisms (GMOs) into the environment. This perspective is critical in discussions about the acceptance and regulation of GE crops. This study therefore regard genetic engineering as a multifaceted technology that plays a vital role in modern agriculture by enabling the development of crops that can better withstand challenges posed by pests, diseases, and climate change. Its application in maize production is particularly relevant for enhancing food security in regions like Bindura District.

2.2.2 Genetically Modified Organism (GMO)

Gollin, (2020) defined genetically modified organism (GMO) as any organism whose genetic material has been altered using genetic engineering techniques. This modification is typically achieved through the introduction of foreign DNA, which can come from different species, allowing for the expression of desired traits that would not occur naturally. Additionally the National Academy of Sciences, (2022) noted that GMOs are organisms that have had their DNA altered in a way that does not occur naturally through mating and or natural recombination. This includes plants, animals, and microorganisms that have been modified for various purposes, such as increased resistance to pests, enhanced nutritional content, or improved shelf life.

Furthermore, Baker and Berenbaum, (2020) described GMOs as organisms that have undergone a process of transformation where specific genes are inserted, deleted, or modified to achieve specific traits. This process can involve techniques such as CRISPR, gene cloning, and transgenic methods, which allow for precise modifications at the molecular level. In a broader context, the World Health Organization (WHO, 2021) emphasizes that GMOs are used in agriculture to improve crop yields and reduce reliance on chemical pesticides, thereby contributing to food security and sustainability. Overall, GMOs represent a significant advancement in genetic engineering, with applications spanning agriculture, medicine, and environmental management, reflecting a complex interplay of scientific innovation and ethical considerations.

2.2.3 Food Security

Food security is a multifaceted concept that encompasses various dimensions of access to food. The World Food Summit (2000) defined food security as a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life. This definition emphasizes the importance of both availability and access to food. The Food and Agriculture Organization (FAO), 2021 expanded on this by stating that food security is not only about the availability of food but also about the ability of individuals to access it. They highlighted that food security is achieved when food is available, accessible, and utilized effectively, ensuring that people can lead healthy lives.

The United Nations (UN, 2020) defined food security as a condition that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life. This definition underscores the importance of stability over time, indicating that food security must be sustained. Additionally, Maxwell and Frankenberger, (2022) suggested that food security is a situation in which all people have access to enough food to lead a healthy and active life. They emphasize the role of social and economic factors in determining food security, highlighting that it is not solely about food supply. Barrett (2021) provided a comprehensive view by stating that food security is a condition in which all people have access to sufficient, safe, and nutritious food to maintain a healthy and active life. He also notes that food security is influenced by a range of factors including economic stability, agricultural productivity, and social safety nets. These definitions collectively illustrate that food security is a complex issue that involves not just the availability of food, but also access, utilization, and stability, reflecting the interconnectedness of various social, economic, and environmental factors.

2.3 Current Food Security Situation in Zimbabwe

Zimbabwe is currently facing significant challenges in its food security and agricultural sector. The country has been grappling with issues such as drought, economic instability, and the impacts of climate change, which have severely affected agricultural productivity resulting in food insecurity. Food insecurity exists when people do not have adequate physical, social or economic access to food (FAO, 2022). ZimVAC (2021) observed that since the year 2000, Zimbabwe has been experiencing economic and humanitarian challenges resulting from a complex web of overlapping factors, some of which include erratic weather patterns, hyperinflation, a shrinking economy and a receding international community. This has induced severe hardships on the already impoverished households resulting in worsening vulnerability for both rural and urban populace. Due to a nexus of multidimensional environmental, socio-economic and political factors, year after year, the country has ceased to be self-sufficient on food. Some regions like Matabeleland North and South provinces, Mashonaland East and Mashonaland Central provinces, have been experiencing transitory food insecurity year in year out, (Chikozho, et al, 2024).

Previous studies on Zimbabwe’s food security situation, as conducted by ZimVAC in the years 2022, 2024 and 2025, always indicated that high food insecurity levels were in the rural areas, however, recent 9 studies by the ZIMVAC indicated that 42% of Zimbabwe's population lives in extreme poverty and 26.7% of children under the age of five have stunted growth due to malnutrition. ZimVAC, 2025 also noted that 1.7 million people (35% of the urban population) were food insecure in 2024 and 5 million people faced IPC Phase 3 levels of acute food insecurity from December 2024 to at least March 2025. Agriculture, which is a critical sector for Zimbabwe's economy, has been underperforming. The country relies heavily on rain-fed agriculture, making it vulnerable to climate variability. In 2024, the government reported that only 30% of the arable land was being utilized effectively, leading to lower yields and increased reliance on food imports, FAO, (2025).

The economic situation has also played a role in the agricultural sector's struggles. Inflation rates have soared, affecting farmers' access to necessary inputs such as seeds and fertilizers. In 2024, inflation was reported at around 300%, which has made it difficult for farmers to sustain their operations. As of 2025, it is estimated that around 10 million people in Zimbabwe are experiencing food insecurity, which represents approximately two-thirds of the population, Nyanga et al, 2025. This situation has been exacerbated by poor harvests in recent years, particularly in 2023, where the country faced a 50% decline in maize production due to adverse weather conditions and inadequate farming inputs. In response to the food crisis, the Zimbabwean government has initiated several programs aimed at improving agricultural productivity and food security. These include efforts to enhance irrigation systems and provide support to smallholder farmers. However, the effectiveness of these initiatives remains to be seen, as challenges persist. Zimabwe is classified as a low income country with a diversified economy whose main industrial sectors include mining and Agriculture (Gundu, 2020). Mukarumbwa and Mushunje (2022) concurred with Gundu (2020) indicating that the majority of the Zimbabwean people have always been Agrarian.

2.4 Relationship between maize productivity and food security

Maize productivity is closely linked to food security in Zimbabwe, where maize is a staple crop. Improving maize productivity can increase the availability of food, reduce poverty, and enhance food security (FAO, 2020). A study in Zimbabwe found that a 10% increase in maize productivity can lead to a 6% increase in household food security (Mashingaidze et al., 2020).

The relationship between maize productivity and food security is complex and influenced by various factors, including climate change, pests, and diseases. Climate change can reduce maize yields, leading to food insecurity, particularly among smallholder farmers (Schlenker & Lobell, 2021). However, genetically engineered maize can help mitigate the impacts of climate change by improving drought tolerance and pest resistance.

Improving maize productivity can also have positive impacts on household income and poverty reduction. A study in Kenya found that genetically engineered maize can increase household income and reduce poverty among smallholder farmers (Mugo et al., 2021). By improving maize productivity and food security, genetically engineered maize can contribute to the achievement of Sustainable Development Goal 2 (Zero Hunger) in Zimbabwe.

Despite the potential of genetic engineering to improve maize productivity, there is limited research on the extent to which they enhance the food security levels in countries or communities such as Zimbabwe, particularly in Bindura District. Most studies have focused on the technical aspects of genetic engineering, with limited attention to the extent to which they solve the global crisis of hunger and food security. This study aims to address this gap by investigating genetic engineering in enhancing maize productivity and address food security challenges in Bindura District.

2.5 Genetic Engineering and Maize Productivity

Numerous studies indicate that genetically engineered maize varieties can significantly outperform conventional varieties in terms of yield. For instance, an analysis by Klümper and Qaim (2024) demonstrated that GE maize increased yields by approximately 22% on average compared to non-GE varieties. Genetic engineering allows scientists to modify the genetic makeup of the maize crop to introduce desired traits. This includes enhancing resistance to pests, diseases and environmental stresses. In Zimbabwe, research by Moyo et al. (2021) highlighted that the introduction of Bt maize variety, which is engineered with built in pest resistance or herbicide tolerance to resistant to specific pests and diseases, which reduces crop losses and the need for chemical pesticides. This not only improves yields but also lowers production costs for farmers. Such findings underscore the potential of GE maize to contribute to higher productivity levels, which is essential for addressing food shortages in regions like Bindura.

