

The Effectiveness of Seed Certification and Variety Protection Management Systems on Seed Maize Quality and Market Integrity: A Project Management Perspective

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Abstract: Agriculture is more than just farming—it is the backbone of food security and economic stability. At the heart of any successful agricultural venture is the use of high-quality seed. However, counterfeit seed remains a major challenge, often due to weak regulatory frameworks or a lack of proper seed certification processes. This not only affects farmers but also undermines the Seed and Plant Varieties Act (Cap 326), which is designed to ensure seed quality and protect genetic purity.

Seed certification plays a vital role in guaranteeing seed quality, giving farmers confidence that what they plant will produce the expected results. Enterprise Resource Planning (ERP) systems have become an essential tool in managing seed certification and variety protection, helping to streamline operations, track inventory, and ensure compliance with industry standards.

This study set out to assess how effective seed certification and ERP systems are in maintaining seed maize quality and market integrity, with a special focus on project management practices. A research questionnaire was developed covering key aspects such as seed certification, variety protection, project management success, and market integrity. After conducting a pilot study to confirm its reliability, the full research was carried out, and the collected data was analyzed using statistical methods.

The findings showed a strong relationship between seed certification and market integrity, meaning that when seed certification is compromised, market trust is also affected. Additionally, the study found that successful project management practices play a crucial role in ensuring effective seed certification, which in turn strengthens market integrity. Statistical tests, including analysis of variance (ANOVA), Pearson correlation analysis, and multiple regression models, confirmed that seed certification, variety protection, and project management practices are all interconnected, with a significant combined influence on market integrity. The Pearson correlation coefficient of 0.72 indicated a strong positive relationship between seed certification and market integrity, while regression analysis revealed that variety protection had the highest impact on market integrity ($\beta = 0.455$), followed by project management ($\beta = 0.38$) and seed certification ($\beta = 0.34$). The ANOVA results further demonstrated that these relationships were statistically significant, with a p-value of 0.00000475, reinforcing the critical role of regulatory compliance in maintaining seed quality and market confidence.

Beyond certification, the study highlighted the value of ERP systems in the seed industry. ERP systems improve efficiency by automating tasks, ensuring compliance, and providing real-time monitoring, all of which help in reducing counterfeit seed and maintaining seed quality.

To improve market integrity, regulatory bodies must enforce stricter quality control measures and leverage modern technologies to detect counterfeit seed. Additionally, adopting structured project management frameworks, including ERP systems, can enhance coordination, resource allocation, and monitoring of key processes. Lastly, creating awareness among farmers and industry stakeholders, along with continuous monitoring and evaluation of the seed certification process, is essential in maintaining a transparent and trustworthy seed market.

Keywords: Agriculture, Seed Certification, Variety Protection Management Systems, food security.

1. INTRODUCTION

1.1 Background to the Study

Agricultural success heavily relies on the quality of seeds available to farmers. In Kenya, seed certification and variety protection management systems play a crucial role in ensuring that farmers access high-quality, genetically pure, and reliable seeds. These systems are governed by The Seeds and Plant Varieties Act (Cap 326), which sets standards for certification, registration, and protection of plant varieties. However, despite the presence of a well-defined regulatory framework, challenges persist. Farmers continue to face issues related to counterfeit seeds, weak enforcement of certification standards, and delays in the certification process. These challenges threaten agricultural productivity, reduce market confidence, and undermine food security.

Seed certification is designed to ensure that seeds meet specific quality standards in terms of genetic purity, germination rate, and resistance to diseases. It involves multiple stages, including field inspections, laboratory testing, and post-certification monitoring. However, in practice, inefficiencies such as inadequate regulatory oversight and limited technical capacity weaken the effectiveness of this process. Similarly, variety protection laws are meant to safeguard plant breeders' rights and prevent unauthorized seed reproduction. Unfortunately, enforcement of these laws is often inconsistent, allowing counterfeit seeds to infiltrate the market. The presence of substandard and uncertified seeds not only affects farmer productivity but also distorts the seed market by reducing trust in certified seed suppliers.

