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# ‘Seed Production System in Zambia and Quality of Local Seeds’

**Bachelor’s Thesis**

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**Declaration**

I hereby declare that I have authored this bachelor's thesis carrying the name "Seed Production System in Zambia and Quality of Local Seeds" independently under the guidance of my supervisor. Furthermore, I confirm that I have used only professional literature and other information sources that have been indicated in the thesis and listed in the bibliography at the end of the thesis. As the author of the bachelor's thesis, I further state that I have not infringed the copyrights of third parties in connection with its creation.

In Prague on 21.04.2024 ___________________________

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# ‘Seed Production System in Zambia and Quality of Local Seeds’

**Summary:**

The aim of this thesis ‘Seed Production System in Zambia and Quality of Local Seeds’[1] is to investigate, analyse and provide insights into the seed production practices in Zambia. As part of this analysis, the quality of ‘local seeds’; maize (*Zea mays L.*) and common bean (*Phaseolus vulgaris L.*) are examined.

Seeds play a crucial role in agriculture and food production, as such, seed production systems, which are the processes and activities involved in the production, multiplication, and distribution are central to the continuity of agriculture and food production. This thesis is composed of chapters that analyse how seeds are processed in Zambia, from multiplication to processing and packaging, to quality control and finally the distribution of the seeds. Additionally, the quality of two significant ‘local seeds’ (maize and a variety of common bean locally known as Kabulangeti) is tested through laboratory experiments.

The introduction generally describes why seed production systems are critical to the agricultural process and the key components that make up this system, it further states what the quality of seeds is and why it is important, followed by the objectives which state what the aims of this thesis are. Diving deeper into the aims of the thesis, through literature reviews, an assessment of the current seed production practices, and an evaluation of the existing seed production systems in Zambia is done, including how seeds are produced, the key stakeholders involved, the infrastructure and the regulatory frameworks. As part of analysing the seed production system in Zambia, the quality of maize and beans is examined in the lab, explaining in detail the method that was used in testing the quality of these seeds. Based on these experiments, a chapter of this thesis focuses on the results that were obtained in the experiment and subsequently a discussion of the literature review and results and literature review.

Finally, conclusions are drawn on the seed production system in Zambia and the quality of the tested seeds. Recommendations for improvements or adjustments to the existing system are provided based on these analyses.

**Keywords:** Zambia, Seed Production Systems, Seed Quality, Maize, Beans

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[1] Maize and beans trace their origins to Southern America and spread to different parts of the world (Awata et al., 2019; Catarino et al., 2021).
These two crops have largely been adopted by many African countries due to their ability to thrive in diverse environments and climates, and have become a fundamental dietary component in numerous countries, including Zambia hence the use of the term ‘local seeds’.

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# 1 Introduction

Agricultural sustainability and food security are integral components of Zambia's socio-economic landscape. Townsend et al (2017) cite that the primary source of employment for adults in low-income countries (LICs) continues to be the agricultural sector, particularly in primary agricultural production (Davis et al., 2017, "as cited in" Townsend et al., 2017).

Zambia, as a developing nation, relies significantly on its agricultural sector and seed production systems serve as a critical element for ensuring continued productivity and resilience. Seeds, which are a fundamental unit of agriculture, underpin the entirety of food production and supply. According to FAO et al. (2023), the Prevalence of Undernourishment (PoU) in Africa increased from 19.4 percent in 2021 to 19.7 percent in 2022, primarily due to higher rates in Northern and Southern Africa. The count of individuals experiencing hunger on the African continent has risen by 11 million since 2021 and more than 57 million since the onset of the pandemic (FAO et al., 2023).


*Figure 1: World map showing Zambia's position. (© 2005-2023 Geology.com)*

The increase in the PoU in Africa as stated by FAO, rising from 19.4 percent in 2021 to 19.7 percent in 2022, particularly in Northern and Southern Africa, highlights the pressing challenges in the region. This surge in hunger, affecting an additional 11 million people since 2021 and over 57 million people since the onset of the pandemic, underscores the urgency for robust and sustainable seed systems. Enhancing seed production, accessibility, and diversity becomes critical in addressing food security concerns and building resilience within the agricultural sector to combat the growing hunger crisis. Recognizing the vital role of seeds in the agricultural cycle, this thesis analyses the "Seed Production System in Zambia and Quality of Local Seeds." Considering the growing population of the country and the problems associated with the changing climate, it is crucial to learn and improve how we produce seeds. This is paramount for sustaining Zambia's agriculture.

‘Seed production systems’[2] involve a wide range of activities from multiplication and processing to packaging, quality control, and distribution. These processes are central to the uninterrupted flow of agriculture and the subsequent production of food. As the demands on agriculture intensify, the efficiency and effectiveness of these seed production systems become crucial for maintaining food security and fostering overall economic development. This thesis looks at the processes that govern the production, evaluation, and distribution of seeds.

Seed quality is a key aspect of seed production, as it holds immense significance for agricultural success. High-quality seeds are indispensable for achieving optimal crop yields, pest resistance, and overall crop performance (Kumar et al., 2023).

Part of this study focuses specifically on the quality of two staple crops in Zambia — maize (*Zea mays L.*) and common bean (*Phaseolus vulgaris L.)* which are integral to Zambia's agriculture and nutrition. Maize and beans trace their origins to Southern America and spread to different parts of the world through various travellers and traders (Awata et al., 2019; Catarino et al., 2021). These two crops have largely been adopted by many African countries due to their ability to thrive in diverse environments and climates and have become a fundamental dietary component in numerous countries. Beans are a significant source of protein in the Zambian diet, part of the Jesuit Centre for Theological Reflection (JCTR) ‘Basic Needs and Nutrition Basket’. Catarino et al (2021) stated that common bean is one of the most cultivated pulses, comprising crucial staples and resources for food security due to their malnutrition alleviation potential (Catarino et al., 2021). Beans do not only contribute to food security but are also a valuable crop for smallholder farmers, enhancing their income, playing a role in crop rotation and promoting soil fertility. Maize on the other hand is Zambia’s staple food, it serves as a primary source of calories and nutrition for the population, importance of maize in Zambia extends beyond sustenance, influencing both the economy and cultural practices (Mwanamwenge & Harris, 2017).

Laboratory experiments that involved the growing of the two seeds were made to test the quality of these local seeds which provided some insights into the prevailing seed production landscape.

In a time when the world faces global challenges such as climate change, it is imperative to understand the seed production systems and to ensure the quality of seeds. This is not just a scientific task but a very important step towards building resilience and ensuring food security. This is also emphasized by Haug et al (2023) as they state that as challenges within food systems arise, encompassing issues like climate change, nutritious diets, and social disparities, seed systems must adjust to diverse demands and evolving expectations.

[2] It is important to note that the author of this thesis uses the term ‘Seed Production System’ to refer to Seed Systems which involves activities associated with seed production, multiplication, processing and marketing to ultimate seed use by farmers as stated by Gauchan & Shrestha (2020).

# 2 Aims of the thesis

The primary aim of this thesis is to investigate, analyse and provide insights into the seed production practices in Zambia. The analysis emphasizes the need to evaluate existing systems, understand key stakeholders, assess infrastructure, and explore regulatory frameworks.

A critical aspect of the thesis is to gain a profound understanding of the key stakeholders involved in the seed production process. This includes seed producers, distributors, regulatory bodies, and farmers. By explaining the roles and interactions of these stakeholders, the study aims to provide a perspective on the dynamics shaping seed production practices in Zambia.
Infrastructure plays an important role in seed production, influencing factors such as accessibility, efficiency, and overall system functionality. The thesis also aims to assess the existing infrastructure supporting seed production in Zambia. This evaluation considers physical infrastructure, technological systems, and logistical networks, intending to identify areas for improvement and optimization.
Regulatory frameworks are instrumental in ensuring the quality, safety, and reliability of seeds, therefore this thesis also explores some major regulatory mechanisms governing seed production in Zambia such as policies, standards, and enforcement mechanisms to ascertain their effectiveness.

In addition to the systemic analysis, part of this report evaluates the quality of two crucial crops in Zambia, namely Maize and Common Bean. The assessment focuses on germination as an important parameter. By evaluating the quality of declared seeds from Zambia, the study seeks to identify opportunities for enhancing seed performance and reliability in Zambia.

The ultimate goal of the thesis is to propose actionable recommendations for improving seed performance and reliability in Zambia. By integrating findings from the analysis of existing systems, stakeholder dynamics, infrastructure and regulatory frameworks, the study aims to contribute to the enhancement of seed production practices, quality control measures, and seed certification procedures in Zambia.

# 3 Literature Review

## 3.1 Seed systems in Africa

The seed system in Africa plays a crucial role in the continent's agricultural development. Agriculture in the African economy is a significant contributor, employing about half of the population and constituting 35% of the Gross Domestic Product (GDP) (World Economic Forum, 2023). The challenges of population growth and climate change pose threats to food security, making agricultural development a priority outlined in Agenda 2063 and the Comprehensive Africa Agriculture Development Program (CAADP).

Seed systems, essential for food security and productivity, involve various components such as breeding, production, marketing, and distribution (McGuire & Sperling, 2011). According to the African Union Commission (AUC), in Sub-Saharan Africa, these systems face inefficiencies and bottlenecks, hindering productivity and food security (AUC, 2021).
The seed systems are broadly categorized into formal and informal sectors, with the Quality Declared Seed (QDS) system acting as a compromise solution, particularly in areas where full quality control is challenging. The formal sector involves breeding, evaluation of improved varieties, production and sale of certified seed regulated by governments. On the other hand, the informal sector, not regulated by government policies, relies on farmers producing, obtaining, and distributing seeds based on indigenous knowledge and local social structures (Haug et al., 2023).

Townsend et al (2017) cited that in African countries, farming generates close to 68% of the rural income. The majority of seeds utilized by smallholder farmers in Africa are independently reproduced by the farmers without adherence to formal control processes. Farmer expertise in seed quality control, integral to crop production, is rich and varied, encompassing seed maintenance and adaptation. Those serving as seed custodians—engaged in preserving, saving, utilizing, and experimenting with diverse crops and varieties—play a pivotal role in the maintenance and conservation of agricultural biodiversity (Sthapit et al., 2013).
Additionally, Mbatia (2022) noted that in many sub-Saharan African countries, crop productivity is still low. The author attributed this to many factors which included low access to good quality seeds especially among small-scale farmers. Mbatia further stated that less than 20% of farmland on the African continent uses improved seeds owing to the lack of affordability and accessibility of these improved seeds so enhancing accessibility to QDS presents a promising strategy to narrow the seed access gap and enhance both seed trade and food production in Africa.

The AUC plays a pivotal role in seed sector development, coordinating efforts at the continental level. The AUC advocates, aligns policies and mobilizes support activities to Regional Economic Communities (RECs) and Member States. It promotes efficiency, consensus-building, and adherence to international instruments related to seed sector development and biotechnology. The African Seed and Biotechnology Programme (ASBP), established in 2008, aims to enhance food security, nutrition, and poverty reduction through effective seed systems and the application of biotechnology. Additionally, The African Seed Access Index (TASAI), initiated in 2015, serves as a tool to assess and improve the health of seed systems in African countries. TASAI monitors and compares enabling environments across nations, contributing to improved access to quality seeds for smallholder farmers in Sub-Saharan Africa (AUC, 2021).

A 2021 AUC report on 'The Seed Sector in Africa', explores the collection and conservation of plant genetic resources. The report states that conservation aims to maintain genetic diversity for present and future generations, but limited regulation and challenges such as financial support and human capacity hinder effective conservation processes. African countries have joined international conventions and treaties, striving to address issues related to plant genetic resources, biosafety, and international seed trade. Further, it acknowledges the critical role that gene banks in preserving genetic material, with 42 national gene banks in 23 African countries holding close to 300,000 accessions.
The Consortium of International Agricultural Research Centers (CGIAR) institutions also maintain gene banks for their mandated crops in different centres around the world including Africa. The CGIAR gene banks assume a crucial role in achieving diverse objectives aimed at reducing poverty, enhancing food and nutrition security, and tackling the challenges of climate change, as emphasized by Galluzzi et al. 2016 (Hay et al., 2021).