A study by Nyanga et al, 2020 also reviewed that genetic engineering can help develop maize crops that are more resilient to climate change impacts. This includes creating varieties that tolerate extreme temperatures, drought, flooding or salinity. By enhancing the adaptability of crops, genetic engineering contributes to maintaining stable agricultural production in the face of changing climatic conditions. For example, Pioneer 30S19 is known for its drought resistance and adaptability to different soil types, (Bernard et al, 2020). It performs well in low rainfall areas and has been popular among farmers in regions prone to water scarcity. With climate change leading to increased variability in weather patterns, drought-tolerant maize varieties are crucial because they can thrive in low-water conditions, thus stabilizing food production in drought-prone areas.

By introducing genes responsible for producing specific nutrients, such as vitamins and minerals, scientists can develop biofortified crops that address nutrient deficiencies in vulnerable populations. For example, Biofortified maize varieties can provide essential vitamins and minerals. This approach has the potential to combat malnutrition and improve public health, (Obukosia, 2020). Genetic engineering can also enhance the nutritional profile of maize, addressing malnutrition issues prevalent in many communities.

Research by Haggblade and Tembo (2024) indicated that, by reducing the reliance on chemical inputs and increasing resilience to environmental stresses, genetically engineered maize can promote more sustainable agricultural practices, contributing to long term food security. Certain genetically engineered maize varieties are designed to enhance root biomass, which can improve carbon sequestration in the soil. This contributes to climate change mitigation efforts by capturing and storing carbon dioxide. For example, Bt maize is engineered to express Bacillus thuringiensis (Bt) proteins which provide resistance to certain pests leading to healthier plants with enhanced biomass resulting in increased carbon sequestration in the soil, (Obukosia, 2020).

According to a study by Kahn et al. (2020), farmers in Bindura exhibited mixed feelings about GE maize. While some recognized the potential benefits, such as increased yields and reduced pest damage, others expressed concerns regarding long-term health effects, environmental impacts, and market acceptance. Education and awareness campaigns play a critical role in shaping these attitudes. Research by Haggblade and Tembo (2024) suggests that targeted educational interventions can significantly improve farmers' understanding of genetic engineering, leading to greater acceptance and adoption of GE technologies. Nyanga et al. (2020) noted that the stringent regulatory framework surrounding biotechnology in Zimbabwe creates uncertainty for farmers, dissuading them from investing in GE crops.

2.6 Genetically engineered maize versus conventional maize varieties

Genetically engineered maize seed varieties have been shown to have higher yields than conventional maize seeds. A study in Zimbabwe found that genetically engineered maize varieties yielded 2.5 tons per hectare more than conventional varieties (Mashingaidze et al., 2022). This increase in yield can be attributed to the improved resistance to pests and diseases, as well as the enhanced drought tolerance of genetically engineered maize. Pellegrino et al, suggested that there is a significant difference in yield output between genetically engineered (GE) maize varieties and conventional varieties. Studies have shown that GE maize varieties can increase yields by 20 to 35% compared to conventional varieties and reduced pesticide quantity by 39% compared to conventional maize.

Studies also reviewed that genetically engineered maize seeds have been shown to have improved pest resistance compared to conventional maize seeds. Gouse et al. 2022, found that genetically engineered maize varieties had reduced damage from pests compared to conventional varieties and reduce pesticide quantity by 39%. This trait can help reduce crop losses and improve yields, making genetically engineered maize a valuable option for farmers in Zimbabwe. Research also demonstrated that GE maize varieties have been engineered to be more drought-tolerant. For example drought- tolerant GE maize has been shown to yield significantly better in dry conditions, reporting yield increase of up to 30% compared to conventional maize under similar stress, (Mugo et al., 2021). This trait can help farmers in Zimbabwe mitigate the impacts of climate change and ensure food security

2.7 Theoretical Framework

The study is guided by the Innovation Diffusion Theory developed by Rogers (2023), which explains how new ideas, technologies, or practices are adopted and diffused within a social system. This theory is relevant to understanding the adoption of genetically engineered maize in Bindura District, as it highlights the importance of factors such as awareness, attitudes, and social norms in shaping the adoption decision.

2.8 Conceptual Framework

The conceptual framework for this study illustrates the relationship between genetic engineering, maize productivity, and food security. The dependence of food security on maize productivity is shown. It highlights the potential benefits of genetically engineered maize such as improved yields, disease resistance, and drought tolerance and how these affect the maize productivity and ultimately their influence on food security.

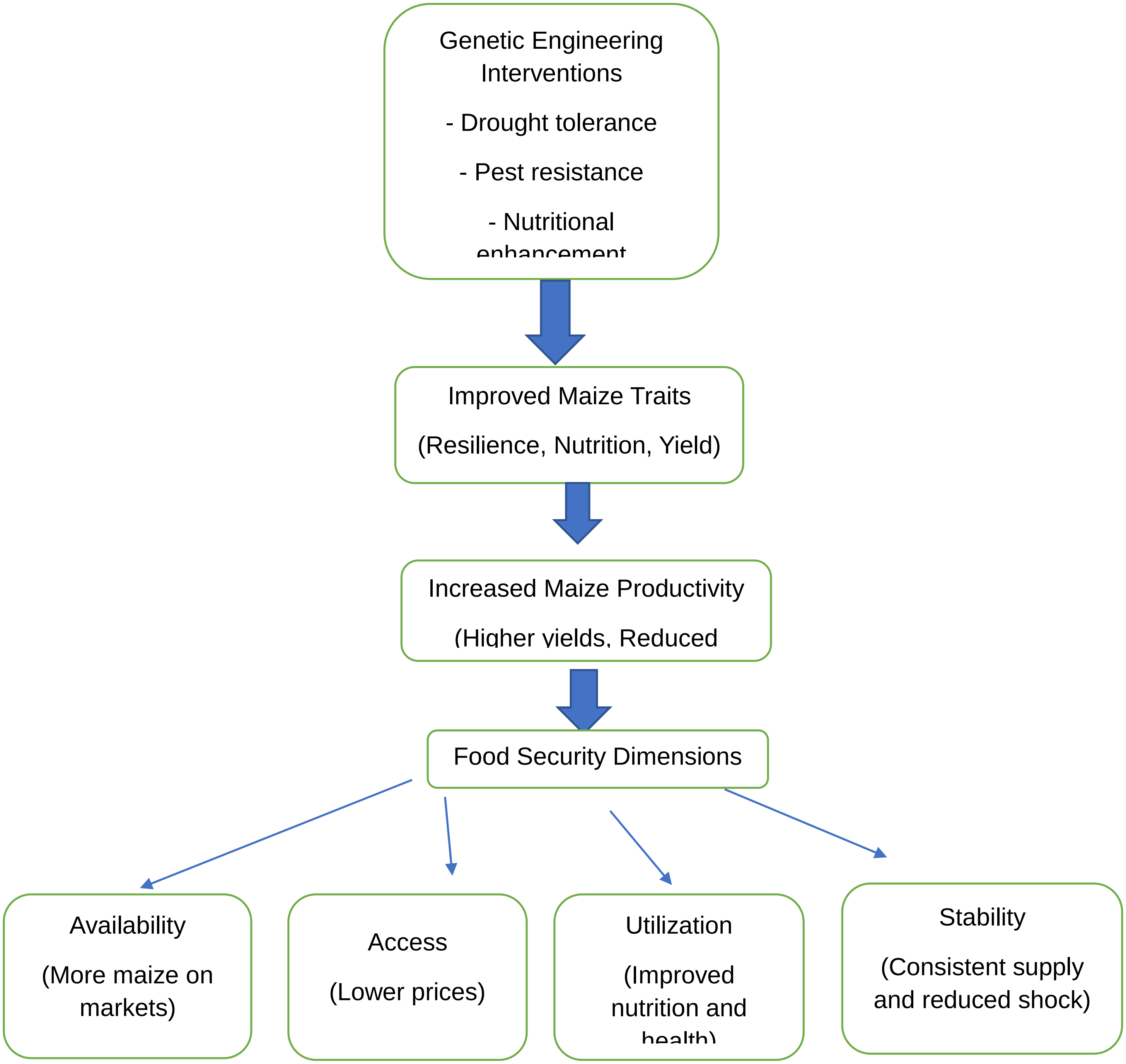

Figure 2.1 Conceptual framework

2.9 Comparative study

A comparative study of genetically engineered maize and conventional maize seeds in Zimbabwe found that genetically engineered maize varieties had higher yields and improved pest resistance compared to conventional varieties (Mashingaidze et al., 2022). This study highlights the potential benefits of genetically engineered maize for improving maize productivity and food security in Zimbabwe.

