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Assessment of Forage Seed Sources, Storage Methods, and Quality Analysis In East Belessa, Central Gondar, Ethiopia

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BAHIR DAR UNIVERSITY

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ASSESSMENT OF FORAGE SEED SOURCES, STORAGE METHODS, AND QUALITY ANALYSIS IN EAST BELESSA, CENTRAL GONDAR, ETHIOPIA

MSc. Thesis

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Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Science (M.Sc.) In Feed and Animal Nutrition

Major Advisor: Yeshambel Mekuriaw (Professor)

Co-Advisor: Dawit Tsegaye (PhD)

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THESIS APPROVAL SHEET

As a member of the Board of Examiners of the Master of Science (MSc.) Thesis open defense examination, we have read and evaluated this thesis prepared by **Ms. Betelhem Atena Tarekegn** entitled **''Assessment of Forage Seed Sources, Storage Methods, and Quality Analysis in East Belessa, Central Gondar, Ethiopia".** We here by certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Master of Science (MSc.) in Feeds and Animal Nutrition.

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DECLARATION

This is to certify that this thesis entitled **''Assessment of Forage Seed Sources, Storage Methods, and Quality Analysis in East Belessa, Central Gondar, Ethiopia".** I Submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in **Feeds and Animal Nutrition** to the Graduate Program of the College of Agriculture and Environmental Sciences, Bahir Dar University by **Ms. Betelhem AtenaTarekegn** (BDU-1500660) is an authentic work carried out by her under our guidance. The matter embodied in this project's work has not been submitted earlier for the award of any degree or diploma to the best of our knowledge and belief.

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DEDICATION

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
ANRS	Amhara National Regional State
ARDU	Arsi Rural Development Unit
CSA	Central Statistics Agency
DAP	Diammonium Phosphate
DDT	Dichlorodiphenyltrichloroethane
EBWOA	East Belessa Woreda Office of Agriculture
EGS	Early Generation Seed
EIAR	Ethiopian Institute of Agricultural Research
ESA	Ethiopian Standard Authority
ESE	Ethiopian Seed Enterprise
ESP	Ethiopia Seed Partnership
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FH	Food for the Hungry
FLDP	Fourth Livestock Development Project
GDP	Gross Domestic Product
ICARDA	International Center for Agricultural Research in the Dry Areas
ILCA	International Livestock Center for Africa
ILRI	International Livestock Research Institute

ISTA	International Seed Testing Association
KII	Key Informants
MoA	Ministry of Agriculture
NGO	Non-Governmental Organizations
SAE	Standards Authority of Ethiopia
SPSS	Statistical Package for Social Sciences

ASSESSMENT OF FORAGE SEED SOURCES, STORAGE METHODS, AND QUALITY ANALYSIS EAST BELLESA, CENTRAL GONDAR, ETHIOPIA

By Betelhem Atena Tarekegn

Supervisors: Prof. Yeshambel Mekuriaw and Dr. Dawit Tsegaye

ABSTRACT

Both the required amount and quality of forage seed are a key input for ensuring higher forage productivity. Access to certified seeds of improved forage varieties remains a challenge for smallholder farmers. This is particularly a bottleneck in areas where drought is common. This study was conducted with the objectives to assess the forage seed sources and storage methods, and to examine the effect of forage seed sources and storage methods on the quality of the forage seed. The study was carried out in 2024 in the East Belessa district of the Central Gonder zone of the Amhara region. The study included both household surveys, monitoring of forage seed storage methods, and laboratory experiments on the sampled forage seeds. Survey data was collected from 120 farmers using a structured questionnaire and leveraged from key informant interviews. Cowpea sample seeds were collected from forage seed sources and storage methods from 54 farmers while mung bean sample seeds were from both forage seed sources and storage methods from 42 farmers. Descriptive statistics and analysis of variance were employed for the survey and laboratory works, respectively. R-package and SPSS (v27.0) software were employed for data analysis. Only 20% and 24% of the respondents accessed the forage seeds from the Bureau of Agriculture (zonal/woreda office) and research centers, respectively. On the other hand, nearly 66% of them got the seed from informal sources, including their own saved seed, farmers, relatives, and neighbors. Farmers don't access sesbania and pigeon pea seeds from formal sources. The laboratory analysis shows that there are significant variations ($p<0.05$) between formal and informal seed sources both for cowpea and mung bean for seed purity, seed germination, thousand seed weight, seedling dry weight, speed of germination, and vigour index two. The variations between cowpea formal and informal sources were significant for seedling shoot length and vigour index one, but not for mung bean. On the other hand, the difference between the formal and informal sources for seedling root length, both for cowpea and mung *bean is not significant. Concerning the different storage conditions for cowpea and mung bean seeds, the study indicates non-significant variations between storage conditions for most of the quality parameters. This shows, that in the study area, the quality of cowpea and mung bean seed is not significantly influenced by storage facilities. Actively seek and use high-quality seed sources, including certified seed formal sources from research centers and agricultural offices, and adopt modern storage techniques (e.g., hermetic storage) to enhance seed viability, and train farmers on best practices for seed storage to minimize deterioration. Furthermore, policymakers assist farmers in accessing improved seed varieties through partnerships with NGOs and private enterprises.*

Key words: *Drought-affected areas, East Belessa district, forage seed, seed quality, and storage methods*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

CHAPTER 1. INTRODUCTION

1.1. Background

Agriculture is the backbone of Ethiopia's economy. The agriculture sector contributes 32.7% to the national GDP, employs more than 80% of the workforce, and shares more than 80% of export earnings (National Bank of Ethiopia, 2021; World Bank, 2020). The sector also supports the livelihoods of millions, for ensuring food security. The agriculture sector provides raw materials for agro-industries, for which the products are supplied to the domestic and international markets. Smallholder farming systems mainly dominates the agriculture sector.

According to FAO (2018), about 74% of the country's farmers are smallholder farmers with an average farm size of less than one hectare. According to Titay Zeleke *et al.* (2021), reported that 73% of households were vulnerable to climate-induced shocks. Moreover, the challenges also influence the livestock sub-sector.

The livestock sub-sector, a critical component of Ethiopia's agriculture, contributes significantly to food security, household incomes, and export earnings (Aleme Asresie and Lemma Zemedu, 2015). It shares 21 and 49% of the national and agricultural GDP of the country, respectively (Azage Tegegne and Getachew Legese, 2020). It provides livestock products for household consumption, including milk and meat. It is also an important source of income generation for households. Moreover, it is used for draught and packing services and maunders for fuel and fertilizers (Azage Tegegne and Getachew Legese, 2020). However, feed shortages remain one of the significant constraints to livestock productivity.

Natural pastures and crop residues are the primary feed sources in Ethiopia. They are nutritionally poor and insufficient to meet the demands of the growing livestock population. According to Alemayehu Mengistu *et al.* (2016), improved forage crops offer a viable solution, enhancing livestock productivity and reducing the pressure on natural grazing resources. Improved forage cultivation can enhance livestock productivity, food security, and environmental sustainability. Forage cultivation includes both the use of improved forage crops along with better farming practices. It also significantly contributes to increased livestock productivity and sustainable farming systems by enhancing feed quality and quantity and diversifying farmer livelihoods(Feyissa Fekede *et al.*, 2022; Mamaru Tesfaye and Lemma Tessema, 2023). Improved forage seed systems are essential to addressing these feed shortages, particularly in drought-prone regions.

The adoption of improved forage crops in Ethiopia remains limited due to systemic challenges in forage seed production, availability, and quality. Hence, the practice of smallholder farmers in Ethiopia in using improved forage crops became quite low. Improved forage seed is one key element that determines forage production and productivity (Dey, 2022). The availability of forage seed, both in terms of quality and quantity, to the farming community is limited. Ethiopia's forage seed sector remains underdeveloped (Alemu Tolemariam *et al.*, 2023). Most forage seeds are exchanged informally among farmers, often without quality assurance, leading to poor germination rates and reduced productivity. The situation forced farmers to use locally available forage seeds, which are commonly not of good quality. This is particularly worse in areas where there is limited infrastructure development and a prevalence of recurrent drought.

The seed storage facilities also contribute to the quality of seed that farmer's use, which eventually determines the growth and yield. Smallholder farmers predominantly rely on traditional storage methods, which fail to maintain seed viability over time. This results in reduced forage yields and limited adoption of improved forage varieties (Dugesar *et al.*, 2021b). Addressing these gaps requires a systematic evaluation of forage seed sources, quality, and storage methods, along with improved coordination among stakeholders.

1.2. Statement of problem

Ethiopia faces recurring droughts and climatic variability that significantly affect agriculture and food security. East Belessa, a district in Central Gondar, has climatic conditions highly affecting the agricultural activities and food security of local communities. The district is characterized by a mixed agriculture system and is rich in livestock resources. Rearing livestock is a key investment in the area both for food security and to improve household income. Farmers in the district cultivate different forage crops to feed their livestock (EBWAO, 2024). However, the livestock sector is hindered by inadequate access to quality forage seeds, a critical input for improving feed availability and productivity. According to the district office of agriculture (EBWAO, 2024), farmers in East Belessa district depend mostly on informal seed sources, such as farmer-to-farmer exchanges, which often lack quality assurance. The absence of a well-developed and sustainable forage seed system exacerbates seed scarcity, limiting the availability of adaptive and high-performing forage species. Moreover, traditional seed storage practices further degrade seed quality, reducing germination rates and viability, particularly in drought-affected areas.

Despite the critical role of forage seeds in livestock production and food security, limited research has been conducted to assess the sources, storage methods, and quality of forage seeds in East Belessa. There is also an insufficient understanding of how these factors influence forage seed distribution and accessibility. Addressing these gaps is essential to developing resilient forage seed sources that meet the needs of smallholder farmers, enhance livestock productivity, and support food security in drought-prone regions.

1.3 Objectives

1.3.1. General objective

The main objective of this research is to assess the forage seed sources and their implication on seed quality in East Belessa district.

1.3.2. Specific objectives

1. To assess the forage seed sources in East Belessa district.
2. To examine the effect of forage seed sources on the quality of the seed.
3. To investigate the different forage seed management practices (storage) and how they relate to seed quality.