The African seed system is a complex and evolving network. The industry's competitiveness is a key aspect, and it is defined by the ability of firms and the overall sector to capture market share and grow through productivity improvements. According to Agrilinks (2020), the number of active seed companies varies across countries, with Nigeria leading in terms of quantity. The ownership of seed companies is mainly local, with African-owned companies dominating the seed industries in most countries. Non-African multinational seed companies are active in some countries, contributing a significant market share, especially in East and Southern Africa (Agrilinks, 2020)
Total sales of certified seed, particularly for maize and rice, are significant in East and Southern African countries where these crops are staple foods. Government parastatals are actively involved in seed production and marketing in some countries, with varying market shares. The length of the seed import and export process varies, with differences in regulations and procedures among regions (AUC, 2021)
In a study conducted by Takeshima et al. (2022), seed certification capacity in Nigeria and several other African countries was examined (with varying years). The investigation revealed varying numbers of seed inspectors across different nations. For instance, Liberia had 1 inspector, Burundi had 7, Rwanda had 8, Kenya had 50, Nigeria had 60, and South Africa had the highest number at 180, followed by Zambia with 118. This discrepancy in the number of seed inspectors among African countries could indicate disparities in the level of emphasis or investment placed on seed certification processes (Takeshima et al., 2022).

Seed policy and regulations are crucial for the functioning of the seed industry. Regional economic blocs, such as the Economic Community of West African States (ECOWAS), Common Market for Eastern and Southern Africa (COMESA), Southern African Development Community (SADC), and East African Community (EAC), have adopted harmonized seed regulations to streamline processes and promote seed quality (Hunga et al., 2023).
The variety release process, seed inspection services, efforts to combat counterfeit seeds, and the status of seed subsidy programs are essential components of the seed system. Seed inspection services face challenges in personnel and funding shortages, leading to issues with the production and sale of sub-standard certified seeds (AUC, 2021).

Counterfeit seeds pose a significant challenge, with reported cases in various countries. In a case in Uganda, Toro (2014) reported that counterfeiters employed tactics such as dying regular maize to mimic high-yield seeds, deceiving farmers who end up with non-germinating seeds after paying for seemingly promising ones. A study by World Bank researcher James Joughin revealed that only 13% of farmers in Uganda purchased improved seeds from formal markets, with the majority relying on seeds saved from previous seasons or obtained informally. The author noted the lack of trust in local seed markets, exacerbated by the widespread counterfeiting issue, thereby hindering the adoption of modern agricultural techniques. Toro also added that counterfeiting extended beyond seeds, with reports of agro-chemicals, herbicides, and fertilizers that were not of standard further undermining agricultural productivity.

In many countries across Africa, efforts to address this issue include awareness campaigns, and IT-based solutions for traceability and authentication systems. Seed subsidy programs, aimed at improving farmers' access to improved seeds, have been implemented in several countries, but challenges such as late payments to seed companies impact their effectiveness (Mtolo, 2023).

Possessing a well-established system, the formal seed sector ensures seed quality throughout the production and dissemination processes. Nevertheless, in numerous regions globally, notably in Africa, the formal sector contributes only a minority of the seeds required by farmers (Greenberg, 2019).

Farmers' access to quality certified seed is influenced by factors like the concentration of rural agro-dealer networks, availability of seed in small packages, and the seed-to-grain price ratio. (AUC, 2021). The availability of seed in small packages is not consistent across countries, and the seed-to-grain price ratio reflects the cost and quality of seeds, with hybrid maize having higher ratios.

In Africa, seed legislation has played a crucial role in establishing national seed industries, often guided by international donor agencies over the past two decades. However, a challenge lies in the tendency to apply overly rigorous criteria from developed countries, potentially hindering practical value and decentralized seed production. Seed certification is often mandatory in many African countries, influencing the seed system by restricting it to the formal sector and concentrating production, increasing costs and potentially delaying seed availability to farmers. Plant Breeder's Rights, providing property rights for breeders, are not widely established in developing countries, potentially limiting private-sector research. While compulsory, the lack of staff often results in non-compliance with legal provisions, and optional certification might encourage seed production in the informal sector (Lanteri & Quagliotti, 1997).

Dynamic and diverse as it may be, the African seed system plays a vital role in the continent's agricultural landscape. Characterized by varying levels of competitiveness and ownership structures across countries, comprising a growing number of active seed companies. The industry is primarily dominated by African-owned companies, while non-African multinational seed firms contribute significantly in some regions. Sales of certified seed, particularly for staple crops like maize and rice, are substantial in East and Southern Africa. Challenges such as delays in the variety release process, issues in seed inspection services, and the prevalence of counterfeit seeds exist. The effectiveness of seed policies and regulations varies, with regional economic blocs adopting harmonized regulations to streamline processes. Institutional support through regulatory authorities, seed trade associations, and accredited seed laboratories contributes to the industry's development. Farmer access to quality certified seed depends on factors like the concentration of agro-dealer networks, availability of small seed packages, and seed-to-grain price ratios. Overall, the African seed system reflects a complex interplay of strengths and challenges that significantly impact food security and agricultural development across the continent.

## 3.2 Seed system in Zambia

It has already been established by many authors that seed systems play a crucial role in the agricultural landscape, influencing the productivity of the crops, food security and the development of the economy. The agricultural sector in Zambia employs a substantial portion of its growing population and maize is a staple crop, playing a crucial role in the country's food security (IMF, African Dept., 2023).

Agricultural practices in Zambia exhibit a mix of small-scale subsistence farming, particularly in rural areas, and commercial farming, which includes large-scale operations with a focus on export crops like tobacco, cotton, and horticultural products. However, the majority of agricultural activities are primarily carried out by smallholder farmers.

Nagarajan et al., (2020) reported that in Zambia, the seed inspection landscape is facilitated by a total of 118 licensed seed inspectors, comprising 83 from private entities and 35 operating under the authority of the Zambian Seed Control and Certification Institute (SCCI). This regulatory framework has been in place since 1995, emphasizing the country's commitment to maintaining seed quality and ensuring adherence to certification standards.

Zambia boasts an integrated seed system that encompasses both formal and informal sectors, with substantial contributions from both public and private entities. The regulatory body for seed traders in Zambia is called the Zambia Seed Traders Association (ZASTA), established in 1999, it is a non-governmental, non-political and non-profit making organization that is affiliated to the African Seed Trade Association (AFSTA). Its primary objective is to serve as a national forum facilitating the exchange of ideas and experiences, formulate recommendations to the government and other stakeholders concerning seed policy, with a general commitment to promoting the seed industry in Zambia. Various seed companies like Seed-Co, Zamseed, Corteva, Syngenta, MRI seed, Amiran Zambia, etc., are members of this association (ZASTA, 2024).

Historically, the government held a controlling stake in activities ranging from breeding to seed production, marketing, quality control, and certification. However, this landscape underwent a significant transformation during the economic liberalisation of the 1990s. In the aftermath, numerous private companies, such as Seedco, Zambia Seed Company (ZAMSEED), Maize Research Institute (MRI), Pannar Seed Company, and Kamano Seeds Company, have entered the arena, investing in seed breeding, production, and marketing. This shift reflects a more diversified and dynamic approach to seed-related activities in Zambia (Kalinda et al, 2014).

Zambia's seed industry has undergone significant development over the past years and this growth is attributed to the efforts made in making seed laws and regulations that look to address aspects such as seed certification, testing laboratories, and the distribution and marketing of seeds. Blekking et al (2020) stated that the focus on enhancing germplasm quality and the use of inorganic fertilizers is based on the assumption that by intensifying production and increasing yields, smallholders can enhance food security. The idea is that improved yields will result in a surplus, enabling smallholders to potentially sell their excess produce in the open market.

According to a case study on Farmer Managed Seed Systems (FMSS) in Zambia that was conducted by Nkhoma and Nangamba (2017), up to 90% of smallholder farmers in Zambia use their own-saved seeds. This underscores the vital role of farmer-managed seed systems in Zambia's agricultural landscape. This system allows farmers to maintain a level of self-sufficiency and independence in their agricultural practices. It empowers them to control their seed supply, reducing dependency on external sources and mitigating the potential risks associated with market fluctuations or seed unavailability. It is particularly important for small-holder farmers who may have limited resources and need resilient, locally adapted varieties that suit their specific agro-ecological conditions (Nkhoma & Nangamba, 2017).

For the vast majority of farmers, FMSS represent the most dependable and cost-effective sources of seeds. In this system, farmers exchange seeds and other generative materials through informal networks. This transfer occurs through various means such as barter exchange, swapping, as a gift or purchasing directly from other farmers. Additionally, trading or selling of these materials takes place outside the formal regulation and commercial seed sector (Coomes et al, 2015).

Further, Coomes et al, (2015) challenged their identified misconceptions of farmer-served systems, arguing the importance that these networks have. The authors noted that farmer-to-farmer exchanges encourage community collaboration and knowledge sharing, through this system, farmers not only obtain diverse seed varieties but also benefit from the collective wisdom and experience of their peers. This informal network contributes to the preservation and enhancement of local seed biodiversity, as well as the dissemination of best practices for crop cultivation. Coomes et al (2015) further pointed out that, purchasing seeds locally at markets strengthens the local economy and encourages the growth of regional seed markets and that this economic interdependence creates a sustainable cycle where farmers support one another, and local markets thrive, promoting economic resilience and stability within communities.

Furthermore, Nkhoma & Nangamba (2017) state that rural communities incorporate both improved and local crop varieties, however, the accessibility of hybrid varieties is constrained by the financial limitations of numerous marginalized farming communities, hindering their ability to purchase seeds. The limited availability of local varieties also poses a challenge to these farmers. Often, farmers resort to planting whatever seed is available rather than choosing the most suitable seed for their specific conditions, emphasizing the critical influence of seed availability on agricultural practices. This underscores Zulu's (2000) assertion that in the absence of alternatives, farmers resort to utilizing whatever is at their disposal.

In a discussion paper by the Zambia Alliance for Agroecology and Biodiversity (ZAAB), it was mentioned that despite being more prolific and providing the majority of seeds to farmers in the country, FMSS receives minimal to no support from the government (ZAAB, 2020).

Farmer-served systems primarily rely on locally saved seeds from previous harvests and farmer-to-farmer exchanges. Additionally, they incorporate Open-Pollinated Varieties (OPVs) and recycled hybrids, particularly for maize. In the case of local varieties and recycled seeds, farmers engage in intentional selection. The process involves carefully choosing seeds from their harvest that exhibit robust health and show no signs of insect infestation. This seed is then carefully stored for the next season through different methods which include hanging in kitchens, where the smoke serves as a protective measure against pests and diseases. Certain crops, such as pumpkin and sorghum, are positioned on rooftops or any accessible container, with the addition of powdered detergent for pest control. While achieving maximum yield is often the primary breeding goal, it is crucial to also consider factors such as the quality of the harvested product, crop maturity times, resistance to diseases and drought, and various other agronomic traits (Nkhoma & Nangamba, 2017).