Genetic engineering has the potential to improve food security by increasing crop yields, improving crop resistance to pests and diseases, and enhancing nutritional content. A study in Kenya found that genetically engineered maize can improve food security by increasing yields and reducing poverty among smallholder farmers (Mugo et al., 2021). However, adoption is hindered by factors such as seed accessibility and cost. Addressing these challenges through policy interventions and farmer education could facilitate wider adoption of genetically engineered maize.

2.10 Summary of Literature Review

The literature reviewed in this chapter has highlighted on genetic engineering in maize production, with a focus on its potential to enhance productivity and address food security challenges in Zimbabwe. It has also examined empirical studies on genetically engineered maize, comparing its performance to conventional maize seeds. The findings of this review suggest a positive relationship between maize productivity and food security denoting genetically engineered maize does improve maize productivity and food security in Zimbabwe, but further research is needed to fully understand its benefits and challenges.

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CHAPTER 3
METHODOLODY

3.1 Introduction

This chapter outlines the research methodology employed in this study to assess genetic engineering in enhancing maize productivity and addressing food security challenges in Bindura District, Zimbabwe. The chapter analyses the conceptual model that has guided this study and the variables that were hypothesized on genetic engineering in enhancing crop productivity and addressing food security. The research methodology was designed to ensure the collection of high-quality data which could be used to address the research problem and achieve the study's objectives.

3.2 Description of study area

The study was conducted in the district of Bindura, which is located in the Mashonaland Central Province of Zimbabwe. The district is divided into 21 wards and is characterized by smallholder farming systems, with maize being a major crop (ZIMSTAT, 2022). Bindura District is approximately 88 kilometers northeast of Harare, the capital city and is situated at an altitude ranging from 1,200 to 1,500 meters above sea level, which contributes to its moderate climate. The area experiences a subtropical climate with distinct wet and dry seasons. According to Moyo, 2022, the rainy season typically extends from November to March, with average annual rainfall ranging from 600 to 800 millimeters. This climate is conducive to maize cultivation, which is the staple crop for most households in the district. Agriculture is the primary livelihood for the majority of the population in Bindura. The district's farmers primarily practice subsistence farming, with maize being the most widely cultivated crop. Other crops grown include sorghum, millet, and various legumes.

Despite the reliance on traditional farming methods, many farmers are increasingly adopting modern agricultural practices, including the use of hybrid and genetically engineered maize varieties, to enhance productivity and cope with challenges such as climate variability and pest infestations. FAO, 2020 further explained that Bindura District has a diverse population, with various ethnic groups contributing to its cultural richness. However, the district faces several socioeconomic challenges, including poverty, limited access to markets, and inadequate infrastructure. Food insecurity is a pressing issue, particularly during drought years, which underscores the importance of improving agricultural productivity through innovations like genetic engineering. The district's smallholder farming systems also provide a suitable context for investigating the adoption and impact of genetically engineered maize among smallholder farmers.

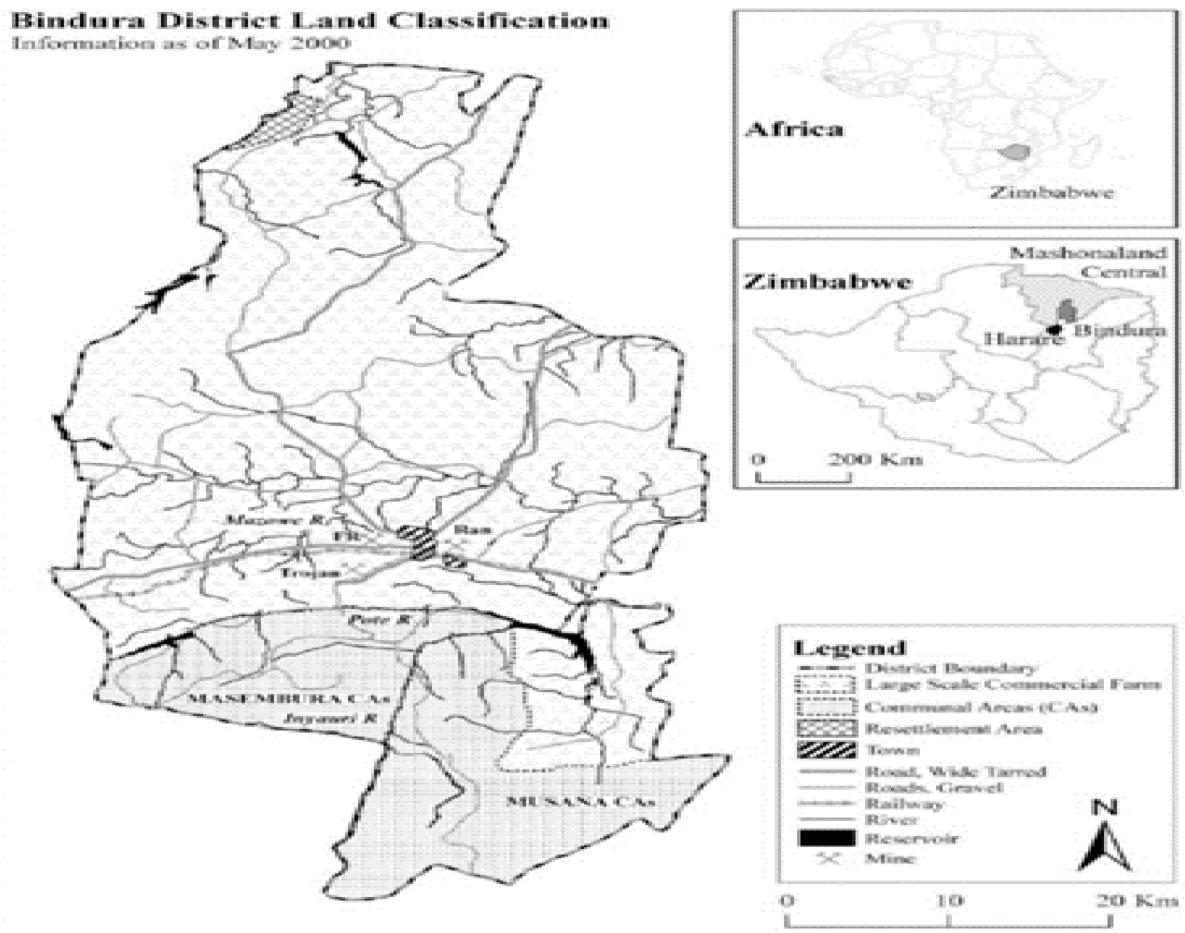

Figure 3.1 Description of study site (*Adapted from Atlas, 2019*)

3.3 Research design

The study employed a survey research design, which involves collecting data from a sample of farmers in Bindura District using questionnaires and interviews. The survey design allows for the collection of data from a large sample size, providing a representative picture of the population (Fowler, 2023). Research questions and objectives guided the development of the survey instrument, ensuring that the data collected was relevant and useful for addressing the research problem.

3.4 Research approach

This study used a mixed-methods research approach, combining both quantitative and qualitative data collection and analysis methods. The mixed-methods approach allows for a comprehensive understanding of the research problem, providing both numerical data and in-depth insights into the perceptions and attitudes of farmers towards genetically engineered maize (Creswell & Plano Clark, 2021). The quantitative approach was used to collect data on the socio-economic characteristics of farmers, their experiences with genetically engineered maize, and the impact of the technology on maize productivity and food security.