This study seeks to evaluate how well the current seed certification and variety protection management systems function in maintaining seed maize quality and market integrity. It will assess whether these systems effectively protect farmers from counterfeit seeds and ensure compliance with genetic purity standards. Additionally, the study will explore how project management practices can be applied to improve efficiency, risk mitigation, and regulatory enforcement in seed certification.

1.2 Relevance to Kenya's Seed Certification System

Kenya, through KEPHIS and the Seeds and Plant Varieties Act (Cap 326), aligns with international best practices but faces implementation challenges similar to those in other developing countries. While Kenya Seed Company controls 70% of the local seed maize market, issues such as counterfeit seeds, regulatory loopholes, and delayed certification timelines impact market integrity.

1.3 Statement of the problem

High-quality seed maize is the foundation of a productive agricultural sector, yet farmers continue to face challenges in accessing genuine, certified seeds. The widespread presence of counterfeit seeds and weak enforcement of certification regulations have significantly undermined the reliability of seed markets. Many farmers have experienced cases where seeds they purchase fail to produce the expected yield because they are not true to type, raising concerns about the credibility of certification bodies. This lack of trust in the seed certification system threatens food security and the overall stability of the agricultural industry.

The existing regulatory framework under the Seeds and Plant Varieties Act (Cap 326) is designed to enforce strict seed certification and variety protection standards. However, enforcement gaps, ineffective monitoring, and coordination challenges among key stakeholders allow substandard seeds to enter the market. Farmers often bear the cost of these inefficiencies, experiencing financial losses due to poor crop performance. Breeders, regulatory agencies, and seed merchants struggle to implement variety protection laws effectively, further complicating efforts to ensure quality seed distribution.

Additionally, weak stakeholder coordination limits the effectiveness of the regulatory framework. Without proper oversight and accountability, counterfeit seeds continue to infiltrate the market, diminishing the integrity of the entire seed supply chain. While project management principles have been widely used in various industries to improve efficiency and mitigate risks, their application in seed certification and variety protection remains underexplored. Structured project management strategies could play a crucial role in strengthening certification processes, enhancing compliance, and improving overall market integrity.

This study aims to bridge the gap by evaluating the current effectiveness of seed certification and variety protection systems while exploring how project management principles can be leveraged to enhance regulatory compliance and transparency in the seed industry.1.5

1.4 Objectives of the study

1.4.1 General Objective

The general objective is to determine the Effectiveness of Seed Certification and Variety Protection Management Systems on Seed Maize Quality and Market Integrity

1.4.2: Specific Objectives

The specific objectives are:

- i) To evaluate the effectiveness of seed certification system in ensuring seed maize quality, with a focus on trueness to type and genetic purity.
- ii) To assess the impact of counterfeit seed on market integrity within Kenya Seed Company Limited's supply chain and evaluate KEPHIS's role in mitigating its effects on farmer productivity and food security.
- iii) To analyze the effectiveness of variety protection management systems in preventing unauthorized seed production and maintaining seed quality standards.
- iv) To explore project management best practices (as outlined in PMBOK) that can enhance quality assurance, risk mitigation, and regulatory compliance in the seed sector.

1.5 Research Questions

- i) To what extent does seed certification guarantee trueness to type and genetic purity?
- ii) What are the major factors contributing to the presence of counterfeit seed in the market and what does KEPHIS do to mitigate its effects on farmer productivity?
- iii) How effective is the variety protection management system in preventing unauthorised production of substandard seed?
- iv) How can project management best practices (as outlined in PMBOK) enhance quality assurance, risk mitigation, and regulatory compliance in Kenya's seed sector?