In 2020, Blekking et al identified the key actors in Zambia's seed certification process where hybrid seeds undergo a comprehensive process involving development, evaluation, certification and subsequent distribution. The diverse actors, each contributing to different parts of the system include the Zambian Agriculture Research Institute (ZARI) which takes on the role of developing improved seed varieties for widespread use, the Seed Control and Certification Institute (SCCI); responsible for testing and certifying seeds, ensuring their quality, the Farmer Input Support Programme (FISP) which has a focus on disseminating hybrid seed varieties.
He also indicates that there are eight private seed developers, spanning domestic, regional, and multinational scopes that are instrumental in developing seed varieties, applying for seed release through the Variety Release Committee, and replicating and marketing approved seed varieties. The Variety Release Committee, comprising stakeholders from various sectors, plays a central role in reviewing seed applications and determining the suitability of seeds based on Distinctness, Uniformity, and Suitability (DUS) criteria, as well as assessing the Value of Cultivation and Use (VCU) (Blekking et al., 2020).
Public and private agricultural extension officers[3] contribute by creating and maintaining a variety of demonstration plots, while agricultural input dealers and non-governmental organizations (NGOs) aid in the distribution of seed varieties to smallholders through both traditional purchasing and program implementation. Finally, farmers themselves play a crucial role in selecting varieties for cultivation (Blekking et al., 2020).

### 3.2.1 Key stakeholders

In recent years, Non-Governmental Organizations (NGOs) have gained growing significance, particularly within the seed system domain. Their role mainly extends to managing seeds of minor crops that may not draw the attention of private seed companies. NGOs operate in marginal and remote areas underserved by the private sector and implement input support programs, especially in response to disasters like droughts or floods, which threaten farmers' livelihoods. Activities carried out by these NGOs encompass seed distribution, training, advocacy for local seed banks, and facilitating seed production at the community level (Kalinda et al, 2014).

According to the USAID, the 5 predominant seed systems in Zambia include 1) farmer-saved, 2) NGOs and cooperatives, 3) Public-Private, supported by Zambia Agriculture Research Institute (ZARI) and local seed companies, 4) Private, supported by international seed companies, and 5) Private, supported by out-grower schemes for export commodities. The development of crop varieties is done by public research institutions, universities and private seed companies (USAID, 2016). The agricultural landscape in Zambia is shaped by the Ministry of Agriculture (MOA), where seeds are cultivated under the purview of the Zambian Agriculture Research Institute (ZARI), certified via the Seed Control and Certification Institute (SCCI) and promotion

[3] According to the FAO. 2019. *Agricultural Extension Manual*, by Khalid, S.M.N. & Sherzad, S. (eds). Apia. An extension agent / officer is an educated, trained professional working with farmers. Their roles include (but are not limited to); assist farmers to identify and overcome problems, assist farmers to make better use of resources/technology, introduce new technologies (new varieties, crops, breeds, etc.), provide information on new promising research results.

for widespread seed distribution is fostered by the Farmer Input Support Programme (FISP) (Blekking et al., 2020).

The study by Nkhoma and Nangamba (2017) which explores Farmer Managed Seed Systems (FMSS) in Zambia explains that ZARI, a department in the Ministry of Agriculture, plays a crucial role in providing services to farmers, adapting crop technologies, and addressing farmer needs for increased productivity and crop resilience. ZARI engages in genetic material acquisition, utilizing Participatory Variety Selection (PVS) on-farm to assess acceptance and adaptability. The institute targets smallholder farmers, emphasizing strategic research on climate change, drought tolerance, and nutritional aspects. Challenges faced by ZARI include limited off-takers for seed production, leading to a focus on on-farm seed development and the encouragement of local seed companies' traits.

The National Plant Genetic Resources Centre (NPGRC), under the Ministry of Agriculture, coordinates the National Genebank, aiming to conserve genetic variability for future agricultural support. The NPGRC conducts on-farm characterization and multiplication of germplasm, involving farmers and local extension staff. Efforts, however, are constrained by resource limitations (Nkhoma & Nangamba, 2017).

The Southern African Development Community (SADC) Plant Genetic Resources Centre (SPGRC), established in 1989, aims to conserve and sustainably utilize regional plant genetic resources. Based in Lusaka, Zambia, SPGRC collaborates with National Plant Genetic Resources Centres (NPGRCs) to minimize genetic erosion by supporting on-farm conservation and providing technical assistance. Currently, there is seed harmonization under the Southern African Development Community (SADC).

The Seed Control and Certification Institute (SCCI), under Zambia's Ministry of Agriculture, serves as the country's seed certification authority. It enforces regulations, conducts tests on new varieties, and manages the Variety Register. SCCI's adoption of UPOV guidelines, particularly the 1991 convention, raises concerns for Farmer Managed Seed Systems (FMSS), as highlighted by ZAAB's position paper on the potential limitations. SCCI's two-stage variety registration procedure includes pre-release testing and the release stage, where approved varieties undergo seed multiplication and distribution through contracted out grower commercial farmers, with consideration for exemptions based on specific criteria (Nkhoma & Nangamba, 2017; SPGRC Annual Report, 2016; SCCI functions and procedures). The release of developed varieties that undergo mandatory testing for Distinctness, Uniformity and Stability (DUS) and Value for Cultivation and Use (VCU) (2-year testing) is done by the Seed Control and Certification Institute (SCCI). SCCI also regulates the production of pre-basic, basic, and certified seeds for various crops by registering seed growers and issuing them a seed grower's license, which authorizes them to produce seeds of released varieties. Additionally, SCCI inspects seed growers at different crop growth stages through its seed inspectors who have established guidelines (variety descriptors). Isolation distance is key in seed production to eliminate contamination of seed (to produce true-to-type crops). These seed standards are also available for different crops (L. Sinyinda, ZARI, Personal Communication, January 29, 2024).

The mandate of SCCI is governed by the Seeds Act of Zambia, chapter 352 of the laws of Zambia and the Plant Pests and Diseases Act (CAP 346). The SCCI uses the Organization for Economic Co-operation and Development (OECD) system of certification, which includes the following seed classes; pre-basic seed, basic seed and certified seed (OECD Seed Schemes, 2024).

Commercialization of released varieties is carried out by private seed companies that contract farmers to produce seeds on their behalf, primarily engaging commercial farmers with sufficient land and access to irrigation. These varieties can be licensed from public institutions such as ZARI, which is mandated to develop varieties with desirable traits for farmers. Farmers receive basic seed, which they use to produce certified seed under a contract with the respective seed company. Consequently, seed companies hold seed growers licenses, enabling them to engage farmers in producing seeds on their behalf.

The seed produced by contract farmers undergoes processing, including shelling, grading, and packaging for sale after treatment with chemicals to prevent insect damage. This results in certified seeds ready for the market and available to farmers. The sale of this seed is facilitated by agro-dealers, and some are supplied to the government through the Farmer Input Support Program (FISP). Zambia ensures the quality of seed in the market through a principle called 'truth in labelling'. Seed labels are applied after rigorous lab testing for germination, purity, and other parameters. SCCI certifies each seed every season by sampling and assessing for germination, analytical purity, seed vigor, moisture content, and seed health.

The certification scheme comprises five primary components which include; variety testing, variety release, field inspection, laboratory analysis and post-control. Firstly, there is variety testing, where the characteristics and performance of different varieties are evaluated. Following this, the process involves variety release, which determines the official approval and release of the tested varieties. Field inspections play a crucial role in monitoring and ensuring the compliance of seed production fields with established standards. Laboratory analysis, guided by ISTA (International Seed Testing Association), is a meticulous examination of seed samples to assess their quality and adherence to set criteria. Finally, post-control involves ongoing measures to verify and maintain the quality of the certified seeds in the market. Together, these components form a comprehensive framework to ensure the integrity and reliability of certified seeds within the agricultural system (L. Sinyinda, ZARI, Personal Communication, January 29, 2024).

This accreditation process ensures that the seeds distributed by various distributors including NGOs align with established criteria, thus enhancing the effectiveness of their efforts in addressing rural developmental issues.

Numerous NGOs and international organisations in Zambia address developmental issues in rural areas, emphasizing livelihoods, health, and education. Many incorporate food security components, promoting conservation farming and agroforestry while providing farming inputs such as seeds and fertilizers. Recognition and support for Farmer Managed Seed Systems (FMSS) are growing, with organizations like ZAAB advocating for policies benefiting smallholder farmers. As stated by Nkhoma and Nangamba (2017), some of these organisations include Participatory Ecological Land Use Management (PELUM) Zambia, operating for over a decade, PELUM empowers small-scale farmers through poverty eradication, seed and food security, and improved livelihoods. They collaborate with partners on community seed multiplications and capacity-building for community seed banks. On the other hand, We Effect runs the Farmers Organizations Fighting Poverty and Injustice (FOFPI) program, empowering farmer-based organizations to address members' needs sustainably. FOFPI focuses on supporting rural development and improving the livelihoods of smallholder farmers, particularly women.

Oxfam, present in Zambia since the 1980s, focuses on sustainable livelihoods, health, education, water, and disaster preparedness. They support farmer seed enterprises, enhancing smallholder farmers' access to quality seeds. The Food and Agriculture Organization (FAO) collaborates with

Zambia on priorities like agricultural productivity, food security, natural resource management, and livelihood resilience improvement.
HarvestPlus collaborates with ZARI to develop vitamin A maize varieties to combat deficiencies in Zambian children. These biofortified maize varieties are licensed to private seed companies, distributed through various channels, and aim to improve nutrition among smallholder farmers (HarvestPlus, 2024).

Zambia's seed industry, is mainly driven by private companies like Zamseed and Seedco. These private companies produce maize varieties that seek to address the climate challenges, however, the focus remains on maize, with limited attention to legumes and other small grains. ZARI reports 19 registered seed companies in Zambia, with a few prominent ones focusing mainly on hybrid maize seed. Kamano Seed Company stands out for deliberately producing seeds targeted for small-scale farmers, including traditional crops (Nkhoma & Nangamba, 2017).
Seed production by smallholder farmer groups is growing in Zambia. These groups can select, multiply and conserve seeds of desired crops and various standards such as certified, QDS or producer-assured seed. In a research conducted by Dey et al (2022), on the strengths and weaknesses of organized crop seed production by smallholder farmers: A five-country case study, which included Zambia, they noted that each seed producer group included in the study sample had undergone formal and/or informal training. Their training sessions were commonly delivered by participants in development projects, as well as by the National Agricultural Research System (NARS), local government extension agencies, farmer organisations, and private sector entities. This indicates the various levels of involvement by different stakeholders and highlights the efforts that are being made to establish a comprehensive approach to skill development and knowledge transfer within the agricultural sector (Dey et al, 2022).

Tripp (2000) argues that there is a need for increased investment by public research programs in promoting and producing breeder and foundation seed. The suggestion is to make seed certification voluntary and simplify variety registration. Emergency seed programs are advised to focus more on variety adaptation and seed quality, supporting local seed enterprises rather than competing with them. Seed companies are encouraged to enhance their retail networks. NGO seed projects should carefully consider marketing and sustainability issues. Tripp (2000) emphasizes the importance of integrating donor-funded projects, currently operating independently, into a coherent, long-term, nationally-directed seed strategy.

### 3.2.2 Infrastructure

Basic physical and organisational structures and facilities form the backbone of a functioning society and economy. They facilitate economic development by providing essential frameworks for businesses to operate efficiently. Roads, bridges, and transportation networks, for instance, enable the movement of goods and people, fostering trade and economic growth.

Lanteri and Quagliotti (1997) assert that infrastructure is pivotal for disaster resilience and response. Well-built structures and communication networks can withstand and recover from natural disasters more effectively, minimizing the impact on communities. They enable faster recovery from disasters by facilitating the precise identification and distribution of seeds to the affected areas.

The infrastructure of a seed production system is of paramount importance as it serves as the foundation for ensuring the availability of high-quality seeds, which are fundamental to agricultural productivity. Inadequate road infrastructure in rural regions raises marketing and distribution expenses for seed distributors, restricting the availability of improved seeds for small-scale farmers residing in remote areas. Consequently, farmers have turned to using recycled seeds of poor quality (Zulu, 2000). Izuogu et al (2023) also affirmed this in their recent review of the Nigerian seed system.