The qualitative approach will be used to gather more in-depth information on farmers' perceptions and attitudes towards genetically engineered maize, as well as their experiences with the technology. The mixed-methods approach is particularly useful in this study because it allows for the triangulation of data, which can increase the validity and reliability of the findings (Bryman & Bell, 2022). The quantitative data can provide a broad overview of the research problem, while the qualitative data can provide more nuanced insights into the experiences and perceptions of farmers.

3.5 Population study

The study population consisted of smallholder maize farmers, agricultural extension officers and agronomists within Bindura District. These stakeholders possess firsthand knowledge and experience pertinent to maize cultivation practices and food security issues in the area.

3.6 Sampling procedure

The research population included all smallholder maize farmers in Bindura District, estimated at plus or minus 90 800 maize smallholder farmers, (AGRITEX, 2024). A multi-stage sampling technique was used to select 5 wards out of 21 wards in Bindura district using simple random sampling. From each selected ward, 2 villages were selected using simple random sampling, resulting in a total of 10 villages. From each selected village, 20 smallholder farmers were selected using simple random sampling, resulting in a total sample size of 200 farmers. The sample size was 200 smallholder farmers, selected using Slovin's formula with a margin of error of approximately 0.07.

Slovin's Formula for sample size determination

Slovin's formula is given by:

$n = N / (1 + N(e^2))$

Where:

n = sample size (200)

N = total population (90800)

e = margin of error (0.07 or 7%)

Given n = 200 and N = 9800, e:

$200 = 9800 / (1 + 9800(e^2))$

$e \approx 0.07$

A sample size of 200 farmers was determined based on the research questions and objectives, as well as the level of precision required for the study (Fowler, 2023). A larger sample size would provide more precise estimates, but it would also increase the cost and time required for data collection. The sample size of 200 farmers was logically sufficient to provide a representative picture of the population and to achieve the study's objectives.

Inclusion Criteria for the study included

- Smallholder farmers who grow maize as a primary crop

- Farmers who are registered with the local agricultural extension office or farmer organization

- Farmers who are willing to participate in the study

Exclusion Criteria for the study population included

- Large-scale commercial farmers

- Farmers who do not grow maize as a primary crop

- Farmers who are not willing to participate in the study

3.7 Data Collection procedure

3.7.1 Survey Questionnaires

The researcher used questionnaires to collect quantitative data from a sample of 200 smallholder farmers in Bindura District. The questionnaire was designed to collect data on farmers' socio-economic characteristics, their experiences with genetically engineered maize, and the impact of the technology on maize productivity and food security. The questionnaire was pre-tested with a small group of farmers to ensure that it was valid and reliable (Creswell & Plano Clark, 2021).

The survey questionnaire consisted of both closed-ended and open-ended questions. The closed-ended questions were used to collect quantitative data, while the open-ended questions were used to collect qualitative data (Fowler, 2023). The questionnaire was administered through face-to-face interviews with the farmers, which allowed for the collection of high-quality data and minimized the risk of non-response.

3.7.2 Interviews

In-depth interviews were conducted with a subset of 20 farmers to gather more detailed information on their experiences and perceptions of genetically engineered maize. The interviews were semi-structured, allowing for the collection of rich and nuanced data (Braun & Clarke, 2021). The interviews were conducted in a quiet and private setting, and were audio-recorded with the consent of the participants.

The interviews were used to gather more in-depth information on the farmers' experiences with genetically engineered maize, including their perceptions, benefits, challenges, and their experiences with the technology (Creswell & Plano Clark, 2021). The interviews also allowed for the collection of data on the farmers' attitudes and opinions towards genetically engineered maize, which provided valuable insights into the research problem.

3.8 Validity and reliability

The study ensured the validity and reliability of the findings by using a combination of data collection methods and data analysis techniques (Creswell & Plano Clark, 2021). The questionnaire was be pre-tested with a small group of farmers to ensure that it was valid and reliable. The interviews were conducted with a subset of farmers to gather more in-depth information and provide additional insights into the research problem.

The study also ensured the validity and reliability of the findings by using stratified random sampling technique, which ensures that the sample is representative of the population (Fowler, 2023). The sample size was determined based on the research questions and objectives, as well as the level of precision required for the study.

3.9 Data analysis procedure

After gathering data from the sampled area, the data went through several steps until it was analysed. Data was cleaned and coding was done using SPSS analysis package. Table 3.1 is a summary of how the data was analysed:

Table 3.1 Analytical tools

No	Objective	Analytical tool
1	To compare the yield output of genetically engineered maize Varieties with conventional varieties	T-test
2	To explore the knowledge and attitude of farmers towards genetically engineered maize	KAP Analysis
3	To assess the challenges associated with the adoption of genetically engineered maize varieties	Correlation Analysis
4	To determine the potential contribution of genetic engineering to food security in Bindura	ANOVA

3.10 Ethical considerations

The study was conducted in accordance with the principles of informed consent, confidentiality, and anonymity (Bryman & Bell, 2022). Farmers were informed about the purpose and procedures of the study, and their consent was obtained before data collection. The data collected was kept confidential and anonymous, protecting the privacy and rights of the participants. The study also ensured that the participants are not harmed or exploited in any way (Creswell &

Plano Clark, 2021). It was conducted in a way that is respectful and considerate of the participants' time and resources.

3.11 Limitations

The study had several limitations, including the potential for bias in the sample selection and data collection process (Fowler, 2023). The findings may also have been limited by the quality and availability of secondary data. These limitations were acknowledged and addressed in the study's methodology, ensuring that the findings are valid and reliable.

The study's sample size might also have been a limitation, as it might not be representative of the entire population of smallholder farmers in Bindura District (Fowler, 2023). However, the sample size was determined based on the research questions and objectives, as well as the level of precision required for the study.

3.12 Summary

This chapter has outlined the research methodology employed in this study to investigate the role of genetic engineering in enhancing maize productivity and addressing food security challenges in Bindura District, Zimbabwe. The study's findings will provide evidence-based insights into the potential benefits and challenges of genetically engineered maize, informing policymakers, farmers, and other stakeholders about its adoption and sustainable use. The research methodology is designed to ensure the collection of high-quality data that can be used to address the research problem and achieve the study's objectives.

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CHAPTER 4

ANALYIS OF SIGNIFICANT DIFFERENCE IN YIELD OUTPUT BETWEEN GENETICALLY ENGINEERED MAIZE VARIETIES AND CONVENTIONAL VARIETIES AND PERCEPTIONS AND ATTITUDES OF FARMERS TOWARDS GENETICALLY ENGINEERED MAIZE

Abstract

This chapter presented, analysed and discussed results on assessment of genetic engineering in enhancing maize productivity and addressing food security challenges in Bindura district, Zimbabwe. The chapter presented the demographic characteristics of the study dominated by females. The study established that genetically engineered (GE) group had a mean yield per hectare of 5.32 with a standard deviation of 2.923, while the conventional group had a mean yield per hectare of 2.58 with a standard deviation of 1.447. This farmer's response indicated that increased knowledge about genetically engineered maize can lead to a more positive attitude towards its adoption. Education and awareness programs can play a crucial role in promoting the adoption of new technologies. However, some farmers view genetically engineered maize as a profit-driven technology rather than a solution to agricultural challenges. This perception can affect attitudes towards adoption and use. The study recommended government and private sector organizations to invest more in genetic engineering research to develop maize varieties since results showed that they give yield which is 2.7ton s more than convectional varieties and improve food security.

4.1 Introduction

This chapter is concerned with the presentation, analysis and discussion of research findings on assessment of genetic engineering in enhancing maize productivity and addressing food security challenges in Bindura district, Zimbabwe. Furthermore, this chapter highlights the profile of respondents, data presentation, discussion and analysis of significant difference in yield output between genetically engineered maize varieties and conventional varieties and perceptions and attitudes of farmers towards genetically engineered maize in Bindura District. Much of the comparison will be on understanding if the arguments by scholars in literature matched with reality as obtained from the research findings.

4.2 Materials and Methods

4.2.1 Description of study area

The study was conducted in Bindura District, natural region 2a, characterized by annual rainfall of between 800mm to 1200mm, maize is produced both under dry land and irrigation, and over 500 of farmers operate under small scale. This region was selected due to its significance in maize production and the potential impact of genetic engineering on local food security.