1.3 Research questions

1. What are the main sources of forage seeds in East Belessa district, and how are farmers accessing these forage seeds?
2. Is there a relationship between different forage seed sources and seed quality parameters?
3. Is there a relationship between forage seed storage methods and seed quality parameters?

CHAPTER 2: LITERATURE REVIEW

2.1. Role of Improved forages in Ethiopia

Improved forages play a crucial role in sustainable livestock production and environmental management in Ethiopia. They provide high-quality feed, enhance soil health, and reduce greenhouse gas emissions(Dey *et al*., 2022; Tulu *et al*., 2023). Integrating forages with crops and soil conservation practices can increase adoption and productivity(Alemayehu Mengistu *et al*., 2016). Cultivated forage-based diets can significantly reduce feeding costs and methane emissions in both dairy and fattening sectors(Dey *et al*., 2022). Overall, improved forages offer substantial and long-term benefits for Ethiopian farming systems, contributing to increased crop yields, livestock productivity, and environmental sustainability, but many farmers may not adopt improved forage varieties due to a lack of awareness or access to high-quality seeds, and farmers may lack the knowledge or training on how to effectively cultivate and manage improved forage (Alemayehu Mengistu *et al*., 2016).

A key component of agriculture, livestock production can help many people in developing countries maintain their standard of living and maintain their access to food (Girma Asefa and Zelalem Bekeko, 2022). In Ethiopia, rearing livestock produces up to 80% of farmer income. Out of all the countries in Africa, Ethiopia has the largest livestock population (Shimelis Mengistu *et al.*, 2021).

Livestock's economic contribution and productivity, but are far from reaching their full potential

Because of several limitations. The lack of both quantity and quality feed supplies is frequently mentioned as one of the primary constraints limiting our country's livestock resources from being used. The primary sources of livestock feed in smallholder mixed crop-livestock production systems include crop residues, natural pastures, and other agricultural byproducts. However, natural pastures and crop residue the two most common feed sources have poor nutritional value. The supply and availability of high-quality feeds (cultivated forages and concentrates) are inadequate. Better forages can provide beneficial nutrients, particularly in areas where accessibility to agro-industrial waste products is limited (Adugna Tolera *et al.*, 2019).

The needs of smallholder farmers and specialized large-scale forage providers have been fulfilled by a variety of forage development strategies, and suitable species for each strategy were identified for Ethiopia's various agroecologies (Adugna Tolera *et al.*, 2019).

2.2. Improved Forage seed in Ethiopia

A seed is the product of a fertilized ovule that consists of the embryo, seed coat, and cotyledon(s). In terms of seed technology, any part of the plant body that is used for the commercial multiplication of crops is called the seed. To make available good quality seeds to farmers, seed certification is necessary, which is a scientifically designed process (McDonald and Copeland, 2012). The seed is the carrier of the genetic improvements brought about by modern plant breeding. The success with which the new individual is established the time, the place, and the vigor of the young seedling is largely determined by the physiological, biochemical, and genetic features of the seed (Boelt *et al.*, 2015).

The development of seeds and seed systems in sub-Saharan Africa has come under increased attention due to calls for the reduction of poverty, zero hunger, and climate change adaptation (Mulesa, 2021). The goal has been specifically to develop and provide smallholder farmers with high-quality seeds of improved varieties to increase agricultural productivity and production, improve nutrition, strengthen the resilience of the system, and generate income. Some policies and programs have received help from donor countries, multilateral institutions, foundations, and non-governmental organizations (NGOs) to help achieve these goals (Mulesa, 2021).

The Arsi Rural Development Unit (ARDU) initially introduced pastures, annual forage legumes, and perennial grass species in the 1970s. The unit supported and received favorable evaluations from farmers, who multiplied starter seeds of oats, vetch, and fodder beet (Alemayehu Mengistu and Robertson, 2013).

Systems for producing fodder were implemented by the MoA's Fourth Livestock Development Project (FLDP) in 1987 and 1988. More focus was placed on herbaceous and tree legumes in the FLDP project, which gathered seeds primarily from many model farms and forage development sites. Three methods were introduced by FLDP: specialist seed production enterprise, opportunist seed production, and contractual system of forage seed production (ILRI, 2014).

Contractual forage seed production: The FLDP established this system to demonstrate better forage production and utilization methods to producers while also producing high-quality seed at the level of individual farmers and cooperatives at a comparatively low cost of production. Forage seed was generated in large quantities during the FLDP project time. However, there was little seed exchange between farmers. The farmers kept depending on the government to sell their goods, but this stopped.

Opportunistic seed production: This system uses a dual business strategy that combines the production of livestock and forage seeds. When a farmer anticipates a successful sowing year and a healthy seed market, seed production begins. If not, the practice of producing fodder for cattle is used. This business requires very little further funding. Controlling plant density, managing proper crop hygiene, producing adequate nutrition, irrigation, and additional crop management are all necessary.

Specialized seed production enterprise: A specialized seed production company needs a significant investment in workers, equipment, fertilizer, chemicals, and electricity. Under this method, the crop is considered a high-value crop, and the seed company is certainly an effective business. A more precise management skill is required including utmost care in site selection. The private sector has only been engaged in forage seed production activities in recent years. Even though more people are participating, the ability is still small and insufficient to meet Ethiopia's demand for forage seeds. Companies that produce and distribute certified seed include Eden Field Agri-Seed Enterprise, Sidama Seed Enterprise, and Sidama Improved Forage Seed Producers (Lemi Gonfa, 2015).

2.3. Forage seed system in Ethiopia

The term seed system can be defined as the interaction between seed supply and demand, which results in the farm-level utilization of seeds, and thus crop genetic resources.

Livestock productivity in Ethiopia is low. The main reason contributing to low livestock production is inadequate feed, both in terms of quantity and quality, in addition to issues with animal health. Lack of animal feed continues to be the primary factor limiting livestock numbers and production in both highland and lowland areas.

Forage seed producers are not well organized to collect, store, and test forage seeds. Individual farmers produce almost all forage seeds on a contractual basis and cooperative-supported farmers and distributed using informal seed distribution pathways Southern Agricultural Research Institute (SARI) Hawassa, Ethiopia (Deribe Gemiyu *et al*., 2012). Seeds obtained from uncertified sources are poor in purity and viability. Farmers do not use fertilizer and associated management packages for forages, thus, results in low production and yield (Deribe Gemiyu *et al*., 2012).

Utilizing improved forage varieties has several advantages. In addition to enhancing animal nutrition, which leads to more productive cattle, it also supports crop output by preserving soil fertility through nitrogen fixation. While grazing reduces the land's fertility, forage farming improves the condition of the soil. Intercropping species, such as coffee and Desmodium or maize and Lablab, is more beneficial than producing only one crop.

The production of high-quality seeds of a wide variety of forage types that are rapidly available and affordable for farmers is ensured by a sustainable forage seed system. However, in Ethiopia, farmers have not yet benefitted from the advantages of using quality forage seed due to a combination of factors, including inefficient seed production, distribution, and quality assurance systems, as well as inadequate technical capacities (Dey, 2022).

In Ethiopia, there is currently little focus on improving the production, distribution, and promotion of forage seeds. Because they use their limited land for growing food and income crops, the majority of smallholder farmers are unable to develop and market improved forage crops. NGOs and regional agricultural bureaus frequently give seed for free or at reduced prices (Dey, 2022).

2.4. Forage seed sources in Ethiopia

A sustainable forage seed source ensures the production of high-quality seeds of a diverse range of forage varieties that are timely available and accessible at affordable prices to farmers. However, in Ethiopia, farmers have not yet benefitted from the advantages of using quality forage seed due to a combination of factors, including inefficient seed production, distribution, and quality assurance systems, as well as inadequate technical capacities. In Ethiopia, both formal and informal forage seed sources operate. However, a very limited quantity of seed is produced within the formal seed sources (Kalsa and Dey, 2022). Despite the strong justification for increasing the availability and use of improved forage seeds, public seed enterprises have so far shown little interest, probably for technical/commercial reasons (Dey, 2022). Informal production and supply dominate the forage seed source in Ethiopia(Etsubdink Tekalign, 2014a). Seed used by Ethiopian smallholder farmers is saved on-farm and exchanged among farmers (Otieno *et al.*, 2017).

2.4.1. Formal forage seed sources in Ethiopia.

Ethiopia's Forage seed Sources comprise both formal and informal components. The formal seed source, primarily led by the Ethiopian Seed Enterprise (ESE), faces several challenges, including limited production and a lack of interest from the government in expanding forage seed production. The ESE has focused on grain production, with forage seed production only introduced later, primarily limited to oats and vetch (Yonas Sahlu, 2012). Forage seeds were introduced later to the formal seed sector in limited quantity. However, forage seed production was not new to the country. According to Alemayehu Mengistu and Getnet Assefa (2012), the Arsi Rural Development Unit (ARDU) introduced forage and pasture seed in 1970 and used to multiply and distribute mainly oat and vetch seed to the farmers involved in the project seems that the formal seed source followed the same pattern of activity since foraging seed production activities of ESE focused only on these two forage crops.

Although there were several forage seed organizations and projects, their links with ESE remained very weak. The Ethiopian Institute of Agricultural Research (EIAR) and the herbage seed unit of the International Livestock Center for Africa (ILCA) [now International Livestock Research Institute (ILRI)] were the major sources of breeder seed of forage varieties (Yonas Sahlu, 2012). The Fourth Livestock Development Project (FLDP) of the Ministry of Agriculture (MoA) exerted another effort to produce and distribute forage seed to small farmers in some parts of the country (Fekede Feyissa *et al.*, 2018). The FLDP also initiated contractual seed production with individual farmers and farmer cooperatives. The emphasis of the project on forage seed production and dissemination of the various types of forages including grasses, herbaceous and tree legumes and the activity stopped as soon as the project was phased out (Etsubdink Tekalign, 2014b). In general, formal forage seed production and distribution led by ESE have remained insignificant over the last two decades. The forage seed sector was dominated by projects and Non-Governmental Organizations (NGOs) activities that operated informally (Yonas Sahlu, 2012). The International Center for Agricultural Research in the Dry Areas (ICARDA) and ILRI contributed to the forage seed sector through a series of joint seed production training courses and workshops (Mesfin Dejene *et al.*, 2012).