A well-established seed system involves dedicated facilities equipped with advanced technology for cultivating, processing, and treating seeds, adhering to stringent quality standards. These facilities, often operated by government agencies or private entities, contribute to the development of improved crop varieties with desirable traits such as higher yield, disease resistance, and adaptability to specific environmental conditions. In addition, infrastructure plays a crucial role in maintaining the genetic purity of seeds through controlled processes, preventing contamination and ensuring consistency in crop performance. Efficient storage facilities within this infrastructure further guarantee the preservation of seed viability over time. Infrastructure also supports research and development initiatives, enabling the introduction of innovative seed varieties that address evolving agricultural challenges. Ultimately, a well-organized seed production system is essential for promoting food security, sustainable farming practices, and the overall advancement of agriculture. The utilization of high-quality seeds alone can result in a yield increase of 15-20% (Shaheb et al., 2015).

In Zambia, the formal seed system relies on well-structured physical infrastructure that encompasses various stages of the agricultural process, from seed production to distribution. The country's seed production centres, comprising both government-owned farms and private seed companies, serve as crucial hubs for cultivating quality seeds. These facilities adhere to stringent standards set by the Seed Control and Certification Institute (SCCI), ensuring the production of seeds that meet regulatory specifications.

The seed systems are influenced by policies within the agricultural sector and regulated through a framework encompassing seed policies, legislations, and laws related to plant variety protection (Haug et al., 2023)

Processing units form another integral part of Zambia's seed system, equipped with advanced machinery to clean, grade, and treat seeds effectively. Adequate storage facilities are essential to preserving seed viability, preventing deterioration and ensuring long-term availability. Warehouses equipped with controlled temperature and humidity levels contribute to the durability of stored seeds. The National Agricultural Information Services (NAIS) provides guidelines for proper seed storage, further reinforcing the importance of quality maintenance throughout the seed supply chain. Efficient distribution networks are imperative for timely and widespread seed dissemination. Collaborative efforts between the government, NGOs, and private entities contribute to enhancing these distribution networks (NAIS, 2024).

Specialised infrastructure, such as research centres or processing plants, supports innovation, production, and distribution. This, in turn, boosts the competitiveness of a region's economy. Research and development centres, such as the Zambia Agriculture Research Institute (ZARI), form an additional layer of support for the seed system. These institutions focus on advancing agricultural practices by researching new seed varieties, crop improvement, and disease resistance, contributing to the overall resilience and sustainability of Zambia's seed infrastructure (ZARI, 2024).

Specialised structures as well as physical infrastructure like roads and buildings influence the existence and operation of seed systems in various parts of a country. Zulu (2000) noted that seed companies directed their focus primarily on major cash crops such as cotton, maize, sunflower, and soybean while neglecting minor crops like cowpea, millet, cassava, and groundnut. This lack of attention was attributed to two main reasons. Firstly, the difficulty in distributing these seeds to rural areas, where these crops are predominant, due to challenges posed by inadequate and poor infrastructure. Secondly, seed companies were less inclined to operate in rural areas because farmers often saved their own seeds, creating uncertainty for repeated sales, despite evidence indicating shortages of these seeds (Zulu, 2000).

The effectiveness of physical and technological infrastructure, coupled with the significant transaction expenses linked to distributing seed to numerous scattered small-scale farmers, remain limiting factors for the development of maize seed industries (Smale et al., 2013).

Enhancing agricultural resilience and productivity in Zambia necessitates the decentralization of seed systems infrastructure. This ensures broader access to improved seeds and promotes local adaptation.

### 3.2.3 Regulatory frameworks

Seed, as a commodity, demands particular attention due to its intricate characteristics such as viability, germination, purity, and occasionally, variety identity, which can be challenging to evaluate at the point of sale. Since these attributes may only become apparent post-planting or even during harvest, the implementation of a control system becomes imperative (Tripp, 2000).

Agricultural sector policies mold seed systems, overseeing them through the implementation of seed policies, legislations, and laws related to plant variety protection. These regulatory frameworks operate at various levels, encompassing regional and international mechanisms (Haug et al., 2023).

Zambia's seed system operates within a comprehensive regulatory framework that encompasses standards, procedures, and incentives. The regulatory landscape is designed to ensure the quality, integrity, and efficiency of the seed sector. One key institution in this regard is the Seed Control and Certification Institute (SCCI). The SCCI plays a central role in the regulatory framework by overseeing the certification processes for seeds. Through stringent evaluation criteria, the institute ensures that seeds meet established standards for purity, germination, and variety. It oversees variety testing, release, and registration, along with seed inspection and testing, ensuring the delivery of high-quality seeds to farmers. It actively engages in training stakeholders and assumes a pivotal role in policy formulation, providing guidance, and administering seed legislation, specifically managing the Plant Varieties and Seeds Act. The SCCI's multifaceted responsibilities are integral to fostering the efficient functioning of the seed trade. Certification processes are instrumental in maintaining the quality of seeds available to farmers, fostering confidence in the agricultural community (Kalinda et al, 2014).

The regulatory framework also addresses broader policy considerations related to seed production, distribution, and farmer engagement. The regulatory framework provides incentives to encourage compliance with quality standards and best practices. These incentives may include support for certified seed production, distribution networks, and training programs. By fostering an environment that rewards adherence to high-quality standards, the regulatory framework contributes to the overall success and effectiveness of Zambia's seed system.

Subsidies for fertilizer and seed are still the cornerstone of many governments' agricultural strategies, of which Zambia is a prime example (Mason et al., 2013). Since the 1990s, Zambia has had various frameworks concerning agricultural input subsidies which have included the Fertilizer Credit Programme and Fertilizer Support Programme (FSP). Following these attempts, the Farmers Input Support Programme (FISP) emerged to provide subsidies for agricultural inputs to alleviate poverty and enhance food security. For a farmer to be a beneficiary of the FISP, they must have met certain eligibility criteria such as being a member of a registered organization, being an active farmer, not cultivating more than five (5) hectares of land, paying farmer contributions, not employed (under government or in the formal sector) and not be a beneficiary of similar government programs such as the Food Security Pack (Mtolo, 2023).
Utilizing input cooperatives is instrumental in enhancing access to contemporary agricultural inputs, such as improved seed varieties and inorganic fertilizers, along with technical knowledge (Ortmann & King, 2007; Blekking et al., 2021). The promotion of the usage of commercially developed hybrid seeds and fertilizers is a fundamental component of agricultural development plans in numerous Southern African countries (Mason et al., 2013; Blekking et al., 2021).
To seed systems, the Farmers Input Support Programme (FISP) tries to ensure that its beneficiaries have access to good quality seeds which are in its case hybrid seeds. The typical FISP process involves, identifying, registering and verifying beneficiaries and procuring the inputs followed by the subsequent distribution of the inputs. This is essentially implemented using two approaches; one is the Direct Input Supply (DIS) which is the traditional way and the other is the E-Voucher System which was introduced in the 2015/2016 farming season (Zulu, 2020). The E-Voucher system was abandoned in the 2021/2022 farming season with the possibility of re-evaluation and potential revival in the future. The DIS system neglects the variations in soil fertility and climatic conditions across the country. Consequently, it adopts a blanket fertilizer recommendation irrespective of the specific characteristics of each area (Mtolo, 2023).
In their assessment of 'seed systems development to navigate multiple expectations in Ethiopia, Malawi, and Tanzania', Haug et al. (2023) findings regarding equitable access indicate that in Malawi (a neighbouring country to Zambia), agricultural input subsidy programs have aimed to reduce seed costs, thereby improving accessibility for smallholders. However, challenges like insufficient farmer coverage and a predominant emphasis on maize seeds, among other issues, have been acknowledged (Haug et al., 2023). This is also a notable challenge in the implementation of the Farmers Input Support Programme in Zambia as pointed out by Mtolo (2023).
McGuire and Sperling state that ineffectively structured seed assistance has the potential to compromise resilience by introducing mal-adapted or untested new varieties, reducing the diversity of crops/varieties in crucial supply channels, displacing local seed enterprises, and fostering dependency on repeated aid, thereby weakening farmers' adaptive behaviours. (McGuire & Sperling, 2013)

The concept of Farmers' Rights, acknowledged by the FAO International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) whose objectives are the conservation and sustainable use of all plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security highlights the crucial role farmer's play in conserving and utilizing crop diversity. As per the ITPGRFA, the responsibility falls on national governments to advocate for legislation and implement measures in support of Farmers' Rights (FAO, 2023). Although obligated to fulfil the terms of the ITPGRFA, ZAAB (2020) notes that the effective implementation of these measures in Africa, including Zambia, has been limited.

As discussed by Lanteri and Quagliotti (1997) in the problems related to seed production in the African region, there is a need to cultivate an effective feedback mechanism from farmers to breeders, allowing the incorporation of farmers' specific needs and responses to newly released varieties into ongoing selection programs.
Government institutions and mechanisms that are inclusive and effective, coupled with access to technology, data, and innovation, are crucial catalysts within the comprehensive array of policies, investments, and legislation aimed at transforming seed systems to enhance the affordability and overall access to high-quality seeds. The 2021 State of Food Security and Nutrition in the World provided an example of how food and agricultural policies possess the capacity to influence access to nutritious food (FAO et al., 2021). In the same manner, seed and agricultural policies hold the potential, either directly or indirectly, to positively impact the availability, access, and cost of quality seeds. Policy measures, including standards, fiscal considerations, labelling requirements, seed variety reformulation, public procurement strategies, and marketing policies, also contribute to shaping seed systems.

Understanding the characteristics and performance of local seeds is therefore crucial for informing policy interventions aimed at enhancing seed accessibility and affordability, especially for smallholder farmers who heavily rely on these traditional varieties for sustenance and livelihood. The methodology employed in this study encompasses laboratory analyses to assess the quality of local seeds that were obtained from Zambia.

# 4 Methodology

Part of this thesis evaluated the quality of two seeds from Zambia i.e. maize (*Zea Mays L.*) and common beans (*Phaseolus Vulgaris L.*) that were grown in a controlled lab environment for a specific period of time. This sample was conveniently selected.

## 4.1 Material and methods

In the experiment, 3 maize samples and 2 common bean samples were used. In total 5 different samples were observed.
Two of the maize samples are termed as local maize because they were not hybrid but instead recycled from one season to another, differentiated by how long they were kept and whether a preservative chemical was added or not. The other sample of maize was a hybrid maize seed called Aminika WH507 produced by Western Seed Co. Ltd in Kenya and is also used and grown in Zambia.

The sample seeds were as follows; (i) local maize, less than 6 months old post-harvest, treated with chemicals to keep it longer – the chemical that was used is a common grain and cereal protection dust called "Shumba Plus" which contains pirimiphos methyl and thiamethoxam, (ii) local maize, 1-year-old post-harvest without any preservative chemical added, (iii) hybrid maize, treated – pink in colour produced by Western Seed Co. Ltd in Kenya, (iv) common bean, less than 6 months old, known by the variety name Kabulangeti according to the Zambia Agricultural Research Institute bean descriptor, (v) common bean more than 6 months old, known by the variety name Kabulangeti according to the Zambia Agriculture Research Institute Bean Variety Descriptor (3$^{rd}$ Edition, 2021).

The samples were labelled as follows:

Sample 1 – New Maize (Local Maize with Shumba Preservation Dust – Less than 6 months old)
Sample 2 – Hybrid Maize (Aminika WH507, Pink in Colour – Treated)
Sample 3 – New Beans (Variety Name Kabulangeti – Less than 6 months old)
Sample 4 – Old Beans (Variety Name Kabulangeti – More than 6 months old)
Sample 5 – Old Maize (Local Maize without Preservation Chemicals – 1 year old)

Following the International Seed Testing Association (ISTA) recommendations, the experiments were done in 4 replications of each sample, with each having 50 seeds (1000 seeds were germinated for each sample). The weight of 1000 seeds was measured and recorded and the germination was done in 2 rounds at different temperatures.