4.2.2 Research Design

A survey-based research design was employed to assess the impact of genetic engineering on maize productivity and food security. This design allowed for the collection of mostly quantitative and partly qualitative data to address significant difference in yield output between genetically engineered maize varieties and conventional varieties and perceptions and attitudes of farmers towards genetically engineered maize in Bindura District.

4.2.3 Sampling procedure

A random sampling approach was used to select 200 of maize farmers for participation in the study. This method ensured a representative sample of the population. And 20 lead farmers were selected for the interviews to analyse the perceptions and attitudes of farmers towards genetically engineered maize in Bindura District

4.2.4 Data collection procedure

Data were collected through surveys and interviews. The data collection instruments included questionnaires and interview guide. These methods allowed for the gathering of detailed information on significant difference in yield output between genetically engineered maize varieties and conventional varieties and perceptions and attitudes of farmers towards genetically engineered maize in Bindura District.

4.2.5 Data analysis procedure

Collected data were analysed using statistical software and thematic methods. Descriptive statistics and inferential statistics were employed to identify significant differences in maize productivity and food security outcomes between genetically engineered and conventional maize varieties. In addition thematic analysis were used to gather perceptions and attitudes of farmers towards genetically engineered maize in Bindura District

4.2.6 Challenges encountered during data collect

Several challenges were encountered during data collection, including access to remote areas this is due to some study sites were located in remote areas with limited road infrastructure, making it difficult to reach farmers and collect data in a timely manner. In addition, some farmers were hesitant to participate in the study due to concerns about the potential risks and benefits of genetic engineering. Building trust and rapport with respondents was crucial to overcoming this challenge. Furthermore, ensuring the accuracy and completeness of data collected from farmers and experts was a challenge, particularly in cases where respondents had limited literacy or record-keeping skills. To mitigate these challenges, the research team employed strategies such as working with local partners and using local languages. Despite these challenges, the study was able to collect valuable data that addressed the research objectives.

4.3 Results

4.3.1 Questionnaire response rate

Table 4.1: Response rate

Distributed questionnaires	Returned questionnaires	Response Rate (%)
200	187	93.5

Source: Primary data (2025)

Results in Table 4.1 shows that the study distributed 200 questionnaires to maize farmers. A total of 187 questionnaires were successfully returned. This means that a response rate of 93.5% was obtained. The response rate agrees concurs with Bryman, (2023) who opined that response rate of 50% is satisfactory while a response rate above 70% is very good. Therefore, the response rate was very good which could be due the use of very simple language in the questionnaires and as well as their brief nature.

4.3.2 Demographic characteristics

Table 4.2: Demographic characteristics of respondents N=187

Variable	***Categories***	***Frequency***	***Percent***	***Mean***	***Standard dev.***
Gender	Male	78	58.3	.42	.494
	Female	109	41.7		
	Total	**187**	**100**		
Age	18-25 years	15	8.0		
	26 to 35 years	20	10.7		
	36 to 45 years	36	19.3		
	46 to 55 years	66	35.3		
	56 years and over	50	26.7	2.62	1.214
	Total	**187**	**100**		
Education level	No formal education	15	8.0	1.79	.753
	Primary school	32	17.1		
	Secondary school	118	63.1		
	Tertiary school	22	11.8		
	Total	**187**	**100**		
Experience growing maize	0 to 5 years	25	13.4	2.17	1.215
	6 to 10 years	24	12.8		
	11 to 15 years	57	30.5		
	16 to 20 years	56	29.9		
	21 years and over	25	13.4		
	Total	**187**	**100**		

Source: Primary data (2025)

The results in Table 4.2 show that majority (58.3%) of the respondents were females while 41.7% were males. This implies that maize production is dominated by females. In addition, a large representative of the study (35.3%) was aged 46 to 55 years while 26.7% of respondents were aged 56 years and above. This shows that maize production is mostly undertaken by aged people with the youth making up a small representative. Furthermore, 63.1% of the respondents in the study area have attained secondary level of education, while a least (8.2%) did not attend any formal education. Thus, 92.8% of the respondents had the basic tools to be considered literate. Katema et al (2017) stated that high literacy levels have a positive influence on improving production capacity and viability of enterprises undertaken. Finally, Majority of respondents (30.5%) had been involved in maize production for a period of 11 to 15 years followed by 29.9% of respondents with 16 to 20 years' experience growing maize. This shows that farmers in the study had more experience growing maize and able to provide knowledge that relates to the study under inquiry.

4.3.3 Significant difference in yield output between genetically engineered maize varieties and conventional varieties

Table 4.3: Group Statistics

	What type of maize do you currently grow	N	Mean	Std. Deviation	Std. Error Mean
Yield per ha	Genetically engineered maize	97	5.32	2.923	.297
	Convectional maize	90	2.58	1.447	.153

Source: SPSS (2025)

The results of the study shows that the genetically engineered (GE) group had a mean yield per hectare of 5.32 with a standard deviation of 2.923, while the conventional group had a mean yield per hectare of 2.58 with a standard deviation of 1.447. These results indicate that the GE group had a higher mean yield per hectare compared to the conventional group.

Table 4.4: Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Yield per ha	Equal variances assumed	41.648	.000	8.041	185	.000	2.745	.341	2.071	3.418
	Equal variances not assumed			8.226	142.686	.000	2.745	.334	2.085	3.404

Source: SPSS (2025)

The Independent Samples T-Test revealed a statistically significant difference in yield per hectare between genetically engineered (GE) crops and conventional crops. The results show a mean difference of 2.745 indicating that GE crops have higher yields. At 95% confidence interval with a p-value of 0.000 which is less than 0.05, indicating statistically significant difference. The results indicate that GE crops have significantly higher yields than conventional crops, with a mean difference of 2.745 units per hectare. The 95% confidence interval suggests that the true mean difference is likely to be between 2.085 and 3.404 units per hectare.

4.3.4 Perceptions and attitudes of farmers towards genetically engineered maize

The study used KAP analysis to gather the perceptions and attitudes of farmers towards genetically engineered maize. Most farmers interviewed indicated positive attitude towards genetically engineered maize.

One farmer interviewed shared that:

"After learning more about genetically engineered maize, I think it could be beneficial for our farm. It could help us increase yields and reduce pesticide use."

Another farmer added that:

"I have done my research on GE maize, and I'm confident in its safety and benefits. I believe it can help address some of the challenges we face in maize production."

Furthermore, another farmer interviewed mentioned that:

"GE maize has improved my livelihood significantly. I've been able to increase my income and invest in other aspects of my farm. I'm grateful for this technology."

In addition, another farmer said that *"GE maize has been a game-changer for me. It's resistant to pests, which means I do not have to use as many pesticides. This saves me money and reduces the environmental impact."*

However, other farmers had a different attitude and perception towards genetically engineered maize.

One farmer indicated that:

"I think genetically engineered maize is just a way for companies to make more money. I'm not sure it's really beneficial for us farmers."

Furthermore, another farmer chipped in mentioning that:

"I'm worried about the potential risks of genetically engineered maize. What if it contaminates our traditional crops or affects our health"

4.4 Analysis and discussion of results

This section provides an analysis and discussion on results presented in the above section. The results on assessment of genetic engineering in enhancing maize productivity and addressing food security challenges in Bindura district, Zimbabwe.

4.4.1 Significant difference in yield output between genetically engineered maize varieties and conventional varieties

The study results revealed that the genetically engineered (GE) group had a mean yield per hectare of 5.32 with a standard deviation of 2.923, while the conventional group had a mean yield per hectare of 2.58 with a standard deviation of 1.447. This could be attributed to high seed vigour of GE maize, better drought tolerant of GE maize compared to conventional varieties. The results agree with Nyanga et al, 2020 reviewed that genetic engineering can help develop maize crops that are more resilient to climate change impacts. This includes creating varieties that tolerate extreme temperatures, drought, flooding or salinity. Furthermore, results from the study are in sync with Mashingaidze and Frankenberg (2022) conducted a study in Zimbabwe found that genetically engineered maize varieties yielded 2.5 tons per hectare more than conventional varieties.