1.6 Justification for study

The effectiveness of seed certification and variety protection management systems is critical to ensuring seed maize quality and market integrity in Kenya. This study is justified for the following reasons:

i) Enhancing Seed Quality and Trueness to Type

Frequent complaints from farmers about seed not being true to type indicate potential weaknesses in the seed certification process. By evaluating the effectiveness of KEPHIS's certification framework, this study aims to identify gaps and recommend improvements to enhance seed genetic purity and trueness to type.

ii) Combating Counterfeit Seed and Strengthening Market Integrity

The presence of counterfeit seed threatens market confidence, farmer productivity, and food security. By focusing on Kenya Seed Company Limited's supply chain, this study will assess the extent of the problem and evaluate the effectiveness of KEPHIS's regulatory measures in combating counterfeit seed.

iii) Regulatory and Policy Improvements

The study will provide insights into the enforcement of the Seeds and Plant Varieties Act (Cap 326) and how KEPHIS ensures compliance. This will support policy recommendations for improving seed certification, variety protection, and market surveillance.

iv) Application of Project Management Best Practices (PMBOK)

Managing seed certification and variety protection involves multiple stakeholders, risks, and compliance challenges. This study will integrate project management best practices (as outlined in PMBOK) to enhance risk mitigation, quality assurance, and regulatory efficiency in the seed industry.

v) Contribution to Knowledge and Industry Best Practices

There is limited research on the effectiveness of seed certification and variety protection from a project management perspective. This study will bridge that gap by providing empirical data and recommendations that can be applied to improve seed regulatory frameworks and strengthen market confidence in certified seed.

1.7 Scope of study

This study focuses on the effectiveness of seed certification and variety protection management systems in ensuring seed maize quality and market integrity in Kenya. The research is specifically limited to two key institutions: Kenya Plant Health Inspectorate Service (KEPHIS) and Kenya Seed Company Limited (KSC).

2. LITERATURE REVIEW**2.1 INTRODUCTION**

The quality of seed maize is a cornerstone of agricultural productivity and food security, directly influencing crop yields, resilience to environmental stresses, and the economic viability of farming systems. Seed certification and variety protection management systems have emerged as critical institutional mechanisms to ensure the production and distribution of high-quality seeds while safeguarding market integrity. These systems aim to regulate seed production, verify varietal identity and purity, and protect intellectual property rights, thereby fostering trust among stakeholders in the seed supply chain. From a project management perspective, the effectiveness of these systems hinges on their ability to coordinate diverse actors—such as breeders, seed companies, certification agencies, and farmers—while optimizing resources, timelines, and outcomes. Recent studies have increasingly explored how these mechanisms impact seed maize quality and market dynamics, particularly in the context of evolving agricultural challenges like climate change, counterfeit seeds, and global trade demands.

Seed certification serves as a quality assurance process, ensuring that seeds meet predefined standards for genetic purity, germination rates, and freedom from pests and diseases. Scholars such as Bishaw and Gastel (2009) emphasize that certification bridges the gap between formal breeding programs and farmers by guaranteeing access to reliable seeds of improved varieties. Similarly, variety protection management systems, often grounded in frameworks like the International Union for the Protection of New Varieties of Plants (UPOV), incentivize innovation in plant breeding by granting intellectual property rights to developers of new maize varieties (Gadwal, 2003). These systems are particularly vital in maize-dependent regions, where hybrid seeds dominate due to their high yield potential, yet their efficacy relies heavily on robust implementation and enforcement.

Despite their importance, the effectiveness of seed certification and variety protection systems remains contested. Louwaars (1994) argues that while formal seed systems enhance quality control for commercially viable crops like maize, they often fail to address the needs of smallholder farmers who rely on informal seed networks. Moreover, inconsistencies in regulatory frameworks across countries can undermine market integrity, as highlighted by David and Sperling (1999), who note the challenges of harmonizing seed laws in regions like sub-Saharan Africa. Recent research also points to project management factors—such as stakeholder collaboration, resource allocation, and monitoring—as determinants of success in these systems (Makanda, 2018). For instance, the Drought Tolerant Maize for Africa (DTMA) initiative demonstrates how coordinated efforts between public and private sectors can enhance seed quality and availability, yet gaps in scalability and adoption persist (CIMMYT, 2017).