The first round of the experiment was conducted at 25 degrees Celsius for 7 days and the second round of the experiment was conducted at 15 degrees Celsius for 17 days. Identical growth environments in the lab for each temperature were maintained including humidity and light. On the first day of planting, 40ml of deionized water was applied to each filter paper before putting the seeds and covering the box.
After planting, the seeds were observed every 24 hours for several days (7 days for the first round and 17 days for the second round) to check on the progress. Every box was opened and every seed was checked. For any seed with a sprout longer than 3mm, it was counted as germinated.

Check the appendix for images to see the various stages.

## 4.2 Data analysis

The analysis of the samples was made using Microsoft Excel. Appropriate graphs were prepared to graphically compare the growth parameters (germination %) from all samples over the period of growth (days).

The samples were analyzed based on the temperature they were germinated and the type of seed i.e. a graph comparing all maize (*Zea mays L.*) samples at 25 degrees Celsius and a graph comparing all bean (*Phaseolus vulgaris L.*) samples at 25 degrees Celsius. The same was done for the samples germinated at 15 degrees Celsius.
Observations of the physical appearance of the samples were made and noted.

# 5 Results

The laboratory experiments conducted as part of this study represent a crucial phase in the understanding of the "Seed Production System in Zambia and Quality of Local Seeds." The experiments aimed to show insights into the germination and growth characteristics of the two key seeds —local maize (*Zea mays L.*) and beans (*Phaseolus vulgaris L.*)—with a special focus on the influence of preservation chemicals.

**Round 1 – Germination at 25 Degrees Celsius**

The 5 samples observed in this round of germination exhibited different traits throughout the observation period. Two separate graphs are used to show the results at this temperature.

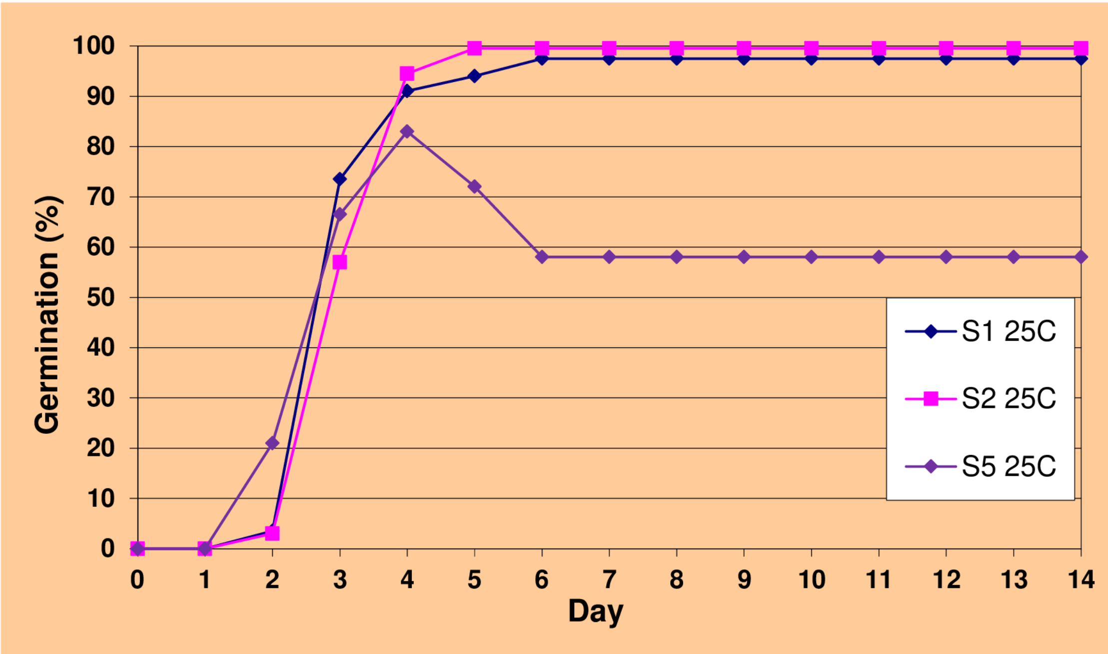


**Figure 2:** Samples 1, 2 and 5 (all maize samples) at 25 degrees Celsius. S1 25C = Sample 1 (New Maize – Local Maize with Shumba Preservation Dust – Less than 6 months old), S2 25C = Sample 2 (Hybrid Maize – Aminika WH507, Pink in Colour – Treated) and S5 25C = Sample 5 (Old Maize – Local Maize without Preservation Chemicals – 1-year-old). S2, although it was slower in germination for the first 2 days of observation, it was the only seed that eventually achieved 100% germination. It can be seen that S5 records a decrease in germination percentage after the fourth day.

Sample 1 (New Maize – Local Maize with Shumba Preservation Dust – Less than 6 months old) displayed varying degrees of germination across different dishes – some seeds did not exhibit germination. Moulds were a common observation starting from the second day of observation, indicating potential challenges in seed storage or quality. Interventions such as additional water and light exposure which were effected on day 6 influenced germination patterns. The experiment results provide valuable insights into the responsiveness of sample 1 seeds to preservation chemicals and storage conditions.

Sample 2 (Hybrid Maize – Aminika WH507, Pink in Colour – Treated) exhibited consistent and successful germination across all dishes. The seeds generally took longer to sprout as compared to the other two samples. Interventions, including water addition and light exposure, positively influenced the germination process. In this sample, the absence of moulds and the uniform germination rate was observed. The average weights before planting the seeds were quite uniform which indicates a relatively uniform size across the different dishes.

Sample 5 (Old Maize – Local Maize without Preservation Chemicals – 1-year-old) exhibited unfavourable conditions for germination as can be observed through its decline in germination in Figure 2. This was primarily due to extensive mould growth. A notable proportion of seeds did not germinate, appearing dormant or dead. Seeds that sprouted exhibited abnormalities, including coiled roots and abnormal shoot development. Sample 5 was discarded after day 6 of observations. The decision to discard the samples was driven by the unfavourable conditions for germination. Extensive mould growth and poor germination outcomes rendered the samples unsuitable for further analysis.

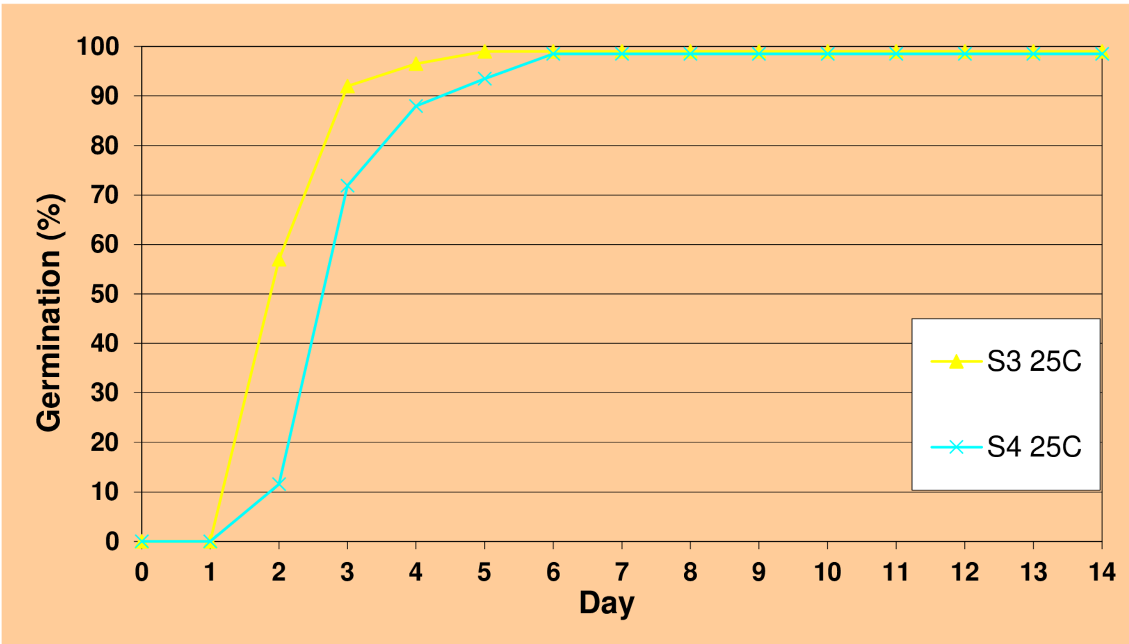


**Figure 3:** Samples 3 and 4 (all common bean samples). S3 25C = Sample 3 (New Beans – Variety Name Kabulangeti – Less than 6 months old), S4 25C = Sample 4 (Old Beans – Variety Name Kabulangeti – More than 6 months old). It can be observed that S3 germinated faster than S4. After day 6, germination is constant because the counting of the seeds has stopped and the plants are left to continue growing for biomass accumulation.

Sample 3 (New Beans – Variety Name Kabulangeti – Less than 6 months old) showed consistent and successful germination across all dishes throughout the observation period. Molds were present in one of the dishes, which could have been an indication of potential challenges in the experimental conditions. The overall average weights indicated a relatively uniform size across the different dishes.

Sample 4 (Old Beans – Variety Name Kabulangeti – More than 6 months old) demonstrated varied success in germination, with some dishes exhibiting challenges such as dormancy and mould appearance. The average weights indicated a relatively uniform size across the different dishes, but the germination issues observed raise concerns about the overall quality and viability of this sample.

**Round 2 – Germination at 15 Degrees Celsius**

In this round of germination, seeds developed much slower as compared to those germinated at 25 degrees Celsius.

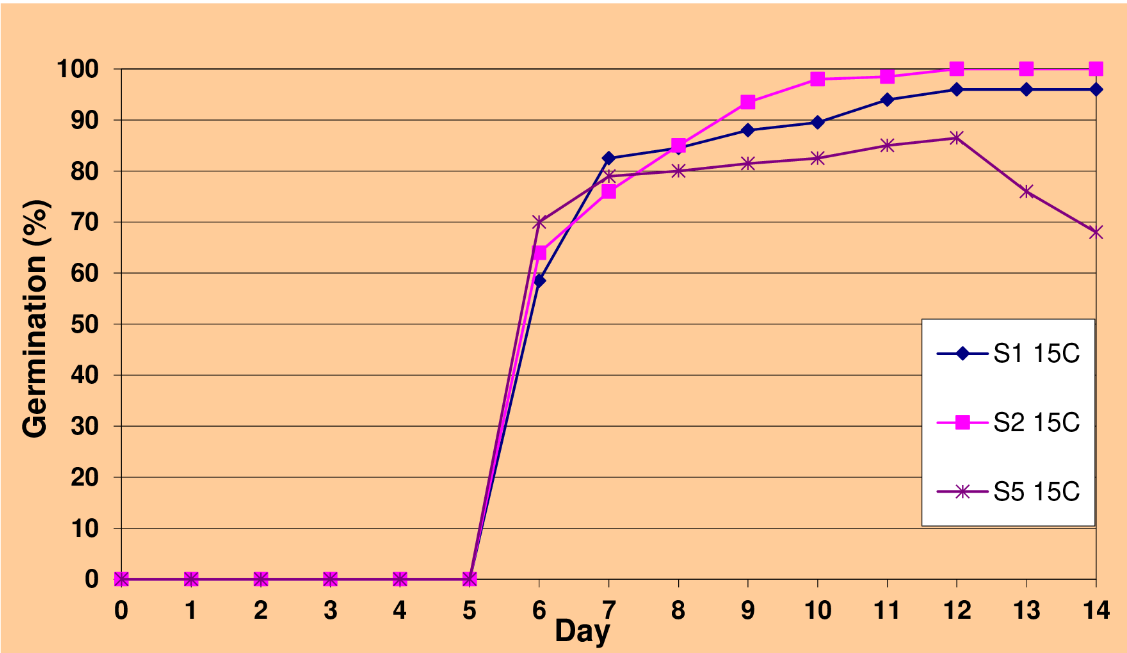


**Figure 4:** Samples 1, 2 and 5 (all maize samples) at 15 degrees Celsius. S1 15C = Sample 1 (New Maize – Local Maize with Shumba Preservation Dust – Less than 6 months old), S2 15C = Sample 2 (Hybrid Maize – Aminika WH507, Pink in Colour – Treated) and S5 15C = Sample 5 (Old Maize – Local Maize without Preservation Chemicals – 1-year-old). At this temperature, all the samples were slow in germination for the first five days of observation, S2 eventually achieved 100%. It can be seen that S5 records a decrease in germination percentage after the twelfth day.