2.4.2. Informal Forage Seed Sources in Ethiopia

Informal forage dominates, with most farmers relying on locally exchanged, farm-saved seeds. This system is highly informal, semi-structured, and crucial to seed security in rural Ethiopia. The informal system is often more reliable and accessible, providing seeds at affordable prices when needed (Mulesa *et al.*, 2024). However, it is limited in ensuring consistent seed quality and does not supply the growing demand for improved forage species (Lemi Gonfa, 2015). The informal seed source, also known as the local system or sometimes as the "farmers" system, is called informal because it operates under non-law regulated and is characterized by the farmer-to-farmer seed exchange (Atilaw Abebe and Korbu Lijalem, 2011).

2.5. Challenges in forage seed sector development in Ethiopia

The development of Ethiopia's forage seed sector faces multiple challenges, mainly due to weak regulatory frameworks, limited research, and inefficient production systems (Mwendia *et al.*, 2018). The absence of clear laws and regulations hampers seed certification and quality control, while weak enforcement further exacerbates the problem. Additionally, poor coordination among government agencies, private enterprises, and research institutions limits effective seed production and distribution.

According to Mijena (2022), a major constraint is the scarcity of high-quality and improved forage seed varieties suited to diverse agroecological conditions. Limited research and development efforts have resulted in a lack of adaptable and resilient forage species, particularly for regions facing recurrent droughts and erratic rainfall. Weak seed multiplication systems, coupled with poor post-harvest handling, storage, and processing facilities, contribute to seed deterioration and low availability of quality seeds. The absence of modern seed processing technologies further affects the efficiency of seed production.

Farmers have limited awareness of the benefits of using certified forage seeds, and weak extension services fail to promote improved production and utilization practices. The forage seed market remains underdeveloped, making it difficult for farmers to access quality seeds. Poor market linkages between seed producers and buyers, combined with high costs of seed multiplication, processing, and storage, discourage investment in the sector (Alemayehu Abebe *et al.*, 2018).

Additionally, limited access to credit and financial support further restricts the growth of forage seed enterprises.

Economic constraints also play a significant role, as many farmers prioritize food crops over forage crops due to land scarcity and immediate financial needs. The lack of incentives to encourage forage seed production, coupled with overgrazing and land degradation, further limits the availability of land for forage cultivation. Poor soil fertility management practices also reduce productivity (Mijena, 2022).

2.5.1. Challenges with forage seed in Ethiopia

Ethiopian universities, regional and federal agricultural research institutes, the International Organization for Research in Agro-Forestry, and the International Livestock Research Institute are among the national and international organizations doing forage research. To fully understand their potential as feed resources in livestock production systems, numerous research studies have been done. Currently, different improved forage species are used in various livestock production systems based on their agro-morphological traits and requirements for optimum production (Mijena, 2022). However, Ethiopia faces significant challenges in forage seed research, limiting the availability and adoption of improved varieties. There is a shortage of well-adapted, high-yielding, and stress-resistant forage seeds suited to different agroecological zones. Inadequate seed multiplication research results in low quality and insufficient supply, while weak certification and quality control mechanisms undermine seed reliability.

Farmers often rely on traditional forage sources due to limited awareness and accessibility (Dey, 2022).

Research institutions operate in isolation, creating a gap between research outputs and farmers' needs. A shortage of trained professionals in forage breeding, agronomy, and seed technology further hinders progress (Diriba Tulu *et al.*, 2023). Poor communication of research findings and weak coordination among government agencies, universities, and the private sector slow the sector’s development (Shimelis Mengistu *et al.*, 2021).

Funding constraints from both the government and donors limit the development of new forage varieties and seed production technologies. Unclear policies and low profitability discourage private-sector investment. Additionally, the high cost of improved forage seed production makes it unaffordable for many smallholder farmers.

Environmental challenges, including droughts, erratic rainfall, soil degradation, and land competition with food crops, further impact forage seed research and production (Alemayehu Abebe *et al.*, 2018). Pest and disease outbreaks also reduce seed quality and yield. Addressing these issues requires stronger research collaboration, better funding, improved seed certification, and climate-smart forage production strategies (Dey, 2022).

2.5.2. Challenges with forage seed producers in Ethiopia

Changing weather patterns significantly affect seed viability and can lead to new pest infestations and disease outbreaks, putting additional pressure on producers. Getting about complex regulations for seed certification and issues related to obtaining a patent for genetically modified seeds can create barriers, particularly for small and medium-sized seed producers who often struggle to compete with larger agribusiness firms (Alemayehu Abebe *et al.*, 2018).

Competitive pricing strategies can get profit margins, while limited access to funding hinders creativity in seed development. Additionally, keeping pace with rapid advancements in agricultural technology presents challenges for smaller producers. Supply chain problems, such as transportation issues and raw material shortages, can affect production schedules and durability in quality (Mijena, 2022). There is also a pressing need for ongoing education and training for farmers to stay updated on best practices in seed production, along with efforts to link the gap between research institutions and producers.

2.6. Seed storage methods in Ethiopia

Seed quality is governed by their genetic makeup; the quality of seeds, however, is deteriorated during storage (Shelar *et al.*, 2008). Thus, seed storage and retention of seed viability have always been important considerations in agricultural production. Poor storage condition gives rise to the deterioration of seed quality and the resultant loss of viability. Storing seeds, just like storing any other live organism has its risks. The risks can be high or low depending on the species, the prevailing weather, the market requirements, and the management provided during storage.

Storage plays an important role in postharvest food supply chains. The smallholder farms in Africa usually store their produce for home consumption or as seed until they sell it in local markets. Various studies conducted in Ethiopia showed that farmers use different traditional storage containers. Smallholder farmers store their seeds in various containers/materials, mostly under ambient conditions this results in a loss of seed viability over a short time. The storage of forage seeds is crucial for maintaining their viability and ensuring quality for future planting. Poor storage conditions lead to seed deterioration, significantly impacting seed viability (Bortey *et al.*, 2016). Proper seed storage is essential to maintain seed quality and ensure availability for future planting (Dugesar *et al.*, 2021a). Forage seed systems and proper seed storage methods play crucial roles in improving the livelihoods of smallholder farmers in drought-affected livestock rearing.

2.6.1 Traditional storage methods

In Ethiopia, smallholder farmers typically use traditional storage methods, such as sacks, gotera, and clay pots (Berhe *et al.*, 2022). These methods are often not ideal, leading to moisture absorption and pest infestations, which reduce seed quality over time (Dugesar *et al.*, 2021b). There are different forms of traditional storage structures, generally made of locally available materials. In different parts of Africa, smallholder farmers use different storage structures to store their forage seeds.

2.6.2 Hermetic storage methods

Hermetic storage methods are gaining attention. Airtight containers, such as metal drums or specialized bags, can prevent moisture and pest entry, thereby preserving seed quality (Dugesar *et al.*, 2021b). However, these methods are not widely adopted due to cost and lack of awareness among farmers. These containers are typically placed in cool, dry, and well-ventilated areas, such as granaries or elevated platforms, to protect the seeds from moisture, pests, and diseases

2.7. Forage seed quality

Forage seed quality directly affects livestock productivity, as the quality of the seed determines the health and growth potential of the forage crop. The key determinants of forage seed quality include genetic factors, seed processing methods, storage conditions, and handling practices (Katoch, 2022b). High-quality seeds lead to better forage yields, which, in turn, improve livestock feeding and overall farm productivity (Michael Turner *et al.*, 2019)

Seed quality describes the potential performance of a seed lot. Forage quality has a direct effect on animal performance, forage value, and ultimately profits (Katoch, 2022a)**.** The determinants of forage seed quality include the genetics of the seed variety, the production and processing methods, storage conditions, handling practices, and adherence to quality standards and certification procedures. Seed producers, distributors, and farmers need to ensure that forage seed lots meet the required quality standards to maximize the potential for successful forage production and livestock feeding. The forage seed producers should get a return from the investment by producing quality forage seeds. Forage quality represents the voluntary intake, rate, and extent of digestion and assimilation of nutrients and energy from forages in livestock (Katoch, 2022a).

Forage quality varies not only among different forages but also within the forage species. Furthermore, the forage quality is also affected by various factors such as antinutritional and antiquity factors, seasonal variations, soil fertility level, disease, and pest incidence, and maturity stage at harvest and storage conditions. Therefore, estimation of forage quality is necessary for assessing whether the kind of feedstuff provided to the livestock is adequate for maintaining their health and productivity (Amary, 2016).

The quality of seeds is considered an important factor in increasing yield. The use of quality seeds helps greatly in higher production per unit area to attain the food security of the country. Quality seeds have the ability for efficient utilization of the inputs such as fertilizers and irrigation. Well-thought policy, planning, friendly regulatory system, facilities for capacity, and structural improvement both in public and private sectors are required for the production, processing, preservation, and distribution of a sufficient quantity of quality seeds in time to the farmers (Seck *et al.*, 2012)**.**

2.7.1. Seed purity

This refers to the percentage of pure seed in a lot. Physical purity is influenced by factors like seed size, appearance, and the presence of contaminants. Physical seed quality refers to the percentage of pure seed of the right crop in a seed lot; sometimes seed size is also accounted for. It is measured by some components viz. Analytical purity, moisture content, size, appearance, color, insect bites, and presence of other undesirable materials.

The quality of a seed lot is based on the physical, genetic, physiological, and phytosanitary quality. Among the aspects, the physical quality of a lot can significantly reduce the productivity of a crop (Michael Turner *et al.*, 2019).

2.7.2. Moisture content

Seeds with high moisture content lose viability quickly. Excess moisture increases the likelihood of mold and fungal growth, making moisture management a critical aspect of seed storage (Copeland and McDonald, 2012). A seed can be regarded as a structure composed of complex substances such as cellulose, starch, fat, and protein, with some water (Copeland and McDonald,, 2012). The moisture content of a sample is, either, the loss in weight when dried, or the quantity of water collected when it is distilled. It is expressed as a percentage of the weight of the original sample. It is the chief reason that causes loss of viability. It is generally assumed that high respiration at high temperatures is related in some way to a rapid loss in germination (Bewley and Black, 2012).