4.4.2 Perceptions and attitudes of farmers towards genetically engineered maize

This farmer's response indicates that increased knowledge about genetically engineered maize can lead to a more positive attitude towards its adoption. Education and awareness programs can play a crucial role in promoting the adoption of new technologies. However, some farmers view genetically engineered maize as a profit-driven technology rather than a solution to agricultural challenges. This perception can affect attitudes towards adoption and use. The findings were in agreement with Kahn et al. (2020) established that farmers in Bindura exhibited mixed feelings about GE maize. While some recognized the potential benefits, such as increased yields and reduced pest damage, others expressed concerns regarding long-term health effects, environmental impacts, and market acceptance. Education and awareness campaigns play a critical role in shaping these attitudes. Research by Haggblade and Tembo (2024) suggests that targeted educational interventions can significantly improve farmers’ understanding of genetic engineering, leading to greater acceptance and adoption of GE technologies.

4.5 Recommendations

Based on the study results, the following recommendations can be made:

- Governments and private sector organizations should invest more in genetic engineering research to develop maize varieties since results showed that they give yield which is 2.7ton s more than convectional varieties and improve food security.
- The government should develop and implement a clear regulatory framework for the development, testing, and deployment of genetically engineered crops to ensure safety and efficacy.
- Furthermore, farmers should be encouraged to adopt genetically engineered maize varieties that have been proven to improve productivity and resilience.

4.6 Conclusion

This chapter presented, analysed and discussed results on significant difference in yield output between genetically engineered maize varieties and conventional varieties and perceptions and attitudes of farmers towards genetically engineered maize in Bindura District, Zimbabwe. The chapter presented the demographic characteristics of the study dominated by females. The study established that genetically engineered (GE) group had a mean yield per hectare of 5.32 with a standard deviation of 2.923, while the conventional group had a mean yield per hectare of 2.58 with a standard deviation of 1.447. This farmer's response indicated that increased knowledge about genetically engineered maize can lead to a more positive attitude towards its adoption. Education and awareness programs can play a crucial role in promoting the adoption of new technologies. However, some farmers view genetically engineered maize as a profit-driven technology rather than a solution to agricultural challenges. This perception can affect attitudes towards adoption and use.

4.7 References

Bryman, J. (2023). *Social Research Methods.* Oxford University, New York. 592pp.

Kahn, M., et al. (2020). *Understanding Farmer Perceptions of Genetically Engineered Maize* in *Zimbabwe.* African Journal of Agricultural Research.

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CHAPTER 5

CHALLENGES OF ADOPTING GENETIC ENGINEERING AND ITS POTENTIAL CONTRIBUTION TO FOOD SECURITY IN BINDURA DISTRICT

Abstract

This chapter presented, analysed and discussed results on assessment of genetic engineering in enhancing maize productivity and addressing food security challenges in Bindura district, Zimbabwe. The chapter presented results on challenges associated with the adoption of genetically engineered maize varieties and potential contribution of genetic engineering to food security in Bindura District. The study revealed that high input cost is a significant challenge faced by farmers in Bindura District when adopting genetically engineered maize that positively affects adopting genetically engineered maize. The study revealed a moderate positive relationship between genetic engineering and food security variables namely food availability, resistance to pests and diseases, nutritional content and crop yield with an R value of .530. The study recommended government to subsidise all inputs of genetically engineered varieties so that they are affordable for farmers to buy.

Key words: Cost, Adoption, varieties, food security, genetic engineering

5.1 Introduction

This chapter is concerned with the presentation, analysis and discussion of research findings on assessment of genetic engineering in enhancing maize productivity and addressing food security challenges in Bindura district, Zimbabwe. Furthermore, this chapter provides data presentation, discussion and analysis of s challenges associated with the adoption of genetically engineered maize varieties and potential contribution of genetic engineering to food security in Bindura District. Much of the comparison will be on understanding if the arguments by scholars in literature matched with reality as obtained from the research findings.

5.2 Materials and Methods

5.2.1 Description of study area

The study was conducted in Bindura District, natural region 2a, characterized by annual rainfall of between 800mm to 1200mm, maize is produced both under dry land and irrigation, and over

500 of farmers operate under small scale. This region was selected due to its significance in maize production and the potential impact of genetic engineering on local food security.

5.2.2 Research design

A survey-based research design was employed to assess the impact of genetic engineering on maize productivity and food security. This design in context of this chapter allowed for the collection of quantitative data to address challenges associated with the adoption of genetically engineered maize varieties and potential contribution of genetic engineering to food security in Bindura District.

5.2.3 Sampling procedure

A random sampling approach was used to select 200 of maize farmers for participation in the study. This method ensured a representative sample of the population.

5.2.4 Data collection procedure

Data were collected through surveys. The data collection instrument included a questionnaire. This method allowed for the gathering of detailed information on challenges associated with the adoption of genetically engineered maize varieties and potential contribution of genetic engineering to food security in Bindura District.

5.2.5 Data analysis procedure

Collected data were analysed using statistical software and thematic methods. Descriptive statistics and inferential statistics were employed to identify challenges associated with the adoption of genetically engineered maize varieties and potential contribution of genetic engineering to food security in Bindura District.

5.2.6 Challenges encountered during data collect

Several challenges were encountered during data collection, including access to remote areas this is due to some study sites were located in remote areas with limited road infrastructure, making it difficult to reach farmers and collect data in a timely manner. In addition, some farmers were hesitant to participate in the study due to concerns about the potential risks and benefits of genetic engineering. Building trust and rapport with respondents was crucial to overcoming this challenge. Furthermore, ensuring the accuracy and completeness of data collected from farmers and experts was a challenge, particularly in cases where respondents had limited literacy or record-keeping skills. To mitigate these challenges, the research team employed strategies such as working with local partners and using local languages. Despite these challenges, the study was able to collect valuable data that addressed the research objectives.

5.3 Results

5.3.1 Major challenges faced by farmers in Bindura District when adopting genetically engineered maize

Table 5.1: Correlations

		Adoption of GE maize	High input cost	Limited knowledge or training	Lack of access to technology	Market issues
Adoption of GE maize	Pearson Correlation	1	.172*	.059	-.061	-.174*
	Sig. (2-tailed)		.018	.425	.406	.017
	N	187	187	187	187	186
High input cost	Pearson Correlation	.172*	1	-.017	-.142	.056
	Sig. (2-tailed)	.018		.814	.053	.452
	N	187	187	187	187	186
Limited knowledge or training	Pearson Correlation	.059	-.017	1	-.120	-.142
	Sig. (2-tailed)	.425	.814		.102	.053
	N	187	187	187	187	186
Lack of access to technology	Pearson Correlation	-.061	-.142	-.120	1	.030
	Sig. (2-tailed)	.406	.053	.102		.687

	N	187	187	187	187	186
Market issues	Pearson Correlation	-.174*	.056	-.142	.030	1
	Sig. (2-tailed)	.017	.452	.053	.687	
	N	186	186	186	186	186
*. Correlation is significant at the 0.05 level (2-tailed).						

Source: SPSS (2025)

The correlation results show a significant positive correlation between high input cost and the adoption of GE maize. The correlation is weak (r = 0.172), but statistically significant (p = 0.018). This suggests that as high input cost increases, the outcome variable also tends to increase. Furthermore, there is a significant negative correlation between market issues and the variable of interest. The correlation is weak (r = -0.174), but statistically significant (p = 0.017). This suggests that as market issues increase, the outcome variable tends to decrease.

5.3.2 Potential contribution of genetic engineering to food security

Table 5.2: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.530[a]	.281	.265	.430	.281	17.741	4	182	.000
a. Predictors: (Constant), Food availability, resistance to pests and diseases, nutritional content and crop yield,									

Source: SPSS (2025)

The results in Table 4.6 shows an R value of .530 indicating a moderate correlation between genetic engineering and food security variables namely food availability, resistance to pests and diseases, nutritional content and crop yield. In addition, the results show R Square of 0.281 indicating that 28.1% of the variance in food security variables is explained by genetic engineering. Furthermore, the results suggest that genetic engineering has a significant positive contribution to food security, as measured by food availability, resistance to pests and diseases, nutritional content and crop yield. The moderate R Square value indicates that genetic engineering is one of several factors influencing food security.