Sample 1 (New Maize – Local Maize with Shumba Preservation Dust – Less than 6 months old) had moulds appear in several dishes, affecting the germination environment. Some seeds remained dormant throughout the observation period. Moulds had adverse effects on seedlings, some sprouts appeared to be choked by these moulds which hindered their growth. However, in several cases, coleoptiles emerged above the filter paper, indicating successful germination despite the presence of the moulds.

Sample 2 (Hybrid Maize – Aminika WH507, Pink in Colour – Treated) (hybrid maize), the seeds exhibited a higher and more uniform germination rate as compared to all the other samples. Most seeds developed long coleoptiles, indicating healthy growth. Despite the growth been slow, the germination progress was consistently positive across dishes.

Sample 5 (Old Maize – Local Maize without Preservation Chemicals – 1 year old) faced challenges with a substantial number of seeds failing to germinate. Molds increased over time, affecting the overall germination process. All four boxes of the planted seeds in this sample had mould infestations, additionally, rotting seeds were equally observed. As compared to round 1 at 25 degrees Celsius where sample 5 (old maize) was discarded after observing its high mould infestation, in round 2 at 15 degrees Celsius, despite high mould infestation, sample 5 was kept till the end of the observation period to see how it would perform.

As it was at 25 degrees Celsius, sample 5 shows a decline in germination after the twelfth day. This was as a result of the moulds that choked and killed some of the seeds. Some seeds became rotten and died which explains the decline. It is also important to note that germination is slower at 15 degrees Celsius. Only after day 5 did we notice an increase in germination (according to our 3mm rule), however, some seeds in S3 (new beans) were observed to have germinated earlier than the rest.

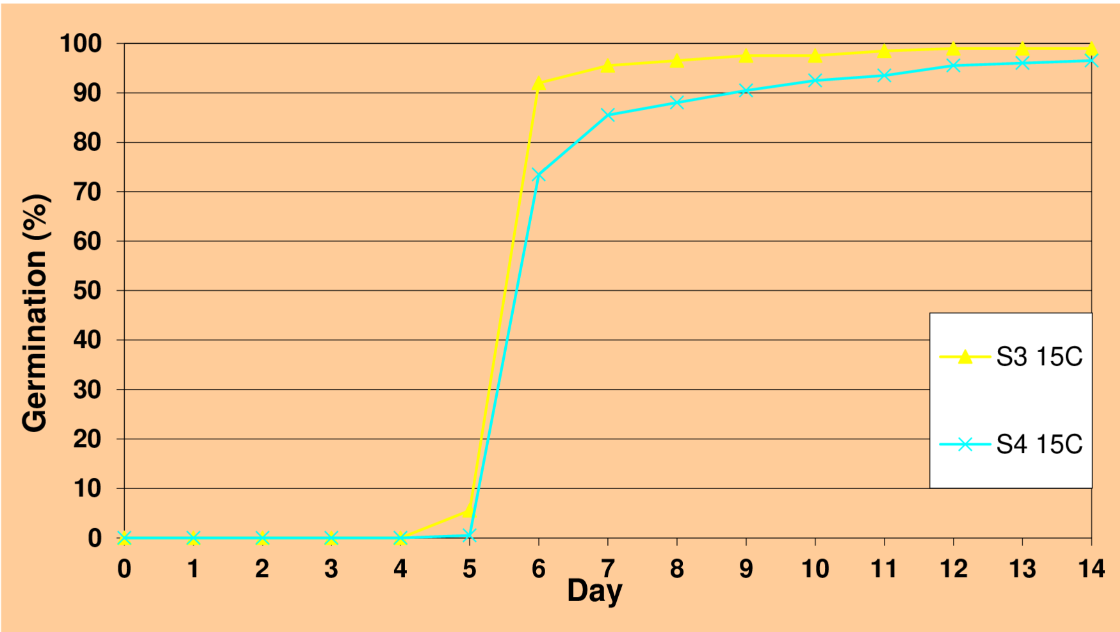


**Figure 5:** Samples 3 and 4 (all common bean samples). S3 15C = Sample 3 (New Beans – Variety Name Kabulangeti – Less than 6 months old), S4 15C = Sample 4 (Old Beans – Variety Name

Kabulangeti – More than 6 months old). It can be observed that S3 germinated faster than S4, there is less than 10% germination while S4 is still at about 0% germination.

Sample 3 (New Beans – Variety Name Kabulangeti – Less than 6 months old) showed a positive germination trend in all dishes. Some seeds showed signs of moulds, and the growth rate varied, but overall, the majority of seeds germinated successfully. A significant number of seeds developed leaves, indicating healthy growth.

Sample 4 (Old Beans – Variety Name Kabulangeti – More than 6 months old) exhibited a mix of successful germination and instances of dormant seeds or short sprouts. Some dishes showed mould spots, indicating potential challenges in germination. Despite challenges, some seeds developed leaves as the observations progressed, suggesting overall successful germination.

**Biomass**

At the end of each observation period for both rounds of germination, the plants were left for 3 days to accumulate some biomass. After which the upper biomass was harvested.
The fresh biomass was weighed and put in the drying chamber to dry for 2 days. After 2 days, the dry biomass was equally weighed. Graphs were then made based on the average of the 4 replications in each sample.

Round 1 – 25ºC Biomass

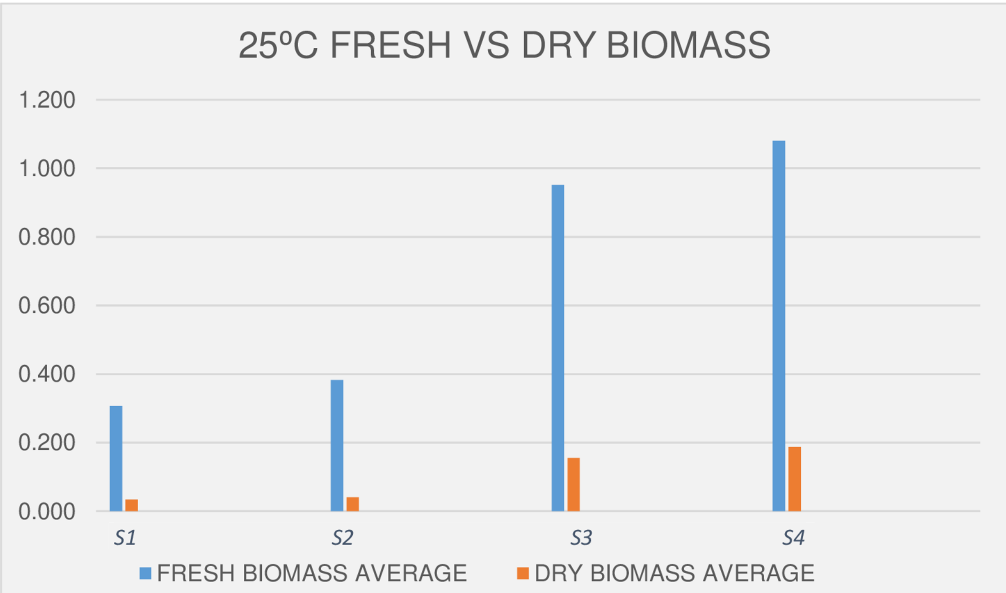


**Figure 6:** Harvested upper biomass. Fresh (blue column) vs. dry (orange column). S1 has lesser amount of fresh and dry biomass as compared to S2. S4 had a higher amount of fresh and dry biomass as compared to S3. Even if S3 performed better in terms of germination, its biomass was less than that of S4.

Round 2 – 15ºC Biomass

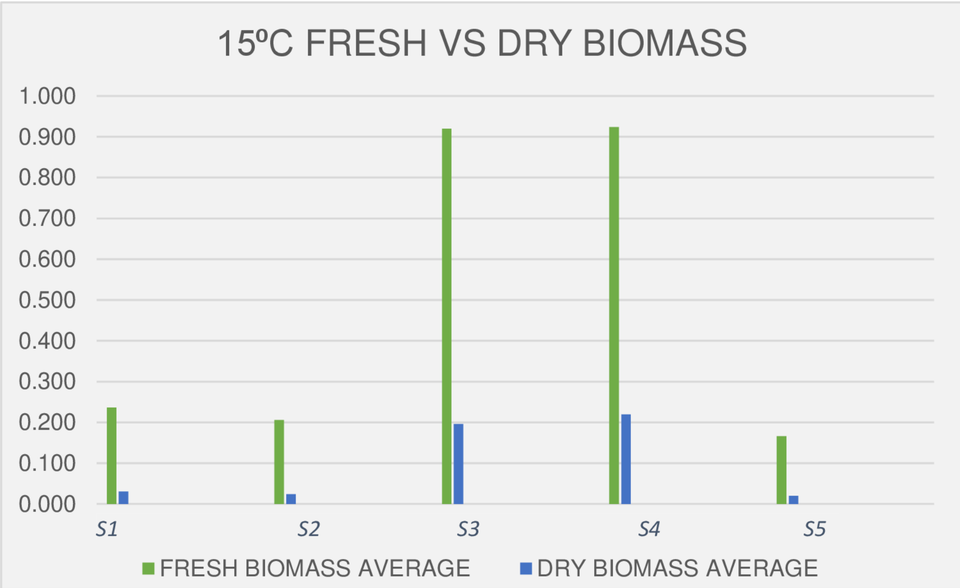


**Figure 7:** Harvested upper biomass. Fresh (green column) vs. dry (blue column).

Maize – S1 (new maize) has higher fresh and dry biomass as compared to S2 (hybrid maize) and S5 (old maize). Even if S5 performed poorly in terms of the percentage of seeds that germinated, it was a significant amount of biomass when compared to the S1 and S2 which had higher germination percentages.

Beans – S3 (new beans) and S4 (old beans) have almost the same amount of fresh biomass. However, S4 has a slightly higher amount of dry biomass as compared to S3.

# 6 Discussion

## 6.1 Evaluation of quality

In the last two decades, agricultural production, food, and nutrition security have faced considerable challenges. While there is a global projection of increased food production in the coming decades, sub-tropical regions, where food security is already a concern, are anticipated to experience a decline in production (Richardson et al., 2011; IPCC 2018; Madin et al., 2022).

Seed systems are integral components of agricultural practices, particularly in developing countries where a substantial portion of the population relies on agriculture for their livelihoods. Smallholder farmers are transitioning from traditional seed exchange systems to cash-based systems as there is the development of hybrid varieties which emerge as a prominent factor contributing to the gradual decline of traditional crop varieties (Cromwell and van Oosterhout, 2000, Bellon et al., 2011, Pautasso et al., 2012, Vincent Ricciardi, 2015). However, farmers lacking resources and having limited access to technical information and quality inputs face heightened vulnerability when attempting to make this transition, as noted by Tripp (2001) (Vincent Ricciardi, 2015).