2.7.3. Thousand Seed weight

Thousand seed weight (TSW) is simply measuring the weight of a thousand seeds. It is usually performed at the same time during the purity test (ISTA, 2016). Thousand seed weight is an important measure for determining seed size, which can impact planting rates and seedling emergence (ISTA, 2016). A thousand seed weight within the seed lot may vary due to different factors such as varietal differences, interplant competition for light, water, and nutrients, and the effect of diseases that contribute to a wide range of seed size (Bishaw *et al.*, 2012). The sample of the seed lot is screened to simulate what would happen when the seed lot is cleaned and processed, and then a thousand seeds are weighed to produce the weight of a thousand seeds in grams. It has the advantage of calculating sowing rates accurately and during screening, a small-sized seed could be removed (Nataline, 2013).

2.7.4. Physiological seed quality

a) Germination capacity

Germination capacity refers to the ability of the seed to emerge and develop into a normal plant under favorable conditions (Nataline, 2013). The germination percentage is an indicator of the seed's ability to emerge from the soil to produce a plant in the field under normal conditions. Therefore, physically uniform seeds of an adapted variety will be useless if it is low in germination or if it fails to germinate when planted (Mutyaba, 2022). High-quality seed germinates earlier and thus produces larger roots and shoots than low-quality seed. Seedlings with longer roots and shoots avoid moisture stress compared to seedlings with short roots (Nataline, 2013).

b) Seed vigor

Vigor refers to the overall health, strength, and viability of the seeds. Seeds with high vigor have better potential for successful germination, rapid and uniform emergence, and establishment of strong and productive forage plants. The main object of testing seed for germination is to gain information about the field planting value of the seed lot and to obtain results that can be used to compare the value of different seed lots. It is used for the testing of germination percentage in the laboratory. The following substratum is required which serves as a moisture reservoir and provides a surface or medium germination and seedling growth (Julio, 2015).

CHAPTER 3. MATERIALS AND METHODS

3.1. Description of the study location

The study was conducted in the East Belessa District, Central Gondar Zone of Amhara region, Ethiopia. The district is bordered in the southwest by Ebenat district, in the west by the west Belessa district, in the northwest by Wegera district, in the north by Jan-Amora district, and in the east by Sahila and Dehana districts of the Wag Hemra Zone (Figure 1). The East Belessa district comprises 30 kebeles (the lowest administrative level in Ethiopia) and two towns. Guhala is the capital city of the East Belessa district, which is found 122 km away from the capital city of the central Gondar zone, 183 km from the capital of the Amhara region, and 729 km from Addis Ababa, the capital of Ethiopia. The district is located at an altitude ranging from 1,496 to 2,000 m above sea level. The district is typically categorized under the typical warm semi-arid climate zone, locally known as kola. Nearly 90% of the district is kola, with hot and dry conditions coupled with minimum annual rainfall. The weather conditions contribute to frequent drought, which aggravates famines.

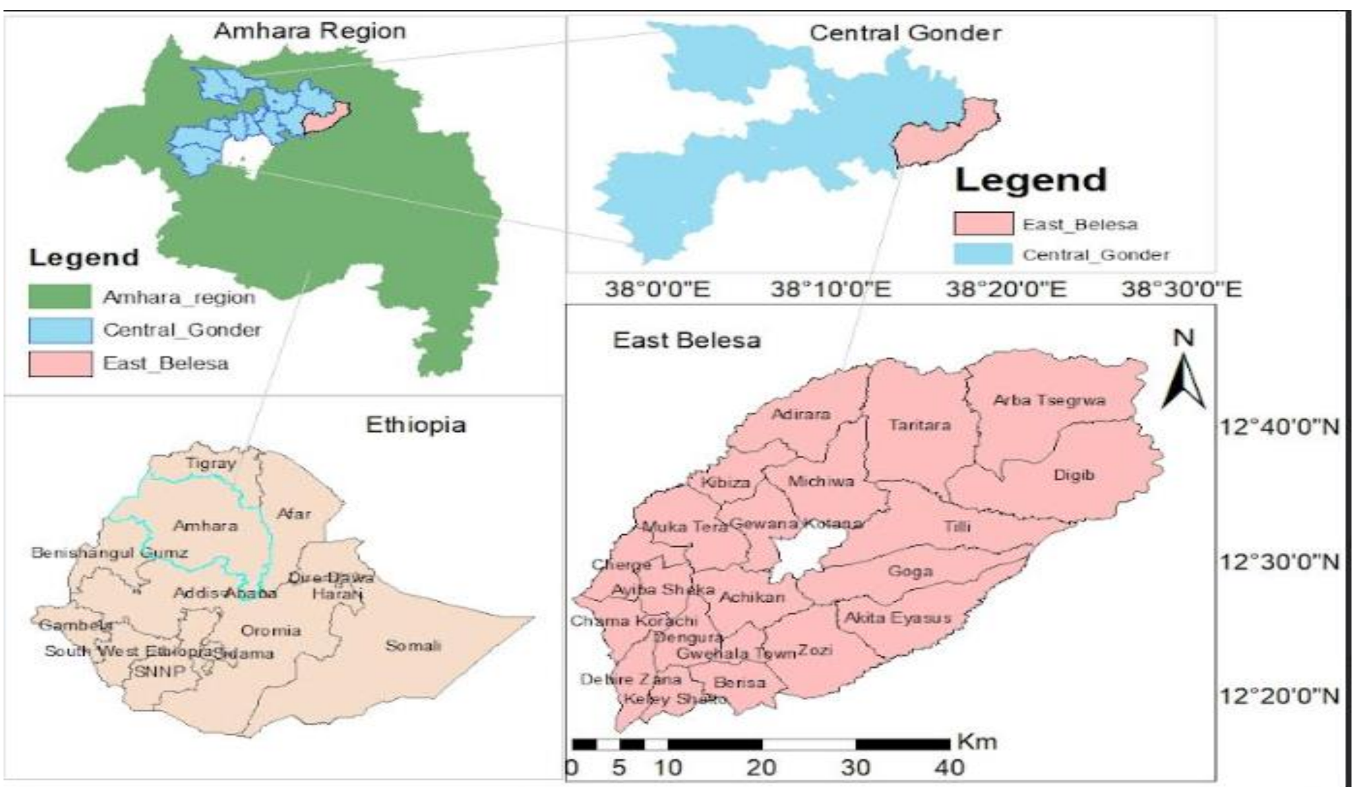

Figure 3. 1 Map of the study area

The total population of the district is estimated at 142,174; of which, 72,606 (51.1%) were males and 69,568 (48.9%) were female. Agriculture is the main means of livelihood for the community in the district. The farming system is a typical subsistence in the district, which is highly dependent on rainfall. Tef, sorghum, and chickpea are the major crops grown in the district. The district is one of the areas of the region where frequent drought is common, which is responsible for food insecurity.

In the Woreda, livestock is one of the major livelihood of the farming community. It is an integral part of crop production and used for draught power to undertake cultivation, threshing, transportation and trampling during the final seed bed preparation. Meat and milk productions are used for home consumption. The sale of livestock and livestock products serve as a source of cash income to buy household needs and agricultural inputs. The Woreda is particularly drought-affected area so that livestock are sold and serve for the purchase of grains and other food items. Manure is also used for fuel and to fertilize homestead crops. However, the development of livestock sub-sector as the other agricultural enterprises in the Woreda has been hindered by the absence of high productive animal breeds, inadequate health services and facilities, shortage of animal fodder and nutrition and absence of good management of livestock resources.

3.2. Study procedures

The study was undertaken in two separate but interrelated tasks. The first one was an assessment aimed at understanding the forage seed systems and forage seed management practices in the district. The second study was a laboratory experiment based on the outcome of the assessment. The assessment confirmed the presence of two seed forage seed systems (Cowpea (Vigna unguiculata) and mung bean (Vigna radiate) formal and informal forage seed systems) in the district. Therefore, a laboratory experiment was conducted to understand the effect of these seed sources on seed quality. Moreover, the experiment assessed the combined effect of seed sources and storage practices on forage seed quality.

3.3. Assessments of farmer’s forage seed production

3.3.1. Sample selection

The study employed multistage sampling procedures. First, East Belessa district was purposely selected for the present study due to the following reasons: 1) the district is one of the drought-affected area. 2) The district is also known for its livestock resources, for which forage production is crucial. According to the Central Gondar Office of Agriculture, farmers in the district used forage seeds for forage production. Second, the study purposely selected four representative kebeles in consultation with the district office of agriculture. These kebeles represented the geographical, production, farmer's practices, and forage seed use experience of farmers in the district. These kebeles were Dengora, Bursa, Achikan, and Gohala Zuria. These kebeles are also known for their better experience in forage seed production. Third, the study selected sample households for interview.

The list of forage-producing farmers from each selected kebele was obtained from the district office of agriculture. The total number of forage-producing farmers was 191. The sampling technique, which was proposed by Cochran (1977), was used to determine the sample size.

To determine the sample size using Cochran's formula, the general formula is:

$$n0= \frac{\boldsymbol{z^2pq}}{d^2}$$

- n0= sample size
- Z = Z-value (e.g., 1.96 for a 95% confidence level)
- p = estimated proportion of the population (0.5)
- e = margin of error (e.g., 0.05)
- Where n0 = required sample size Z = 95% confident limit (1.96) P = proportion of population to be included in the sample (p = 5% = 0.5), q = 1-0.5 = 0.5), d = margin of error (d = 0.05). Therefore, the sample size was no= (1.96)2 x 0.5 x 0.5) / (0.05)2 = 0.9604/ 0.0025 =384.16
- n0=384.16

N = total population size (191)

n = adjusted sample size

$$n= \frac{no}{1+\frac{(no-1)}{N}} = \frac{384.16}{1+\frac{(384.18-1)}{191}}$$ 384.16/3.008384.16=127.12

In this case, I would round it to 127. However, due to constraints, selected 120.

Proportional Random Sampling:

To select the sample from each kebele:

- Total farmers = 191
- Sample size = 120

Calculate the proportion for each kebele:

1. **Dengora**: 29/191×120≈ 19
2. **Bursa**: 84/191×120≈ 52
3. **Achikan**: 41/191×120≈ 25
4. **Gohala Zuria**: 37/191×120≈ 24

127 samples were suggested for the survey. However, due to time and resources constraints the sample size was reduced to 120. A proportional random sampling technique was used to select the 120 sample farmers from the list; 19 farmers from Dengora, 52 from Bursa, 25 from Achikan, and 24 from Gohala Zuria kebeles.