Table 5.3: ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	13.096	4	3.274	17.741	.000[b]
	Residual	33.588	182	.185		
	Total	46.684	186			
a. Dependent Variable: Food security						
b. Predictors: (Constant), Food availability, resistance to pests and diseases, nutritional content and crop yield,						

Source: SPSS (2025)

The results in Table 4.7 shows an F value of 17.741, $p < 0.001$. This implies that the regression model is statistically significant, indicating that genetic engineering has a significant impact on food security variables.

5.4 Analysis and discussion of results

This section provides an analysis and discussion on results presented in the above section. The results on major challenges faced by farmers in Bindura District when adopting genetically engineered maize and potential contribution of genetic engineering to food security in Bindura district, Zimbabwe.

5.4.1 Major challenges faced by farmers in Bindura District when adopting genetically engineered maize

The study revealed that high input cost is a significant challenge faced by farmers in Bindura District when adopting genetically engineered maize that positively affects adopting genetically engineered maize. This could be because farmers who invest more in inputs such as seeds, fertilisers may experience better outcomes, for example, higher yields and improved crop quality. Market issues, on the other hand, have a negative impact on the outcome variable. This could be due to factors such as market fluctuations, lack of market access, or unstable prices, which can hinder farmers' ability to achieve their desired outcomes. The results agree with Haggblade & Tembo (2024) established that adoption of genetically engineered maize is hindered by factors such as seed accessibility, market preference and cost.

5.4.2 Potential contribution of genetic engineering to food security

The study revealed a moderate positive relationship between genetic engineering and food security variables namely food availability, resistance to pests and diseases, nutritional content and crop yield with an R value of .530. In addition, 28.1% of the variance in food security variables was being explained by genetic engineering. Furthermore, the results suggest that genetic engineering has a significant positive contribution to food security, as measured by food availability, resistance to pests and diseases, nutritional content and crop yield. The results were in agreement with Klümper and Qaim (2024) demonstrated that GE maize increased yields by approximately 52% on average compared to non-GE varieties. Genetic engineering allows scientists to modify the genetic makeup of the maize crop to introduce desired traits. This includes enhancing resistance to pests, diseases and environmental stresses. Furthermore, the study established that nutritional content as one of variable with positive effect on food security. The results concur with Obukosia, (2020) revealed that biofortified maize varieties can provide essential vitamins and minerals. This approach has the potential to combat malnutrition and improve public health.

5.5 Recommendations

Based on the study results, the following recommendations can be made:

- Government should subsidise all inputs of genetically engineered varieties so that they are affordable for farmers to buy.
- All agricultural stakeholders should provide training and education programs for farmers, extension agents, and other stakeholders on the benefits and risks of genetic engineering.
- The government should strengthen the capacity of regulatory agencies to effectively regulate genetically engineered crops.
- Furthermore, more long term studies to assess the impact of genetically engineered crops on the environment, human health, and food security should be conducted.

5.6 Conclusion

This chapter presented, analysed and discussed results on assessment of genetic engineering in enhancing maize productivity and addressing food security challenges in Bindura district, Zimbabwe. The chapter presented the results on major challenges faced by farmers in Bindura District when adopting genetically engineered maize and potential contribution of genetic engineering to food security in Bindura district, Zimbabwe. The study revealed that high input cost is a significant challenge faced by farmers in Bindura District when adopting genetically engineered maize that positively affects adopting genetically engineered maize. The study revealed a moderate positive relationship between genetic engineering and food security variables namely food availability, resistance to pests and diseases, nutritional content and crop yield with an R value of .530. The study recommended that government should subsidise all inputs of genetically engineered varieties so that they are affordable for farmers to buy.

5.7 References

Haggblade, S. and Tembo, G. (2024). *Farmer Attitudes Towards Genetically Modified Crops: Evidence from Zimbabwe*. Agricultural Economics, Zimbabwe

Klümper, W. and Qaim, M. (2024). *A Meta-Analysis of the Impacts of Genetically Modified Crops*. PLoS ONE.

Obukosia, S.D. (2020). *Biotechnology of Nutritionally Enhanced Food Crops Targeting Malnutrition in Rural Agricultural Populations: The Case Study of Africa Biofortified Sorghum*. *In Biotechnology in Africa*. Emergence, Initiatives and Future; Wambugu, F., Kamanga, D., Eds.; Science Policy Reports; Springer International Publishing: Cham, Switzerland, 2014; pp. 157–177

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter presents summary, conclusions and recommendations for the study on assessment of genetic engineering in enhancing maize productivity and addressing food security challenges in Bindura district, Zimbabwe. The section on this chapter include research summary, conclusions, policy implications and recommendations, areas of further research, references and appendices.

6.2 Research summary

Maize productivity in Zimbabwe remains low, with average yields of 0.8 tons/ha compared to the global average of 5.6 tons/ha. This low productivity is attributed by various factors, including pests, diseases, and climate change. Genetic engineering has been proposed as a potential solution to improve maize productivity and food security in Bindura District, Zimbabwe. This study aimed to assess the impact of genetic engineering on maize productivity and food security challenges in Bindura District, Zimbabwe, and provide evidence-based recommendations for policymakers and farmers. The study objectives were to determine the significant difference in yield output between genetically engineered maize varieties and conventional varieties, explore the knowledge and attitudes of farmers towards genetically engineered maize, assess the challenges associated with the adoption of genetically engineered maize varieties and determine the potential contribution of genetic engineering to food security in Bindura District. The Innovation Diffusion Theory developed by Rogers (2023), which explains how new ideas, technologies, or practices are adopted and diffused within a social system was the theoretical framework guiding the study. This study used a mixed-methods research approach, combining both quantitative and qualitative data collection and analysis methods. A sample of 200 maize farmers was selected for the study using Slovin's formula. Analytical tools used for the study objectives were T-test, KAP analysis, correlation analysis and regression analysis.

The results indicated that the demographic characteristics of the study were dominated by females. The study established that genetically engineered (GE) group had a mean yield per hectare of 5.32 with a standard deviation of 2.923, while the conventional group had a mean yield per hectare of 2.58 with a standard deviation of 1.447. Farmer's response indicated that increased knowledge about genetically engineered maize can lead to a more positive attitude towards its adoption. Education and awareness programs can play a crucial role in promoting the adoption of new technologies. However, some farmers view genetically engineered maize as a profit-driven technology rather than a solution to agricultural challenges. This perception can affect attitudes towards adoption and use. Furthermore, the study revealed that high input cost is a significant challenge faced by farmers in Bindura District when adopting genetically engineered maize that positively affects adopting genetically engineered maize. The study revealed a moderate positive relationship between genetic engineering and food security variables namely food availability, resistance to pests and diseases, nutritional content and crop yield with an R value of .530.

6.3 Conclusions

The study concluded that genetically engineered (GE) group have a higher mean yield per hectare of 5.32 with a standard deviation of 2.923, while the conventional group have a mean yield per hectare of 2.58 with a standard deviation of 1.447. This means that genetically engineered (GE) produces a yield of 2.7tons per hectare than convectional varieties. This conclusion is supported by Mashingaidze and Frankenberg (2022) conducted a study in Zimbabwe found that genetically engineered maize varieties yielded 2.5 tons per hectare more than conventional varieties.

Furthermore, the study concludes that farmers hold both positive and negative attitude, perceptions and practices towards adoption of genetically engineered varieties. This is due to demographic characteristics of famers, dissemination of information and cost of genetically engineered inputs. The findings were supported by Kahn et al. (2020) established that farmers in Bindura exhibited mixed feelings about GE maize. While some recognized the potential benefits, such as increased yields and reduced pest damage, others expressed concerns regarding long-term health effects, environmental impacts, and market acceptance.