Shaheb et al. (2015) stated that the utilization of high-quality seeds alone can result in a yield increase of 15-20%. In assessing the quality of local seeds in this study, the experiments aimed to show insights into the germination and growth characteristics of the chosen seeds; maize and beans. Notably, within the maize category, the results revealed a significant disparity in germination rates, with sample 2 (hybrid maize) exhibiting an impressive germination percentage of up to 100%, outperforming both sample 1 (new maize) and sample 5 (old maize). The maize that was preserved with the grain and cereal protection dust called “Shumba Plus” displayed a better germination percentage compared to its untreated counterpart sample 5 (old maize), which faced challenges such as mold growth and hindered overall growth leading to a subsequent decline as the observations continued in both temperatures. For beans, the study highlighted the slight superiority of sample 3 (new bean) over sample 4 (old bean) in terms of growth, especially in the round of the experiment at 25 degrees Celsius.

The results of this study support Shaheb et al. (2015) as it was observed that high-quality seeds performed better than the other seeds. This underscores the importance of farmers' access to quality seed. As highlighted by Tripp (2001), the ability of farmers to secure quality seeds, particularly hybrid varieties, is a critical factor in shaping agricultural outcomes.

It is important not only for farmers to have access to high-quality seeds but also to have the resources that facilitate this access. In this context, the term "resources" encompasses not only financial means but also broader aspects such as knowledge, infrastructure, and technological access. Farmers with limited resources may face impediments in acquiring the desired hybrid seeds which are renowned for their superior traits. The challenges associated with resource scarcity may result in compromised access to these high-quality seeds, impacting the farmers' capacity to harness the benefits associated with improved germination rates, crop resilience, and overall agricultural productivity. Based on the findings of the study, a general assumption can be made, suggesting that farmers with access to hybrid seeds or those who can afford to employ protective measures such as chemical treatments have a higher probability of achieving success and accomplishing successful crop production.

In modern agriculture, hybrid seeds stand out as a factor contributing to the significant increase in agricultural output. Hybrids are selected to enhance the traits of the resultant plants, including improved yield, greater uniformity, enhanced colour, and increased resistance to diseases. Improved seeds and hybrid seeds offer a myriad of advantages, contributing to enhanced agricultural productivity and resilience. One notable advantage lies in the substantial yield improvement associated with these seeds. Through careful breeding and selection, improved and hybrid seeds are designed to exhibit higher yields. This increased productivity is crucial in meeting the escalating global food demand and ensuring food security (Siyal, 2019). The results obtained in the hybrid maize seed (sample 2) of this experiment showed a germination percentage of 100% or close to 100% as compared to the other maize samples (samples 1 and 5). This observation aligns with Siyal's (2019) assertions regarding the advantages of hybrid seeds, specifically highlighting their potential for achieving higher germination percentages.

Siyal (2019) goes further by highlighting that the deployment of hybrid seeds provides farmers with a wider sowing window, offering flexibility in planting times. This adaptability enables farmers to optimize planting schedules based on weather conditions and other factors, contributing to improved crop management practices. Reduced plant stress is another significant benefit derived from the use of improved and hybrid seeds. These seeds are often engineered to withstand various environmental stresses, such as pest attacks or adverse weather conditions. This resilience results in healthier plants and minimizes the negative impact of stressors on overall crop performance. In the face of unpredictable climatic patterns, drought-resistant characteristics of certain improved and hybrid seeds become crucial. These seeds are specifically developed to thrive in water-scarce conditions, offering a strategic solution to mitigate the impact of drought on crop yields.

According to Hryncewicz (1992), the ideal temperature for seed germination and development falls within the range of 20°C to 25°C. In our experiment, plants grown in the first round of the experiment at 25 degrees Celsius had a very dense root system as compared to those of the second round at 15 degrees Celsius which were less developed. Additionally, at 25 degrees Celsius, seedlings developed faster and the harvested fresh biomass was higher compared to the one harvested at 15 degrees Celsius. The seedlings grown at 25 degrees Celsius developed and grew better than those at 15 degrees Celsius, this is consistent with Hryncewicz (1992) who stated that the optimal temperature for seed germination and development is between 20 degrees Celsius and 25 degrees Celsius. Temperature profoundly influences various physiological processes in plants, including photosynthesis, enzyme activity, and metabolic reactions. In general, warmer temperatures often enhance the metabolic rate of plants, leading to increased energy production and, consequently, higher biomass accumulation.

In their characterization of formal and FMSS seed markets, ZAAB (2020) highlighted a drawback associated with farmer-managed seed systems – the occasional lack of information regarding the seed quality and attributes (ZAAB, 2020). The quality of the seeds cannot always be assured until after planting. This finding aligns with the results obtained in the experiment, where the farmer-saved seeds, as observed, exhibited lower quality and displayed mould growth several days after planting.

## 6.2 Seed system in Zambia

As established in the investigation and analysis of the seed production system in Zambia, these systems play a critical role in ensuring that farmers have access to high-quality seeds, which, in turn, influences crop productivity, resilience, and overall agricultural development. The efficiency and effectiveness of seed systems are critical factors in the success of agricultural endeavours, making seed quality a central focus. In many developing countries, smallholder farmers face challenges in accessing quality seeds. Limited infrastructure, including inadequate roads and market facilities, can impede the distribution of seeds to remote areas. Additionally, informal seed systems, where farmers save and exchange seeds within their communities, may promote local adaptation but could lead to a decline in seed quality over time due to the lack of control over varietal characteristics.

Mbatia (2022) points out that stringent regulations contribute to maintaining a high calibre of seeds. However, the downside emerges as these strict measures create barriers, hindering the goal of ensuring universal access to seeds (Mbatia, 2022). In analyzing Zambia's seed system, it was observed that governments and non-governmental organizations (NGOs) play a significant role in establishing and supporting both the formal and informal seed systems. This is supported by Blekking et al (2020) who identified the actors in this, stating that entities often engage in research and development to improve seed varieties and facilitate their dissemination to farmers (Blekking et al., 2020).

In a scope review of the 'impact of seed system interventions on food and nutrition security in low- and middle-income countries' by Nabuuma et al (2022), they concluded that interventions centred around seed systems possess the capacity to impact nutritional outcomes, manifesting in both positive and negative effects on aspects such as household resilience, dietary quality, diversity, food security and nutrition status. Their review highlights the interconnected nature of seed systems with other sectors emphasizing the need for capacity building among farmers which is crucial for enhancing their knowledge about the importance of seed quality and proper seed management practices. Training programs empower farmers to make informed decisions regarding seed selection, storage, and utilization. Moreover, adapting seeds to local climatic conditions is essential for building resilience against the impacts of climate change.

When farmers lack access to improved seeds, they adopt alternative options out of necessity. This assertion is supported by Zulu (2000), who explained that the inadequate road infrastructure in rural areas amplifies marketing and distribution costs, thereby constraining the availability of improved seeds for small-scale farmers located in remote areas. As a consequence, farmers turn to utilizing recycled seeds of lower quality (Zulu, 2000).

In their case study, Nkhoma and Nangamba (2017), pointed out that the farmers consulted consistently highlighted that gaining access to various types of seeds, whether they are local, hybrid, or open-pollinated varieties (OPVs), poses significant challenges. The farmers expressed considerable difficulties in obtaining the seeds needed for their agricultural endeavours. This issue encompasses not only the availability of seeds but also factors related to affordability, distribution networks, and overall accessibility (Nkhoma and Nangamba (2017).

The challenges reported by these farmers underscore the importance of addressing barriers to seed access to support and enhance the resilience and productivity of small-scale farming communities. Addressing these concerns could involve implementing strategies such as improving seed distribution systems, promoting financial inclusivity for farmers, and enhancing education and awareness programs on seed options and their benefits.

Studies have highlighted that accessibility and affordability of seeds are critical when it comes to farmer's agricultural practices. For example, Ncube et al (2023) in their comparison of the contribution of formal and local seed systems to household seed security in Eastern Zimbabwe showed that local seed sources were more affordable than formal sources and that there were fewer business centers in more remote areas observed. The authors concluded that their study demonstrated the significant and often overlooked contribution of local seed systems in offering smallholder farmers a more varied and accessible supply of affordable seeds, conveniently available near their homes.

The findings of Ncube et al (2023) echo the FMSS in Zambia. Recognizing the significance of local seed systems in providing smallholder farmers with diverse, accessible, and affordable seed options is crucial for policymakers, researchers, and agricultural stakeholders. This understanding can inform strategies and interventions aimed at strengthening sustainable seed systems, ensuring food security, and promoting resilient agricultural practices that meet the needs of farmers, particularly in geographically remote regions.

Nkhoma and Nangamba (2017) called attention to the Plant Breeders' Rights (PBR) Act which is aimed to protect formally developed plant varieties and reward breeders in the country. However, they noted that it overlooks the fact that traditional varieties are also intentionally cultivated by farmers, who are also breeders. Laws and regulations may inadvertently impact other areas, leading to unintended consequences. Therefore, governments must recognize the ripple effects of their laws, regulations, and policies, particularly when enacting transformative agendas. Compensatory measures should be considered to address these unintended outcomes.

In 2000, Zulu highlighted that the reluctance of seed companies to operate in rural regions persists due to infrastructural limitations and uncertainties about repeated sales. Two decades later, many rural areas in Zambia continue to face challenges related to poor or inadequate infrastructure. However, it is crucial to acknowledge that several seed companies are actively working to address these challenges and extend their services to rural areas. This commitment is also reflected in government initiatives, including deliberate policy interventions such as the Farmers Input Support Programme (FISP). These initiatives aim to enhance accessibility to improved seeds and broaden the scope of the seed system.

# 7 Conclusion

- Statistical disparities in maize and bean germination rates are observed based on storage conditions and preservation techniques, emphasizing the importance of proper storage for seed quality maintenance.
- Temperature significantly affects germination speed, with seeds at 25°C germinating faster than those at 15°C. Hybrid maize exhibits the highest germination rate of up to 100% in both temperatures, while chemical preservatives may not effectively sustain seed quality over time.
- Old bean and old maize germinated slower at both temperatures while the new bean, new maize and hybrid seed were much faster.
- Zambia's seed system comprises both formal and informal sectors, with quality declared seed integrating modern and local varieties. The country possesses the necessary foundation for seed system improvement through policy implementation and stakeholder collaboration.
- Despite current infrastructure limitations, particularly in rural areas, Zambia has the potential to enhance its seed system by leveraging existing resources and aligning policies with strategic objectives.
- Bridging the gap between formal and informal seed systems is crucial for sustained progress in Zambia's seed sector.
- Not only is there a need for increased investment in the seed sector but increased awareness and education among stakeholders are necessary for fostering sustainable seed systems, promoting informed decision-making and development in Zambia's seed production.

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# 9 Appendix

Some images from the lab which were taken over the period of the observations.

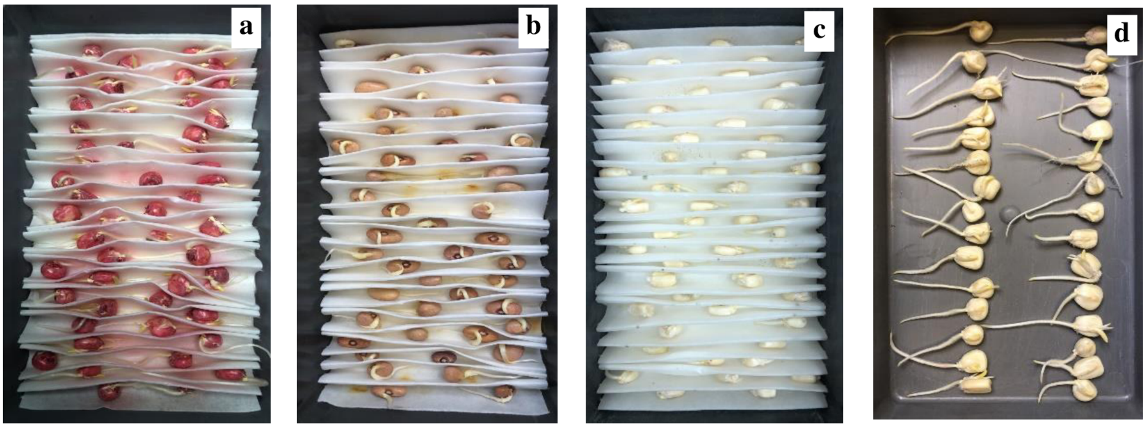


**Image 1:** Germination across samples, (a) is an example of sample 2 (hybrid maize) four days after planting, (b) is from sample 4 (old bean), three days after planting, (c) is from sample 1 (new maize) and (d) is from sample 5 (old maize), three days after it was planted.