3.3.2. Survey data collection and analysis

The data were collected using a structured questionnaire. The questionnaire comprised seven sections: household information, farming practices of the household, agricultural inputs used, forage production practices, forage seed sources, forage seed production, and forage seed management. The questions were developed considering the existing literature and local experience. Experts in the subject matter were invited to review the draft questionnaire. Their feedback was considered accordingly. The revised version of the questionnaire was further pre-tested by five farmers to find out whether the questions were relevant to the context and understandable by farmers. The final version of the questionnaire was then developed by including feedback from the experts and pre-test results. Those questions that were repeated, ambiguous, and difficult to understand by the farmers were removed. Moreover, a few points were added to the final version to grasp better information from the survey.

The laboratory experiments were set based on the outcome of the survey

Three experienced enumerators and me: were employed to interview the respondents. Before their mission, they were briefed about the objectives of the survey and the ethical procedures they should follow. Interviewees were also contacted before the interview for their willingness to participate in the study. All showed interest in being part of the process. Enumerators conducted the interview when the time and place were convenient for the respondents. The researcher worked with enumerators to ensure the data quality. Moreover, a Key Informant Interview (KII) was employed to gather further information from a few experts who are knowledgeable about forage seed production in the district.

3.3.3. Survey data analysis

Before analysis, data curation (process of organizing, maintaining, and ensuring the quality of data throughout its lifecycle) was done. The data were analyzed using Statistical Package for Social Sciences (SPSS v27.0). Descriptive statistics such as minimum, maximum, standard deviation, range, and percentage values were used for analyzing the data.

3.4. Laboratory experiment

The laboratory experiments were set based on the outcome of the survey study. Therefore, the laboratory test was employed to assess the effect of seed sources and storage facilities on the seed quality of cowpeas and mung beans. For the laboratory experiments, sample seeds of cowpea and mung bean were collected from farmers who accessed the seeds from formal and informal sources and used different storage facilities. Therefore, two sets of laboratory experiments were conducted independently for cowpea and mung bean.

3.4.1. Laboratory experiment design and testing procedures

There were two factors to be tested for their effect on the seed quality. These factors were seed sources and storage facilities. There were four combinations of treatments: 1) Seed accessed formal sources stored in sacks, 2) seed accessed from formal sources stored in gotera, 3) seed accessed from informal sources stored in sacks, and 4) seed accessed from informal sources stored in gotera. Therefore, the study used a completely randomized design in a two by two (2*2) factorial arrangement with four replications. The experiments were conducted in the seed quality-testing laboratory of Bahir Dar University.

The study conducted both physical and physiological seed quality testing for cowpeas and mung beans. Quality testing included seed purity, germination, moisture content determination, thousand seeds, speed of germination, and seedling vigor tests.

3.4.2. Physical purity

According to ISTA (2016), the weight of the submitted and working samples of forage seeds is 1000g each, respectively. For each seed sample, about 1000 g of seed sample was used for purity analysis. Each seed sample was divided into four replicates and separated into three components: (i) pure seed, (ii) other crop seed, and (iii) inert matter (ISTA, 2016). The components were weighed on a precision balance to the nearest two decimal places, and the percentages of each component were calculated as follows:

$$\text{Purity\%} = \frac{Weight\ of\ Pure\ seed}{Weight\ of\ working\ Sample} \text{x } 100$$

3.4.3. Moisture content determination

The moisture content was determined using oven dry method. Five grams of seed of each working sample were dried in an oven at 103 ± 2^{0}C for seven hours. The percentage of moisture content was calculated using the following formula suggested by (ISTA, 2016):

$$\text{MC (\%)} = \frac{M2 - M3}{M2 - M1x} \text{X100}$$

Where MC = Seed moisture content.

M1 = Weight of the empty container with its cover

M2 = Weight of the container with its cover and seeds before drying.

M3 = Weight of the container with its cover and the seed after drying

3.4.4. Thousand Seed weight

Thousand seed weight was determined by counting thousand seeds by seed counter from pure seed fraction from each of the samples collected and the average seed weight was calculated according to ISTA standard (ISTA, 2016).

3.4.5. Standard germination test

Four hundred seeds were counted at random from the working seed samples. Then, a hundred seeds were planted from each sample planted from the sample in Petri dishes in four replications.

The planted seeds were germinated in a seed germinator, a temperature was measured from the start day up to the end day by a digital hygrometer for the 3rd to 8th day, germination boxes were removed, and the seedlings were evaluated following the procedures of (ISTA, 2016). The percentage of normal seedlings, abnormal seedlings, and fresh un-germinated and dead seeds were recorded and calculated based on the final count. The results were expressed as the mean percentage of normal seedlings for each seed lot. Therefore, the normal germination percentage was taken as the average number of normal seeds germinated over the final day's period, and it was calculated as below.

Germination Percentage (GP) (%) = $\frac{Total\ number\ of\ normal\ seedlings}{Total\ number\ of\ seed\ sown}$ x100

3.4.7. Seedling vigor test

The seedling vigor test was determined by measuring the shoot and root length of seedlings. The seedling shoot and root length were measured after the final count of the germination test. Ten normal seedlings were randomly taken from each replicate, and shoot, length was measured from the point of attachment to the cotyledon. Similarly, the root length was measured. The averages of shoot and root lengths were computed by dividing the total shoot or root lengths by the total number of normal seedlings measured (ISTA, 2016).

The seedlings' dry weight was measured after the final count of the standard germination test. Ten randomly taken seedlings from each replicate were identified and placed in envelopes and dried in an oven at 80 ^{0}C for 24 hrs. The dried seedlings were weighed by using a sensitive balance and the average seedling dry weight was calculated. For each treatment, two vigor indices were calculated. Seedling vigor index one was calculated by multiplying the number of normal seedlings with the average sum of shoot and root lengths and Vigor index two was calculated by multiplying the standard germination percentage with mean seedling dry weight.

Vigor Index One (VIG-I) = Average Seedling Length × Normal seedling %

Vigor Index Two (VIG-II) =Normal seedling percentage × Seedling mean Dry Weight.

3.4.8. Data analysis

The experimental data were analyzed using the R package. The mean values of seed quality parameters were computed using analysis of variance. The analysis addressed the combined effects of seed sources and storage conditions on seed quality. Moreover, the analysis assessed the individual effects of seed sources and storage conditions on seed quality attributes.

Seed storage and seed systems for forage crops (cowpea and mung bean),
Two separate experiments: 1) for cowpea and 2) for mung bean take samples from farmers for each category for lab analysis for each crop
Comparing more than two means using ANOVA, Design: CRD, Replication: four

CHAPTER 4. RESULTS AND DISCUSSIONS

4.1. Demographic characteristics of the respondents

The socio-economic characteristics of respondents are presented in Table 4.1. About (85%) of the respondents were male-headed households and (15%) were female-headed households. The mean age of the respondents was 45.4 years old with minimum and maximum ranges from 28-72 years old. About (87.3%) of the respondents are under the economic age range of 28-63 years. This indicates that most of them are under active economic and productive age.

Concerning the educational status of the respondents, nearly two-thirds of them are illiterate indicating they do not read and write. The remaining 60% of the respondents are literate with different levels of educational status, including 10% with the highest education of secondary education (grade 9-12). Education has a positive contribution to knowledge transfer and technology adoption. According to the authors Solomon Yokamo (2020) and Galmesa Abebe (2019), who reported that educated farmers are expected to display relatively better evidence due to the process information more rapidly than illiterate ones. As 40% of the respondents are illiterate, this may affect their ability to take up better technologies including forage value chain-related technologies.

The mean household family size of the respondents was 4.2 with minimum and maximum ranges from 2-7. Most interviewed households (85%) do have 3-6 family members. This is less than the regional (4-5) and national (4.5) Average (CSA, 2011). Having more number family sizes with productive age plays a crucial role in improving the livelihood situation of the household through engaging in different income-generating activities (Melaku Debela, 2016). Regarding the marital status of the respondents, 75 % were married and 8.3% of them were single (unmarried). On the other hand, due to various reasons, 7.5% of the respondents were widowed and 9.2% of them were divorced. This result supports by (Melaku Debela, 2016).

Table 4. 1 Socio-economic characteristics of the respondents

Member Characteristics	Value (N=120)
Sex	
Male	85%
Female	15%
Age	
Average	45.4 (28-72) years
Level of educational	
Illiterate	41.7%
Can read and write	28.3%
Primary education (grades 1-8)	20.0%
Secondary education (grades 9-12)	10.0%
Marital status	
Single	8.3%
Married	75.0%
Divorced	9.2%
Widowed	7.5%
Family size	
Up to 2 members	6.7%
3 to 6 members	85%
Above 6 members	8.3%

4.2. Major income sources of the family

The household income sources of the respondents are presented in Table 4.2. Most of the respondents (70%) said that they have income sources from livestock and livestock products, including meat, eggs, milk, and other by-products. Farm household livestock is an important source of cash income, food, manure, and a source of power for cultivation in the rural areas of Ethiopia (Yasin Ahmed and Erimase Tesfye, 2021). Crops/grains were also mentioned as an important income source of the respondents, as mentioned by (61%) of the respondents. Farmers mentioned that they sell grains of cereals, pulses, and oil crops to the market to earn money to support their livelihoods. Nearly half of the respondents earn income from daily labor work. Most said their daily work is mainly on agricultural activities and some on non-agricultural activities such as construction. Concerning the responsibility of a wife regarding additional income (12.3%) to the household, nearly (87%) of the respondents said that the husband responsible for household income. This is a common support Yekoye Abebaw *et al.* (2022), show that in most parts of Ethiopia, men have overall responsibility and contribute to all farm operations and decision-making.