This literature review examines the effectiveness of seed certification and variety protection management systems on seed maize quality and market integrity, with a focus on project management principles. By synthesizing findings from key studies (e.g., Bishaw & Gastel, 2009; Louwaars, 1994; Gadwal, 2003; CIMMYT, 2017), it seeks to identify best practices, challenges, and opportunities for improving these systems. The review is particularly timely given the growing demand for resilient maize varieties and the need to combat seed fraud in increasingly competitive markets. Through this analysis, the

study aims to contribute to a deeper understanding of how project management perspectives can enhance the impact of seed systems on agricultural sustainability and economic outcomes.

2.2 THEORETICAL REVIEW

2.2.1 Seed Certification and Variety Protection

Seed certification is a crucial quality assurance process that ensures farmers receive high-quality seed that meets established genetic, physical, and physiological standards (FAO, 2019). This process involves field inspections, laboratory testing, and post-certification monitoring to confirm that the seed is true to type, free from contaminants, and has high germination rates (Gisselquist & Van Der Meer, 2001).

In Kenya, KEPHIS (Kenya Plant Health Inspectorate Service) oversees seed certification under the Seed and Plant Varieties Act (Cap 326) (KEPHIS, 2022). The certification process follows key steps, including variety registration, field inspections, post-control testing, and sealing of approved seed lots (KEPHIS, 2021). These measures help maintain seed quality, ensuring that farmers get reliable and productive seed for their crops.

Closely tied to certification is variety protection, which safeguards plant breeders' rights through intellectual property rights (IPR) mechanisms. This ensures that registered seed varieties are not illegally reproduced, protecting breeders' investments and encouraging further innovation in seed development (Tripp, 2001).

Kenya follows a Plant Breeders' Rights (PBR) system under KEPHIS, aligned with UPOV 1991 (International Union for the Protection of New Varieties of Plants) standards (KEPHIS, 2020). This system benefits seed companies like Kenya Seed Company Limited (KSC) by preventing unauthorized reproduction or distribution of their hybrid maize seed varieties. By protecting breeders' efforts, variety protection promotes continued advancements in seed technology, ultimately benefiting farmers and the agricultural sector as a whole.

2.2.2 Market Integrity

Market integrity in the seed sector refers to the trust and confidence that farmers, seed merchants, and policymakers have in certified seed. The presence of counterfeit seed undermines market integrity, leading to reduced farmer productivity and losses in the formal seed sector (Spielman & Smale, 2017).

2.2.3 Project Management Application in Seed Certification and Variety Protection

The implementation of seed certification and variety protection management systems is a complex project requiring structured governance, risk management, and compliance (PMI, 2021). The use of Enterprise Resource Planning (ERP) systems has been adopted by regulatory agencies like KEPHIS to improve traceability, enforcement, and efficiency in seed certification.

2.2.4 Impact of counterfeit seed on market integrity and food security

Market integrity in the seed industry refers to the assurance that only genuine, high-quality seeds are sold to farmers, protecting both the seed supply chain and agricultural productivity. However, counterfeit seed has become a significant challenge in Kenya's seed sector, particularly affecting Kenya Seed Company Limited (KSC), which controls approximately 70% of the seed maize market. The presence of counterfeit seed undermines farmer confidence, reduces productivity, and ultimately threatens food security. KEPHIS, as the regulatory body responsible for seed quality enforcement, plays a critical role in ensuring that the market remains free from substandard and illegal seed products.