In addition, the study concludes that high input cost and market issues are major challenges faced by farmers in Bindura District when adopting genetically engineered. On high cost could be due to farmers who invest more in inputs such as seeds, fertilisers may experience better outcomes, for example, higher yields and improved crop quality. Market issues, on the other hand, could be due to factors such as market fluctuations, lack of market access, or unstable prices, which can hinder farmers' ability to achieve their desired outcomes. This conclusion is in sync with Tembo (2024) established that adoption of genetically engineered maize is hindered by factors such as seed accessibility, market preference and cost.

Finally, the study concludes that genetic engineering has 53% potential to contribute to food security. This was revealed by a moderate positive relationship between genetic engineering and food security variables namely food availability, resistance to pests and diseases, nutritional content and crop yield with an R value of .530. The results were supported by Klümper and Qaim (2024) demonstrated that GE maize increased yields by approximately 52% on average compared to non-GE varieties. Genetic engineering allows scientists to modify the genetic makeup of the maize crop to introduce desired traits. This includes enhancing resistance to pests, diseases and environmental stresses.

6.4 Policy implications and recommendations

On Objective 1: To determine the significant difference in yield output between genetically engineered maize varieties and conventional varieties in Bindura District

The study's establishing that genetically engineered (GE) crops have a significantly higher mean yield (5.32) compared to conventional crops (2.58) have important policy implications. Policymakers should prioritize investment in GE research and development to further improve crop yields and address food security challenges. Additionally, governments can provide incentives for farmers to adopt GE crops, such as subsidies or tax breaks, to encourage the transition to more productive and sustainable agricultural practices. This could lead to increased food availability, improved livelihoods for farmers, and enhanced national food security.

On objective 2: To explore the knowledge and attitudes of farmers towards genetically engineered maize in Bindura District.

The mixed attitudes, perceptions, and practices among farmers regarding GE crop adoption highlight the need for targeted awareness and education programs. Policymakers should invest in public outreach and education initiatives to provide accurate information about the benefits and risks of GE crops. This could include training programs for farmers, extension agents, and other stakeholders to address concerns and promote informed decision-making. Furthermore, policymakers should engage with farmers and other stakeholders to understand their concerns and develop policies that address their needs and priorities.

On objective 3: To assess the challenges associated with the adoption of genetically engineered maize varieties in Bindura District.

The high cost of GE seeds and market issues are significant barriers to adoption, particularly for smallholder farmers. Policymakers should develop and implement policies to make GE seeds more affordable and accessible to farmers. This could include subsidies, credit programs, or partnerships with private sector companies to reduce costs and improve market access. Additionally, governments can establish regulatory frameworks that promote fair competition and transparency in the seed market, ensuring that farmers have access to high-quality GE seeds at competitive prices.

On objective 4: To determine the potential contribution of genetic engineering to food security in Bindura District.

The study's finding that GE crops have a 53% potential to contribute to food security highlights the importance of investing in this technology. Policymakers should prioritize GE research and development, focusing on traits that enhance crop yields, nutritional content, and resistance to pests and diseases. Governments can also develop policies to support the adoption of GE crops, such as providing incentives for farmers, investing in infrastructure, and promoting market access. By harnessing the potential of GE crops, policymakers can make significant strides in addressing food security challenges and improving the livelihoods of farmers and communities.

6.5 Areas of further research

Based on the policy implications and recommendations, areas of further research are needed to fully harness the potential of genetically engineered (GE) crops. Key areas of investigation include economic analysis, social and behavioral studies, regulatory frameworks, technological advancements, impact assessment, and policy evaluation. Specifically, research could focus on cost-benefit analysis of GE crop adoption, assessing farmer attitudes and perceptions, and developing guidelines for regulatory frameworks that promote fair competition.

Additional studies could explore new GE traits, long-term impact assessments, and policy evaluations to ensure that GE crops contribute to food security, sustainable agriculture, and improved livelihoods for farmers and communities. By addressing these knowledge gaps, researchers and policymakers can work together to develop evidence-based policies and programs that support the safe and effective deployment of GE crops.

6.6 References

Haggblade, S. and Tembo, G. (2024). *Farmer Attitudes Towards Genetically Modified Crops: Evidence from Zimbabwe.* Agricultural Economics. Zimbabwe.

Klümper, W. and Qaim, M. (2024). *A Meta-Analysis of the Impacts of Genetically Modified Crops.* PLoS ONE.

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6.7 Appendices

Appendix 1: Survey questionnaire

BINDURA UNIVERSITY OF SCIENCE EDUCATION

My name is Margret Chiwara, a Msc. Food Security and Sustainable Agriculture student. I am carrying out a survey on the role of genetic engineering in enhancing maize productivity and addressing food security challenges in Bindura District. Be assured that whatever we are going to discuss on this questionnaire is going to be strictly confidential and information is going to be used only for academic purposes. Do not feel obliged to answer any question but it is my wish that you answer all questions.

Section 1: Demographic Information

Date …………………………………………………

Tick the correct answer

1. Age:

[ ] 18-25

[ ] 26-35

[ ] 36-45

[ ] 46-55

[ ] 56 and above

2. Gender

[ ] Male

[ ] Female

3. Level of Education:

[ ] No formal education

[ ] Primary education

[ ] Secondary education

[ ] Tertiary education

4. Farming Experience (in years)

[ ] 0-5

[ ] 6-10

[ ] 11-15

[ ] 16-20

[ ] 21 and above

Section 2: Knowledge and Attitudes towards genetically engineered maize

5. How familiar are you with genetically engineered maize?

[ ] Very familiar

[ ] Somewhat familiar

[ ] Not familiar

6. What is your overall attitude towards genetically engineered maize?

[ ] Very positive

[ ] Positive

[ ] Neutral

[ ] Negative

[ ] Very negative

7. What benefits do you associate with genetically engineered maize? (Select all that apply)

[ ] Higher yields

[ ] Pest resistance

[ ] Drought tolerance

[ ] Improved nutritional content

[] Other (please specify): ……………………………………………………………………….....................................
.....

8. What concerns do you have regarding genetically engineered maize? (Select all that apply)

[ ] Health risks

[ ] Environmental impact

[ ] Economic costs

[ ] Lack of information

[ ] Other (please specify): ………..

Section 3: Yield Output Comparison

9. What type of maize do you currently grow?

[ ] Genetically engineered maize

[ ] Conventional maize

[ ] Both

10. What is the average yield of your maize per hectare?

Section 4: Challenges in Adoption

12. What challenges do you face in adopting genetically engineered maize? (Select all that apply)

[ ] High seed costs

[ ] Lack of access to technology

[ ] Limited knowledge or training

[ ] Market access issues

[ ] Other (please specify): ……..

13. Have you received any training or information on genetically engineered maize?

[ ] Yes

[ ] No

Section 5: Contribution to Food Security

14 How has genetic engineering affected your food security? (Improved/No impact/Worsened)

15 Do you think genetic engineering has improved your household income? (Yes/No)

16. What additional measures do you think are necessary to enhance food security through genetic engineering?

[ ] More education and training

[ ] Government support

[ ] Research and development

[ ] Improved market access

[ ] Other (please specify): ……..

Section 6: Additional Comments

17. Please provide any additional comments or suggestions regarding genetic engineering in maize production:

Thank you for your participation!

Appendix 2: Interview Guide

INTERVIEW GUIDE

Interview guide to assess the perceptions and attitudes of farmers in Bindura towards genetically engineered maize using KAP analysis:

Section 1: Knowledge

1. Have you heard about genetically engineered maize?

2. What do you know about genetically engineered maize?

3. Do you think genetically engineered maize is safe for human consumption?

4. Have you received any information about genetically engineered maize from extension services or other sources?

Section 2: Attitudes

1. What is your attitude towards genetically engineered maize?

2. Do you think genetically engineered maize can help improve food security in your household?

3. Are you willing to adopt genetically engineered maize in your farming practices?

4. What are your concerns about genetically engineered maize?

Section 3: Practices

1. Have you adopted genetically engineered maize in your farming practices?

2. If yes, how did you learn about genetically engineered maize?

3. What motivated you to adopt genetically engineered maize?

4. Have you experienced any benefits or challenges from using genetically engineered maize?