Table 4. 2 Household income sources

Family income	**Value(N=120)**
Livestock/products	70.0%
Crops/grains	60.8%
Daily labor	46.7%
Trading	36.7%
Responsible for household income	
Husband	86.7%
Wife	12.3%

4.3. Agriculture practices of the households

4.3.1. Livestock rearing practices of the households.

Figure 4.1 presents the livestock-rearing practices of the households interviewed. There were variations observed among the respondents in terms of the types of livestock they rear. Most of the respondents said that they rear chicken and oxen represented by 82.5% and 75.8% respectively. This result regarding chicken disagreed with the result reported by (Wilson, 2010), as stated by the national average, which was 60%. The higher coverage of chicken in the current study than the national average value might be due to the drought the area where livestock rearing was better adapted, and the household's life relied on.

Oxen are the major source of draught power. The use of donkeys for the transport of water and farm goods is very common. Sheep and goats were an integral part of livestock playing versatile roles in the smallholder systems. Results show that higher percentages of farmers do have a moderate number of cows (61.7%), goats (63.3%), sheep (52.5%), heifers (47.5%), and donkeys (60.8%). These results were lower and contradicted the study reported by Melaku Debela (2016), which stated that 93.3 percent of respondents had livestock and the proportion and livestock type owned by respondents were cow (89.2 %), heifer (60.8 %), ox (52.5 %) and goat (88.3%) and sheep (58.3%), and (donkey 47.5%) except the percent covered by oxen and donkey in the current study was exceeded. On the other hand, the coverage of goats in the present study agrees with (Tessema Zewdu *et al.*, 2003), who stated that goats were more predominant in the study area. According to the authors, Girma Asefa and Zelalem Bekeko (2022), Goat populations were certainly increasing due to their high rate of reproduction, tolerance to drought, low cost of feeding, and ease of management, especially during times of feed scarcity.

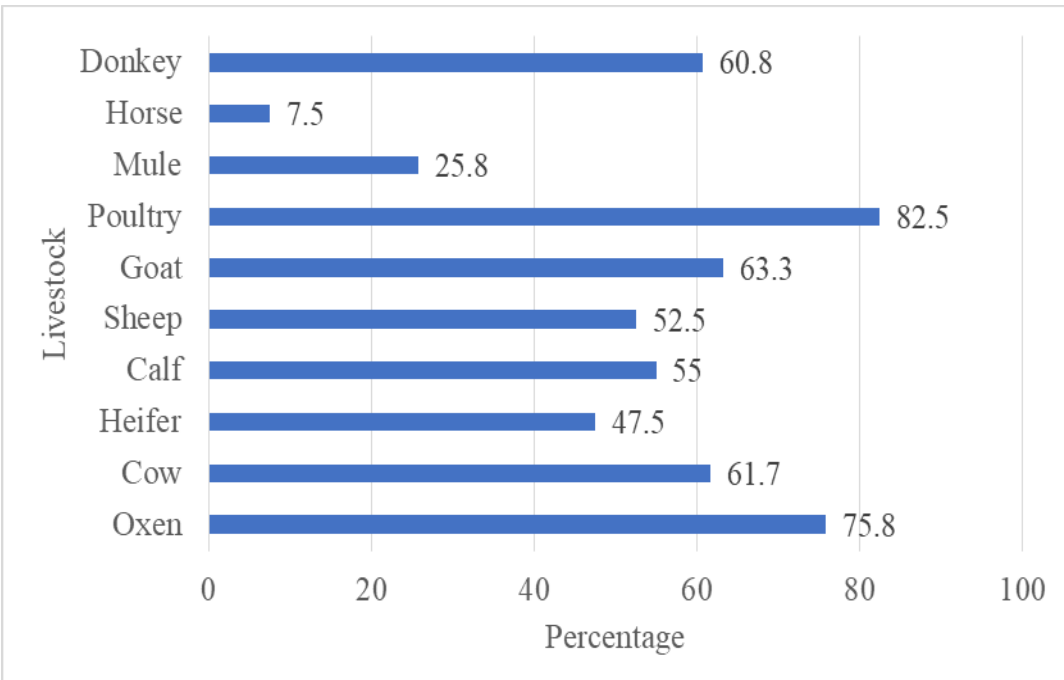

Figure 4. 1 Livestock rearing practices of the households

4.3.2. Major food and forage crops grown in the area

In the study area, according to the district office of agriculture (EBWAO, 2024), farmers are producing diversified fields and forage crops. Table 3 presents the responses of the respondents for the major field and forage crops in the area. Tef is the dominant field crop produced in the area as reported by nearly 71% of the respondents. Tef is the dominant staple food crop in the area as well as in the country (Mohammed Ahmed *et al.*, 2023). Teff is a staple food of the nation and it is the most dominant cereal (Project., 2015). Maize is the other cereal crop widely grown in the study area as represented by nearly half of the interviewees. Concerning pulse crops, field peas (57.5%), chickpeas (55.3%), and faba beans (53.3%) are the major crops in the study area. The main forage species widely grown in the study area are cowpea, Mung bean, pigeon pea, and Sesbania (Table 3). About (45%) of the respondents said that they grow cowpeas, which is followed by Mung bean (35%).

Farmers grow cowpeas for multiple purposes, including household consumption, livestock feed, and income generation. Cowpeas' high protein content makes them an essential food crop, while their forage provides a reliable feed source for livestock (Belete Kuraz and Mulugeta Tesfaye, 2022). According to Selamawit Ketema *et al.* (2021), the crop has a crucial role in addressing both food insecurity, livestock feed shortages, and the dual purpose of the crop presents a unique opportunity to address both food and feed security, as well as nutritional benefits for the livestock. On the other hand, farmers grow Mung beans primarily both for human consumption as well as animal feed. Because of its dual purpose, Mung bean improves both food security and livestock nutrition. This dual-purpose role is particularly significant in the study area with limited resources, as it provides a cost-effective solution to address both nutritional and income needs. Farmers usually use Mung beans as a vital source of protein and for generating income through seed sales (Atalay Habtamu, 2023). Mung bean a short maturity period is an alternative option of animal feed and can be easily grown with a minimum labor requirement (Yehuala Kassa *et al.*, 2022).

Compared to other legumes, both Mung beans and cowpeas demonstrate adaptability, which was vital in the study area where drought is prevalent. Pigeon peas, though less widely adapted in the area (13%), Besides its contribution as animal feed, it is important to promote it to diversify cropping systems and enhance agricultural resilience (Ojwang, 2023). On the other hand, Sesbania a lesser-known but valuable tree legume contributes significantly to soil fertility and livestock feed systems. Its fast growth and high biomass production make it an ideal forage species in mixed farming(Wubshet Tesfaye *et al.*, 2021). Sesbania, by its nature, has high palatability, compatibility, nutritional value, fast growth, and biomass yield (Ababu Firdawok, 2021). Compared to cowpeas and Mung beans, Sesbania is especially advantageous for its ability to thrive on marginal lands, enhancing productivity in areas unsuitable for other legumes. The use of Sesbania as livestock feed was noted in (9%) of households, reflecting its potential to complement other forage crops like

Mung bean and cowpeas. Integration of Sesbania with these legumes can improve overall forage availability and boost livestock health and productivity (Feleke Assefa *et al.*, 2015).

Table 4. 3 Major Food and forage crops grow in the study kebeles (n=120)

Major Field crop	**Percent= (120)**	**Major Forage Crop**	**Percent= (120)**
Teff	71%	Cowpea	45%
Field pea	58%	Mung bean	35%
Chickpea	56%	Pigeon pea	13%
Faba bean	53%	Sesbania	9%
Maize	51%		
Mung bean	35%		

4.3.3. Intercropping of forage crops with other crops

The intercropping of forage crops with cereals, pulses, oil crops, and other forage crops in the study area is presented in Figure 4. 2. The majority (43.3%) of forage-growing households practice intercropping cereals with forage crops. Intercropping forage crops with cereals is a promising practice that enhances resource efficiency. For example, intercropping cowpeas or Mung beans with maize allows for better use of land, sunlight, and soil nutrients. This practice not only increases total biomass yield but also improves soil fertility due to the nitrogen-fixing abilities of legumes (Toker *et al.*, 2024). Farmers in the study area practicing forage-cereal intercropping reported higher productivity and reduced dependency on chemical fertilizers. Intercropping also supports weed and pest management, as the diversity of crops can disrupt the lifecycle of pests and reduce the spread of diseases.

Beyond cereals, intercropping forage legumes with other forage species, such as Sesbania and cowpeas, maximizes forage availability and nutritional quality. While only (10%) of households practice intercropping forages with forages, the potential to improve livestock feed quality and availability through these systems is considerable. The integration of intercropping systems into climate-smart agriculture frameworks can further enhance resilience to climatic variability (Feleke Assefa *et al.*, 2015).

Twenty-five percent (25%) of the respondents intercrop forage crops with pulse crops. This promotes soil fertility, prevents soil erosion, and produces large amounts of high-quality fodder and pulse production grain legumes like faba bean in forage intercrops can provide a more sustainable source of N to cropping systems through biological N fixation (Tamene Tadesse, 2016). Faba bean is considered a cash crop. It grows well on well-structured loam or clay soils for best production (Jensen *et al.*, 2010).

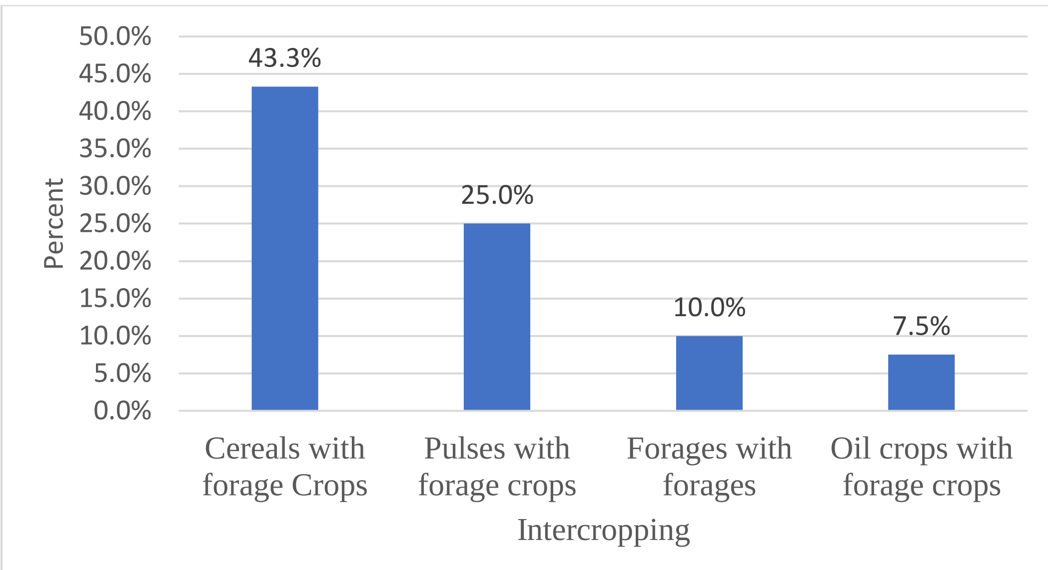

Figure 4. 2. Households' practice of intercropping forages with other crops

4.3.4. Households' agricultural inputs used

4.3.4.1. Households' fertilizers used for forage crops

According to the current results forage crop chemical fertilizers were used by (52%) of responder s. Furthermore, the respondents' participants organic fertilizer (11%). According to Lavison (2013), organic agricultural methods, like the practice of composed and organic fertilizers, increase production. He suggested policy support for encouraging the adoption of these techniques to boost productivity and sustainability.