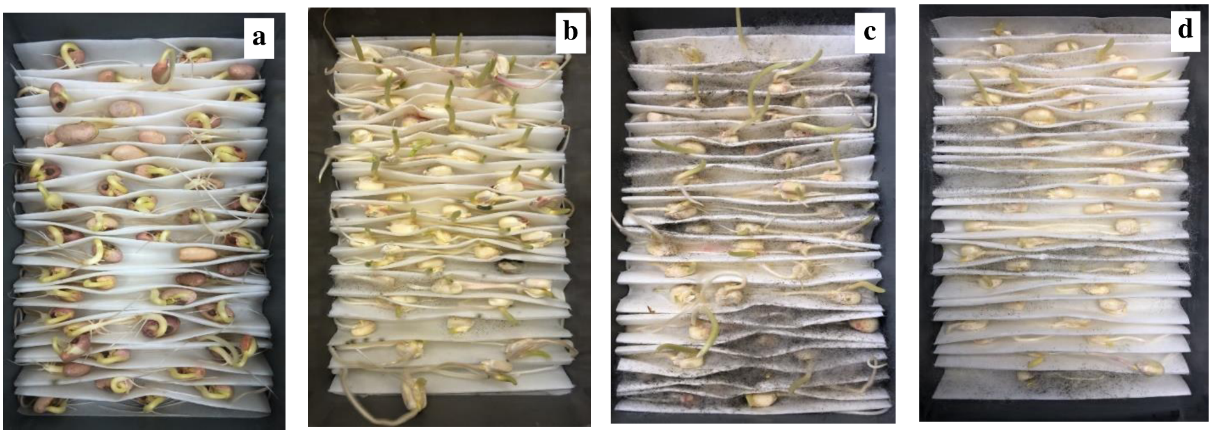


**Image 2:** (a) is an example of the growth from sample 3 (new bean), (b) is from sample 1 (new maize), (c) and (d) are from sample 5 (old maize), (c) was observed a few days later after (d). The dark sections seen in (b), (c) and (d) are moulds.

**Image 3:** First 2 boxes to the left are of sample 3 (new beans) and the other 2 to the right are of sample 4 (old beans), 13 days after planting.

**Image 4:** Shows the growth of the maize from samples 1, 2 and 5 at 15 degrees Celsius, 15 days after planting. The far left (pink) shows sample 2 (hybrid maize), the middle is sample 5 (old maize) and the far right is sample 1 (new maize).

**Image 5:** Samples 1, 2, 3 and 4. Accumulation of biomass from each sample that remained under observation after discarding sample 5.

**Image 6:** Shows the biomass harvested from the samples that were grown at 25 degrees Celsius, 3 days after the observations stopped.


**Image 7:** Developmental stages of the 2 seeds. (a) Common bean (b) Maize. The image shows the different stages of development for the two seeds under observation. They were taken from the samples under observation showing the various stages exhibited throughout the observation period. At the end of the observation period, some seeds remained dormant (no change – as in the far left), others sprouted but did not completely develop and the others developed biomass as seen in the most developed plant in the image (far right).

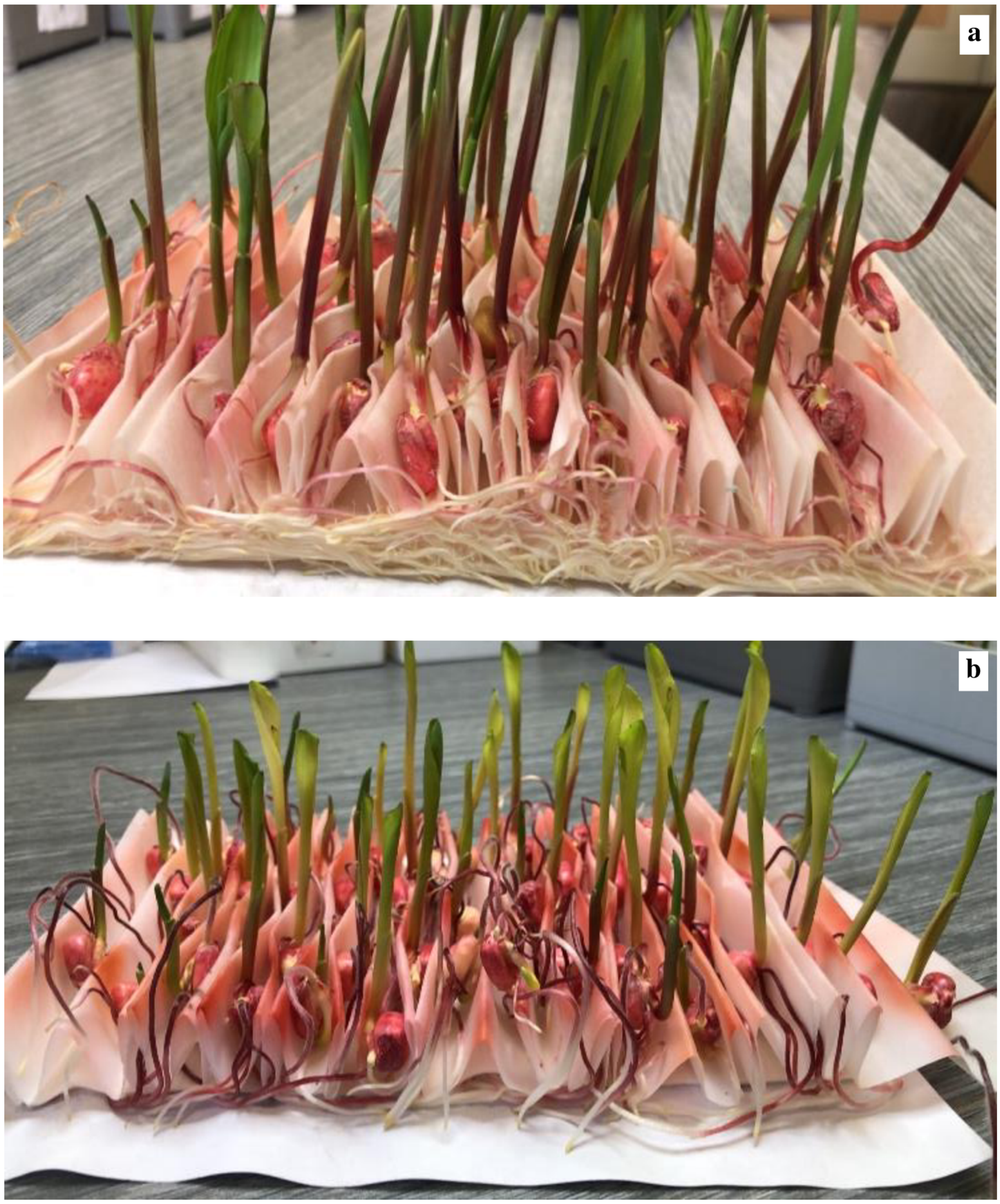


**Image 8:** (a) shows how the seeds that were planted at 25 degrees Celsius had a very dense root system after a few days of observation (10 days later). On the other hand, the root system in (b) – grown at 15 degrees Celsius was less developed as compared to (a) even though it was observed for a longer period (20 days later).


**Image 9:** Samples in the germination chamber before and after accumulation of upper biomass. (a) was taken 7 days after planting and (b) was taken 10 days after planting.

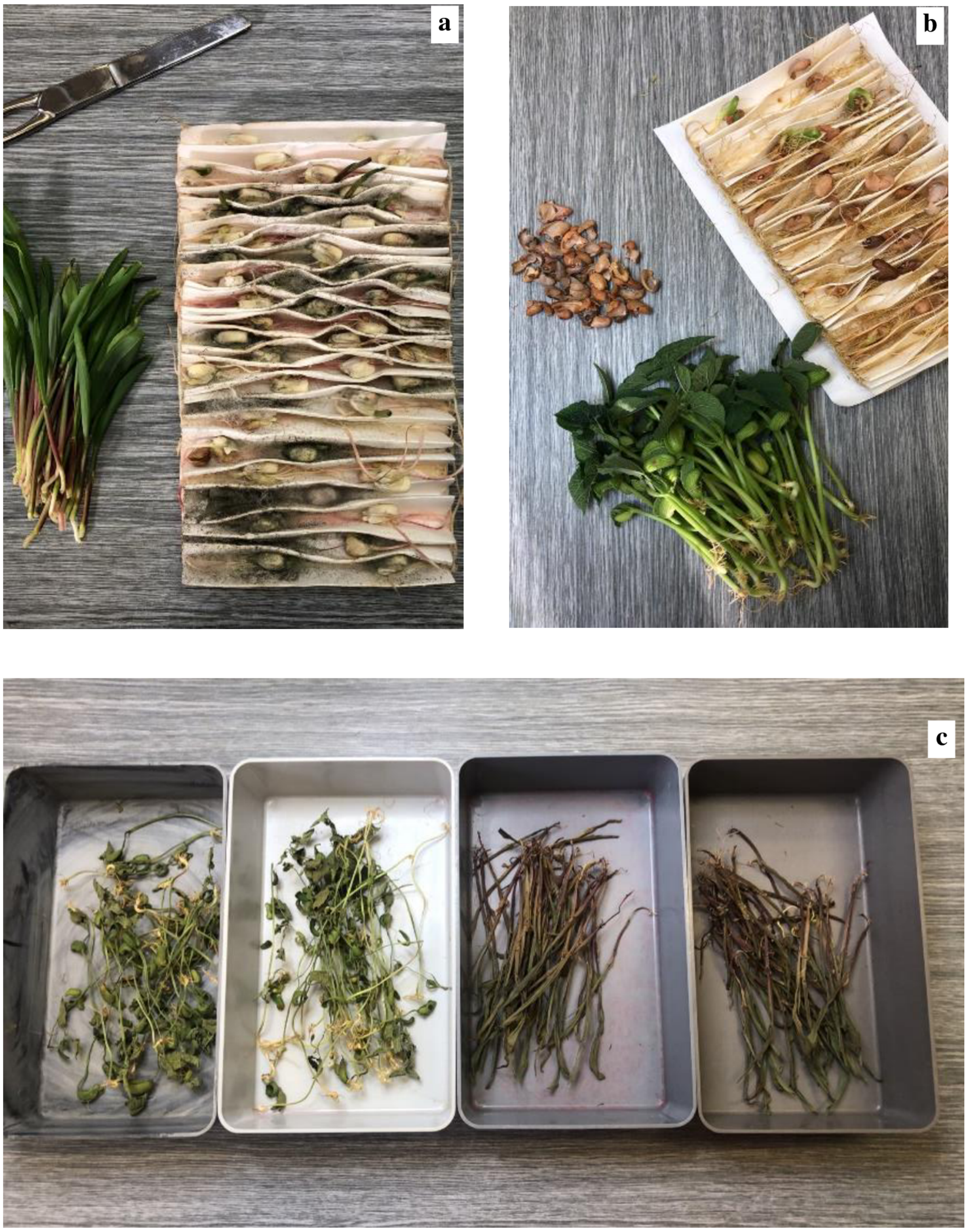


**Image 10:** At the end of each observation in the two rounds of germination, the upper biomass from the plants was harvested, weighed and then dried. After drying, it was weighed again. (a) is sample 1 (New Maize) in round 1 of the experiment at 25 degrees Celsius, the black sections in the filter paper are moulds that developed. (b) is sample 4 (Old Beans). (c) is the biomass for samples 1, 2, 3 and 4 after drying.