Counterfeit seed refers to seed that is fraudulently packaged and sold as certified but does not meet the required genetic or physiological standards. In Kenya, counterfeit seeds often mimic packaging from reputable companies like KSC, making it difficult for farmers to distinguish genuine certified seeds from fake ones. Studies indicate that counterfeit seed has led to significant yield losses, as it lacks the expected genetic traits such as drought resistance, high germination rates, and pest resistance (Muthini et al., 2020). When farmers unknowingly plant counterfeit seed, they experience poor crop performance, leading to financial losses and increased vulnerability to food insecurity. This problem is exacerbated by weak supply chain monitoring, inadequate farmer awareness, and loopholes in seed regulation enforcement.

KEPHIS has implemented several regulatory measures to mitigate the impact of counterfeit seed on market integrity. One of its primary interventions is the enforcement of the Seeds and Plant Varieties Act (Cap 326), which mandates strict

certification protocols and market surveillance. KEPHIS conducts regular seed testing to verify authenticity and penalizes companies or individuals found distributing substandard seeds. Additionally, the introduction of seed traceability systems, such as online clearance codes and tamper-proof certification labels, aims to enhance transparency in the seed supply chain (KEPHIS Annual Report, 2022). However, these measures are not foolproof, as counterfeiters continually adapt their strategies, finding ways to infiltrate the market.

Kenya Seed Company Limited, as the leading seed merchant, has also taken steps to protect market integrity by improving branding, increasing farmer awareness, and working closely with law enforcement agencies. KSC has introduced unique batch numbering, accurate traceability mechanisms, and proper activation of sticker label codes on seed packets. The introduction of scratch-off labels allows farmers to send a code via SMS to confirm the legitimacy of the seed package. (KEPHIS 2021) This system has significantly improved the ability to trace and authenticate seeds, enhancing overall market integrity. These measures allow farmers to verify seed authenticity before purchase, reducing the risk of counterfeit products entering the market. Despite these efforts, the persistence of counterfeit seed indicates that more comprehensive interventions are needed. Strengthening collaboration between KEPHIS, KSC, and other stakeholders in the seed industry is essential for developing more robust anti-counterfeit strategies.

In conclusion, counterfeit seed remains a major threat to market integrity, farmer productivity, and food security in Kenya. While KEPHIS and KSC have made notable strides in combating this challenge through certification enforcement and traceability measures, counterfeiters continue to exploit gaps in the regulatory framework. A multi-stakeholder approach, involving technological advancements, stronger enforcement mechanisms, and increased farmer education, is necessary to safeguard Kenya's seed industry and maintain trust in the seed market.

2.2.5 Project management best practices in the seed sector.

Effective seed certification and variety protection require structured project management approaches to enhance quality assurance, mitigate risks, and ensure regulatory compliance. The Project Management Body of Knowledge (PMBOK) provides a framework that can be applied to the seed sector by integrating structured methodologies into seed quality control, certification, and market oversight (PMI, 2021). The key project management areas relevant to seed quality include scope management, risk management, stakeholder engagement, and integration management.

In the seed industry, quality assurance is a critical component of project management that ensures seed maize meets certification standards. PMBOK emphasizes quality management processes such as quality planning, quality assurance, and quality control (PMI, 2021). These processes align with the requirements of ISO 9001:2015, which many seed certification agencies, including KEPHIS, have adopted to standardize seed testing and inspection procedures (KEPHIS, 2022). Through quality audits, seed testing protocols, and traceability systems, project management principles help maintain trueness to type and genetic purity, reducing the likelihood of seed contamination or mislabeling (Tripp & Louwaars, 2017).

Risk mitigation in seed certification and variety protection involves identifying and addressing risks related to counterfeit seeds, unauthorized variety reproduction, and regulatory non-compliance. PMBOK outlines a structured risk management framework, which includes risk identification, analysis, response planning, and continuous monitoring (PMI, 2021). For instance, Kenya's seed sector has implemented digital tracking systems that allow real-time monitoring of seed movement through unique batch numbering, accurate traceability, and verification codes on sticker labels (KEPHIS, 2021). These measures enhance market integrity by preventing fraud and unauthorized seed distribution. However, enforcement gaps remain due to challenges in stakeholder coordination and inadequate resources (Mabaya et al., 2019).