4.3.4.2. Households' agrochemicals used for forage crops

According to the results, 30% of households use agrochemicals for forage crops. This is a common practice in the study area aiming to maximize yields. The use of agrochemicals is often associated with increased productivity. However, the support for chemical inputs raises questions about long-term sustainability and environmental impact(Pergner and Lippert, 2023).

4.3.5. Main factors that hinder household's farming activities

Several factors challenge the farming activities in the study area. Table 4.5 shows the responses of the interviewed households for key challenges. The market problems, as reported by 85.8% of the respondents. This is due to the existing forage seed market being largely dispersed and fragmented with weak linkages between suppliers and buyers, a general lack of market information, and limited forage extension, the market for forage seeds is unpredictable and the demands were not reliable in the study area. This does not imply forage seed producers need to be linked with forage growers who are then connected with livestock markets such as commercial dairy, feedlots, quarantine stations, district office of agriculture (EBWAO, 2024). The findings of this study indicated that market challenges influenced food security.

High costs of improved seeds (77.5%) and fertilizers (75%) further aggravate financial pressures on farmers, particularly smallholders who lack access to credit (60%) households. These costs limit smallholder farmers' ability to scale up production, particularly in areas with limited access to credit (Kaleb Shiferaw *et al.*, 2017). These constraints limit their ability to adopt modern agricultural technologies that could boost yields and efficiency (Zewdie Habte, 2023). Policies aimed at subsidizing these inputs or providing credit facilities could significantly reduce these financial barriers, fostering greater economic stability (Getachew Diriba, 2024). With 65% of respondents in the study area mentioning land shortages, limited arable land poses a significant barrier to expanding forage production. The average land size of the District East Belessa's total area is estimated to be 1848.29 km^2 (Shumye Worku, 2023). and The regional Amhara National Regional State (ANRS), with a total area of approximately 170,052 km^2 is situated in the northwestern and north-central parts of Ethiopia (Kindye Belaye *et al.*, 2024).

The lack of timely and affordable access to improved forage seeds affects production and productivity. Compared to cereals and pulses, the availability of improved forage seed to the farming community is low due to weak forage seed systems in the country (Dey, 2022). About 63% of households reported seed shortages, while others indicated reliance on less productive local seed varieties for cereal crops (Yekoye Abebaw *et al.*, 2022). Weak agricultural extension systems coupled with poor forage seed systems mean farmers receive limited technical support on forage management, such as optimal planting methods and pest control strategies (Dey, 2022; Mamaru Tesfaye and Lemma Tessema, 2023). Strengthening these systems could address knowledge gaps and improve productivity (Feleke Assefa *et al.*, 2015).

Table 4. 4 Challenges hinder farming activities in the area

Factors	Frequency (N=120)	Percent
Market Problem	103	85.8%
Higher seed cost	93	77.5%
Higher fertilizer Cost	90	75 %
Land shortage	78	65 %
Seed shortage	76	63.3%
Lack of credits	72	60%
Pest and diseases main Factor	66	55%

4.4. Forage seed sources and distribution

4.4.1. Farmers' forage seed sources

Respondents were also asked where they accessed forage seeds. As Table 4.6 below shows that, 20% and 24% of the respondents accessed the seed from public seed enterprises and research centers, respectively. According to the discussion with experts from the district agricultural office and NGOs, farmers do not directly collect the seed from the mentioned main sources. It was the key role of the district office of agriculture and the NGO (Food the Hungry International) to facilitate seed access for farmers. Experts briefed that they approached the nearby research centers and public seed enterprises once they discussed it with farmers. Based on the discussion, they assessed the demand of farmers, which was a basis for the seed request. Farmers in the study areas do not have experience in directly contacting the seed suppliers, as mentioned by KIIs. Develop linkages of NGOs at the farmers' level, as they do have some very definite advantages to offer, due to their close contacts with the farmers and experience in the fields of forage development and forage seed production (Lemi Gonfa, 2015).

The district office of agriculture collaborates with the Gondar Agricultural Research Center, Amhara Seed Enterprise, and NGOs for seed access and distribution. The Central Gondar zone of the agriculture department also facilitates seed access and supports the district in all technical and administrative procedures. Unlike cereal and forage crops, the engagement of public and non-government organizations is important for the sustainability of forage seed production in areas, particularly where there are limitations in infrastructure development (Kalsa and Dey, 2022).

Results also show that about 35% of the respondents used their seed. This shows the experience of farmers in the study area in maintaining the seed as planting material. About 21% of the farmers mentioned that they accessed forage seed from relatives, neighbors, and farmers. This indicates that informal seed sources are the dominant means for farmers to get forage seeds in the area. The wide coverage of informal seed sources is also common for other crops, including field peas (Yenus Ali, 2017) and bread wheat (Yekoye Abebaw *et al.*, 2022). Both private and cooperative entities do not engage in forage seed access in the area.

Table 4. 5 Farmers' forage seed sources

Source	**Frequency**	**Percent**
East Belessa Woreda Office of Agriculture	24	20
Own seed/saved	50	35
Farmers, neighbors, relatives	25	21
NGO (Food for the Hungry)	29	24

While analyzing the seed sources for specific forage crops, farmers accessed cowpea and Mung bean seeds from both formal and informal sources (Table 7). There were no formal seed sources in the area for Sesbania and pigeon peas. In general, most farmers accessed Mung beans from formal sources and cowpeas from informal sources. The lower availability of certified seeds of improved forage varieties to the farming community is associated with the limited capabilities of producers for the production of early-generation and certified seed forage seeds (Dey, 2022;

Feyissa Fekede *et al.*, 2022). A small number of companies engage in forage seed production (Turner *et al.*, 2019).

Table 4. 6 Forage seed sources for selected farmers

	Formal		**Informal**	
Crop	**Frequency**	**Percent**	**Frequency**	**Percent**
Cowpea	15	12.5	39	32.5
Mung bean	28	23.3	14	11.7
Sesbania	0	0	11	9.2
Pigeon pea	0	0	15	12.5

4.4.2. Farmers' forage seed acquisition methods

Regarding the forage seed acquisition methods, 43% of the respondents were accessed by paying cash, 39% free, and 32.5% by subsidies (Table 4.8). Mekonen Haile (2023), also stated that 66% (n=344) of malt barley seeds were acquired by farmers through cash. On the other hand, the acquisition of forage seed using the form of credit was not practiced in the study area.

Table 4. 7 Farmers' mode of seed acquisition (N=120)

Mode of seed acquisition	**Frequency**	**Percentage**
Free of charge	47	39.2
Cash	52	43.3
Subsidies	39	32.5

4.4.3. Reasons for using improved forage seed in the area

Farmers have multiple reasons for using improved forage seed. Figure 4.5 shows that 47% of the respondents used improved forage seed aiming to tackle the drought. About 44% of them said that they used improved forage seed to obtain higher yields. It was mentioned repeatedly by key informants that farmers commonly choose forage varieties having characteristics of drought tolerance and better yield. Moreover, farmers also consider varieties for their specific agroecologies (Girma Abebe and Amanuel Alemu, 2017).

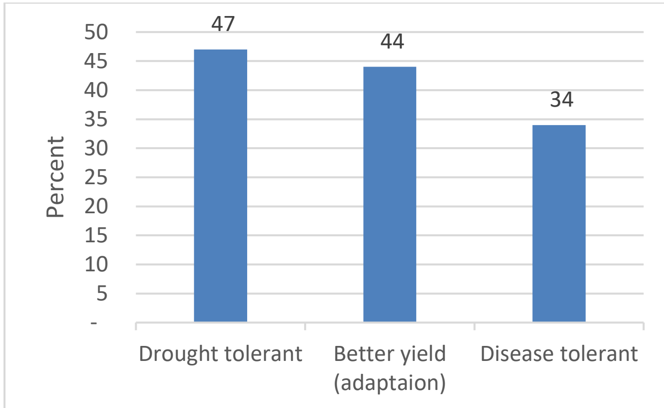

Figure 4. 3 Farmers' reasons for using improved forage seeds

4.4.4. Forage seed used in the area during drought time

The preference for forage seeds by farmers at the time of drought is presented in Figure 4.6. Two-thirds of the respondents preferred cowpeas during the drought season. Cowpea is naturally a drought-tolerant and warm-weather crop, and it can grow under harsh environmental conditions where other major crops fail to grow (Bilatu Agza *et al.*, 2012). Moreover, it matures within a short period which helps the crops to escape from stress (Singh, 2020). More than half (55%) of the respondents considered. Mung bean is an important forage crop at a time of drought. Mung bean needs a short growth duration. Furthermore, it is a lower-water-required crop besides its suitability for cultivation. According to Mohammed Ahmed *et al.* (2017), Mung bean is gaining attention as a short-season crop that can tolerate dry land conditions.