Regulatory compliance in the seed sector is enforced through structured policies such as the Seed and Plant Varieties Act (Cap 326), which provides guidelines on certification, variety protection, and market monitoring. PMBOK's stakeholder management knowledge area emphasizes the importance of engaging regulatory agencies, seed merchants, and farmers to ensure compliance (PMI, 2021). In Kenya, Kenya Seed Company Limited has integrated Enterprise Resource Planning (ERP) systems into its operations, aligning with KEPHIS regulations to streamline certification processes and enhance decision-making (KSC, 2022). While ERP adoption has improved seed tracking and quality verification, studies indicate that resistance to technology adoption and limited technical expertise pose challenges in implementation (Gotor et al., 2018).

To enhance seed sector governance, project management best practices also emphasize integration management, ensuring that various quality control and compliance activities are coordinated. The Bottom-Up Economic Transformation Agenda

(BETA), introduced by the Kenyan government, places emphasis on food security through certified quality seed (Government of Kenya, 2023). This policy shift requires seed regulators and merchants to adopt structured project management methodologies to improve efficiency, traceability, and responsiveness to market demands. Lessons from international seed markets, such as the European Union's Common Catalogue for Plant Varieties, demonstrate how standardized certification processes and digital variety protection systems can enhance market transparency (EU Commission, 2020).

2.3. CONCEPTUAL FRAMEWORK

The conceptual framework for this study is built upon the relationship between seed certification, variety protection management, market integrity, and project management principles in ensuring seed maize quality and food security in Kenya. It outlines how regulatory mechanisms, enterprise resource planning (ERP) systems, and best practices in project management interact to enhance seed quality assurance and market trust.

At the core of this framework is seed certification, which serves as the primary mechanism for ensuring that seed maize meets standards of trueness to type, genetic purity, and quality control. This process is overseen by KEPHIS, which enforces Seed Act Cap 326 to regulate seed production, processing, and marketing. However, challenges such as loopholes in certification processes and counterfeit seed have raised concerns about market integrity.

2.4 REVIEW OF VARIABLES

2.4.1 Independent Variables

2.4.1 a) Seed Certification Standards and Processes

Certification is a cornerstone of formal seed systems, ensuring that seeds meet quality benchmarks. Bishaw and Gastel (2009) note that certification reduces the risk of poor-performing seeds reaching farmers, a key concern in maize production where hybrid vigor is critical.

Stricter standards and enforcement should improve seed maize quality by filtering out substandard lots. They also enhance market integrity by building farmer trust in certified seeds, though Louwaars (1994) cautions that overly rigid processes may exclude informal seed systems, potentially disrupting local markets.

2.4.1 b) Variety Protection Management Frameworks

Gadwal (2003) highlights that variety protection incentivizes breeders to develop high-yielding maize varieties, while also preventing unauthorized replication. This is vital in competitive markets where hybrids dominate.

Effective protection should lead to higher seed quality by encouraging innovation, while also bolstering market integrity by reducing counterfeit seeds. However, weak enforcement, as noted by David and Sperling (1999), can undermine these benefits.

2.4.1 c) Project Management Practices

Makanda (2018) underscores that successful seed system projects—like the (Drought Tolerant Maize for Africa) DTMA initiative—rely on coordinated stakeholder efforts and efficient resource use. Poor management can derail certification or protection efforts.

Strong project management should enhance seed quality by ensuring timely delivery of certified seeds and improve market integrity through transparent processes. CIMMYT (2017) illustrates this with examples of public-private partnerships.

2.4.2. Dependent Variables

2.4.2 a) Seed Maize Quality

High-quality seeds are the foundation of agricultural productivity, particularly for maize, a staple crop globally. Quality directly affects yield and farmer livelihoods.

Certification ensures compliance with quality standards, while variety protection fosters the development of superior varieties. Project management ensures these systems are effectively implemented, and harmonization prevents quality dilution in trade.

2.4.2 b) Market Integrity

A trustworthy seed market is essential for economic stability and farmer confidence. Counterfeit seeds erode this trust, as seen in cases documented by CIMMYT (2017).

Certification builds credibility, variety protection deters fraud, project management ensures transparency, and harmonization minimizes regulatory loopholes.

2.4.3 Considerations of the variables

The interplay between these variables suggests a complex system where independent factors collectively shape seed maize quality and market integrity. For instance, robust certification standards paired with effective project management could amplify seed quality, while variety protection and regulatory harmonization might synergistically strengthen market integrity. However, challenges arise when these systems are misaligned—e.g., strong certification without harmonization could limit market access, or poor project management could undermine protection enforcement.

From a project management perspective, success depends on balancing these variables to achieve measurable outcomes.

This framework provides a foundation for evaluating how seed systems can be optimized to meet the dual goals of quality and integrity in maize markets.

2.5 Critique of existing literature

Existing literature on seed certification and variety protection emphasizes the importance of regulatory frameworks in ensuring seed quality, genetic purity, and market integrity (Gisselquist et al., 2019). Studies highlight the role of certification agencies such as KEPHIS in enforcing compliance with standards, yet many fail to provide empirical data on the effectiveness of enforcement mechanisms (Tripp & Louwaars, 2017). The role of project management principles in seed sector governance is an underexplored area in existing studies. While ERP systems have been widely adopted to enhance seed certification and market oversight, there is insufficient research on their implementation challenges, success rates, and long-term sustainability (World Bank, 2021). Furthermore, studies rarely integrate project management methodologies such as PMBOK's quality and risk management frameworks, which are critical for ensuring regulatory compliance and process efficiency (PMI, 2021).

2.6 Research gaps

While studies on seed sector regulation and certification (Louwaars & de Boef, 2012; Tripp & Louwaars, 1997) primarily focus on policy frameworks, there is limited research on how effectively KEPHIS ensures genetic purity and trueness to type in commercial seed maize. Additionally, although counterfeit seed is widely acknowledged as a threat to market integrity (Gisselquist & Van Der Meer, 2001), little attention has been given to how Kenya Seed Company Limited and KEPHIS manage this risk. Important strategies such as unique batch numbering, digital activation codes, and the rollout of a robust ERP system for better traceability and fraud prevention remain largely unexplored.

3. RESEARCH METHODOLOGY

3.1 Introduction

This study employs a mixed-methods research design, integrating both quantitative and qualitative approaches to comprehensively assess the effectiveness of seed certification, variety protection management systems, and project management applications in maintaining seed maize quality and market integrity in Kenya.

3.2 Research Design

A descriptive research design is used to systematically evaluate the existing seed certification and variety protection mechanisms, their implementation effectiveness, and their impact on market integrity. The study will also explore how project management best practices can enhance regulatory compliance and mitigate risks.

The study will focus on professionals and key stakeholders within Kenya Plant Health Inspectorate Service (KEPHIS) and Kenya Seed Company Limited who are directly involved in seed certification, variety protection, and market regulation. A population of 25 officers will be interviewed in which 20 will be from Kenya seed and 5 from KEPHIS.

3.3 Sampling Technique and Sample Size

A combination of purposive and stratified sampling will be employed to ensure representation from different functional areas within KEPHIS and Kenya Seed Company.

3.4 Stratified Sampling

Respondents will be categorized into relevant groups such as certification officers, seed analysts, compliance officers, customer relations and marketing personnel to obtain balanced insights.

3.5 The sample size

Will be determined based on the total number of relevant employees in both organizations, ensuring that responses reflect diverse perspectives within the seed sector.

3.6 Data Collection Methods

Primary data will be collected using structured questionnaires and surveys targeting selected employees at KEPHIS and Kenya Seed Company. The questionnaire will include both closed-ended and open-ended questions to allow for statistical analysis and qualitative insights.

3.7 Pilot study

In this study, a subset of KEPHIS and Kenya Seed Company staff will participate in the pilot to ensure clarity, accuracy, and consistency of responses. Mugenda and Mugenda (2003) recommend that a pilot study sample should be 10% of the target population, provided that the population is large enough. However, for smaller populations, a slightly higher percentage may be used to ensure meaningful results. Connelly (2008): Reviews of educational research suggest pilot studies often use 10% of the population but notes that for small populations (e.g., $N < 100$), researchers may opt for a fixed number (e.g., 10-20 participants) rather than a percentage to ensure meaningful feedback. Van Belle (2008): Recommends a rule of thumb of at least 12 participants for pilot studies, adjusting upward for small populations to capture variability, but stresses flexibility based on study aims.

Based on the above, 12 participants were chosen for pilot test.

3.8 Ethical Considerations

This study will adhere to ethical research guidelines, ensuring informed consent, confidentiality, and voluntary participation of all respondents. Ethical approval will be sought from the relevant research regulatory bodies before data collection.

3.9 Data Processing and analysis

Quantitative data obtained from surveys and questionnaires will be analyzed using statistical methods, with descriptive statistics (mean, standard deviation, and frequency distributions) applied to summarize findings. Inferential statistics, such as regression analysis or chi-square tests, may be employed to examine relationships between variables. Qualitative data from interviews and open-ended survey responses will be analyzed using thematic analysis, where patterns and themes will be identified and categorized. sources. The findings from the case study will be benchmarked with Project Management Book of Knowledge (PMBOK).

4. DATA ANALYSIS AND DISCUSSION

The results of the survey emphasize the crucial role of seed certification in guaranteeing seed maize quality and maintaining confidence in the market. However, respondents highlighted several challenges, including gaps in regulatory enforcement and inadequate funding, which hinder the full effectiveness of certification processes. Many participants expressed frustration with the bureaucratic and time-consuming nature of the certification system, pointing to the need for more streamlined and efficient enforcement strategies. Although variety protection laws are largely effective in curbing unauthorized seed reproduction, enforcement remains inconsistent, with counterfeit seeds still infiltrating the market and undermining farmer confidence. The introduction of batch numbering and traceability systems has led to some improvements in oversight, but challenges persist in enforcement and public awareness.

Statistical analysis further supports these findings. The Pearson correlation coefficient of 0.72 demonstrates a strong positive relationship between seed certification and market integrity. Regression analysis reveals that variety protection exerts the highest impact on market integrity, with a coefficient of $\beta = 0.455$, followed by project management practices at $\beta = 0.38$, and seed certification at $\beta = 0.34$. The results of ANOVA testing confirm that these relationships are statistically significant, with a p-value of 0.00000475, reinforcing the importance of compliance with regulatory measures in maintaining seed quality and market trust.

5. SUMMARY, CONCLUSION AND RECOMMENDATION

This study highlights how seed certification, variety protection, and project management practices collectively shape the quality of seed maize and influence market integrity. Strengthening enforcement mechanisms and integrating modern tracking systems are vital steps in curbing the proliferation of counterfeit seeds. The findings suggest that imposing stricter penalties on those selling counterfeit seeds and enhancing digital traceability through QR codes and batch numbering will improve accountability. Additionally, fostering collaboration among stakeholders and increasing farmer education on how to identify certified seeds can reinforce market trust. The adoption of enterprise resource planning (ERP) systems will further enhance monitoring and fraud detection. By taking these steps, Kenya can establish a more transparent and reliable seed industry, ultimately contributing to higher agricultural productivity and long-term food security.

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