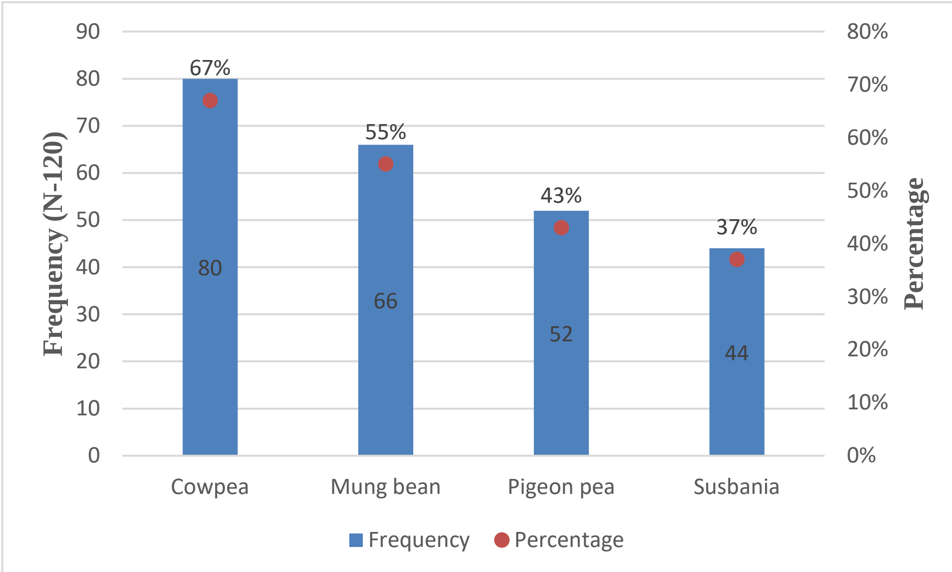

Figure 4. 4 Farmers' preference for forage seed at the time of drought

4.4.5. Farmers' forage seed marketing

Table 4. 9 below shows the experience of farmers selling their forage seeds to different buyers. The majority of them sold forage seed to farmers within the district (95%) and the nearby district (86%) including Kinase Begala and West Belessa districts. Local traders also buy the seed as represented by 36% of the respondents. However, the experience of farmers with intuitional buyers (like NGOs, agricultural offices, cooperatives, public organizations, etc.) is limited as mentioned only by 5% of the interviewees. The engagement of diverse institutions in forage seed marketing is limited, which is associated with the immature forage seed sector in the country (Dey, 2022). The unpredicted forage seed demand, the supply capacity of producers, limited effort from the research and extension, and the limited network among relevant actors affect the forage seed marketing in Ethiopia (Dey, 2022; Getnet Assefa et al., 2012).

Table 4. 8 Forage seed sold by households (n=58)

	Yes		No	
	Frequency	**Percent**	**Frequency**	**Percent**
Individual farmers within the district	55	95	3	5
Individual farmers outside the district	50	86	8	14
Traders	37	64	21	36
Institutional buyers	3	5	55	95

4.4.6. Households' willingness to purchase improved forage seed

About 69% of the respondents show interest in purchasing improved forage seeds from diverse sources. Yield advantage, adaptation to the local condition, feed quality, and tolerance/resistance to diseases are the main reasons mentioned by the respondents (Table 4.10). According to Lemi Gonfa (2015), willingness to pay for improved forage seeds by farmers is associated with the higher yield potential of the improved varieties aiming to improve the production and productivity of livestock.

Table 4. 9 The willingness of the households to purchase improved forage seed (n=83)

Reasons	Frequency	Percent
High yield	60	72.3
Local adaptability	58	69.9
Better feed quality	50	60.2
Disease tolerance/resistance	43	51.8

4.4.7. Farmers' access to forage seed

Respondents mentioned that they do not have access to the forage seeds they want. Figure 4.7 presents the reasons for the limited access to forage seed by the households. Most farmers in the study areas (62%) indicated that shortage of supply was the most significant barrier to accessing forage seed regularly, followed by less attention from the stakeholders (61%), no timely seed delivery (49%), and high price of seed (46%). Karta Kalsa *et al.* (2015) reported similar results for failure to get certified seed of requested malt barley varieties because of seed shortage (61.9%, n=113) and lack of suppliers (27.4%). Lemi Gonfa (2015) also reported that the price of the existing improved forage seed is expensive, and shortage of supply of improved forage seed. The limited capabilities of forage seed suppliers (public research institutes and public seed enterprises), both in terms of staffing and facilities, affect the availability of certified seed forage seed to the farming community (Dey, 2022).

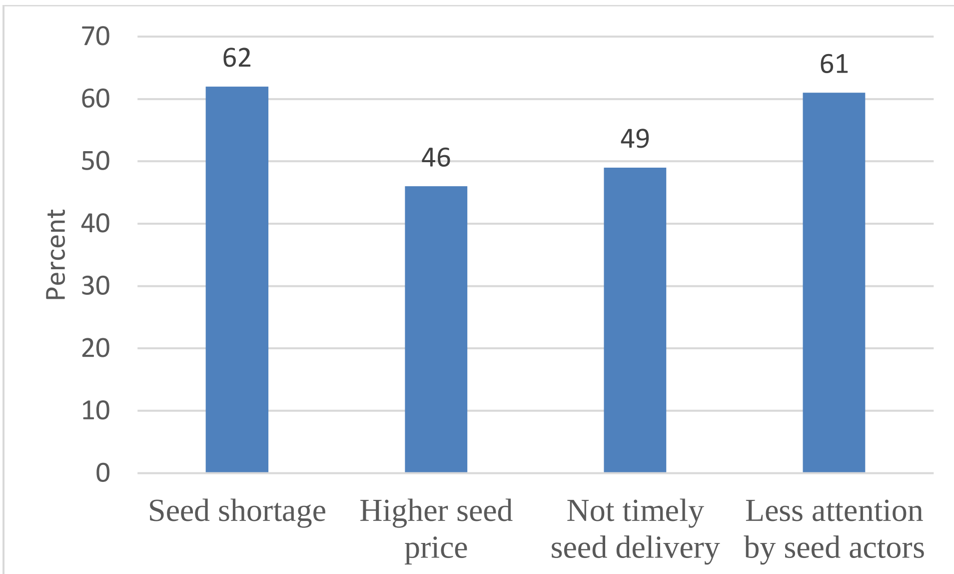

Figure 4. 5 Factors limited forage seed access by farmers (N=120)

4.4.8. Farmers' forage seed production experience

Nearly 55.8% (67) of the respondents said that they have experience in improved forage seed production. All of them were experienced in producing improved forage seed at the individual level. They used the seed for different purposes, including as planting material for the following season, sold it to the local market, and provided it to their relatives and other farmers. About 15% of interviewees produced improved forage seed as a group using the cluster approach. The lower result with a group of farmers produced forage seed because of the limited land size of the individual farmer cluster-based approach in the area, not practiced for crops like forage. However, none of them has experience in producing forage seed as members of the cooperative or any other producing organizations.

4.4.9. Farmers' perception of forage seed quality

Surveyed respondents to assess the quality of forage seeds used several parameters. Figure 4.8 depicts the perception of farmers for forage seed quality. About 55% of the respondent farmers perceived that the seed should be uniform in the field to be considered a quality seed. Half of them perceived that seed free from weeds or others as good quality seed. Studies show that field emergence and freedom from mixtures are mentioned by farmers referring to malt barley seed quality (Karta Kalsa *et al.*, 2015). The findings of this study show that physical purity is an important characteristic for determining the quality of forage seed. Farmers associate physically pure seed with good vigor, better field stand, and higher yield. Moreover, they choose forage seeds free from diseases/insect damage as an indication of good seed health and uniformity in the field as evidence of the genetic quality of the seed. These seed quality attributes mainly determine the germination, establishment, and true types of a given variety. According to Yehuala Kassa (2019), farmers in western Oromia of Ethiopia view physical purity, freedom from weeds and disease, and uniformity as the most critical factors in determining the quality of seeds.

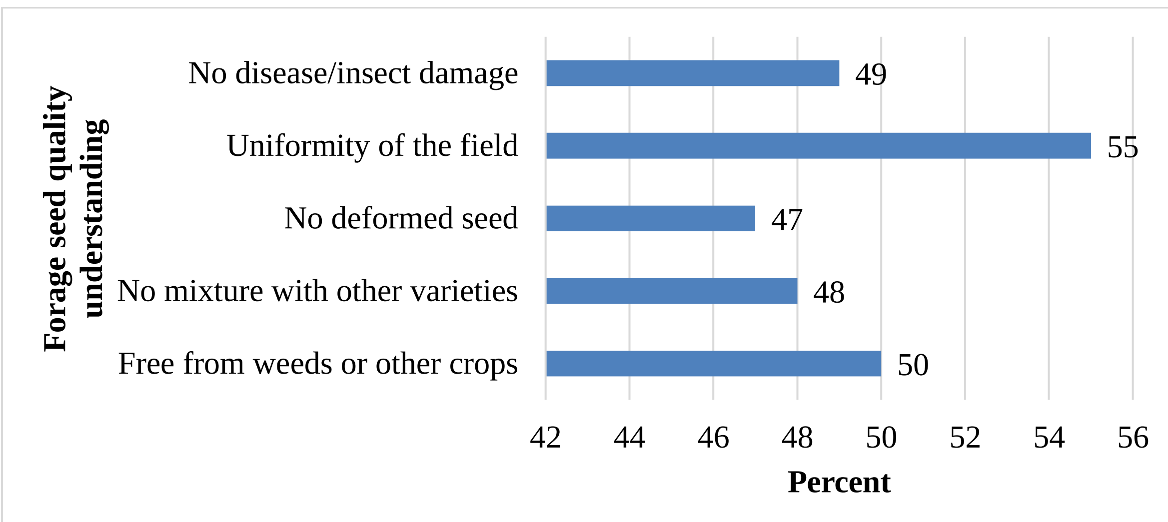

Figure 4. 6 Farmers' understanding of forage seed quality

4.4.10. Farmers' forage seed storage practices

Storage of forage seed using sacks is a common practice in the study area as reported by 87% of the respondents. On the other hand, about 52% of the respondents stored in local structures such as *gota*/*gotera* to protect against storage pests which is found to be the most common and popular grain and seed storage structure in Ethiopia(TsegabTemesgen and EmanaGetu, 2023). A few of the respondents (16%) stored forage seeds in clay pots. Concerning the use of treatments by farmers during forage seed storage only 24% of the respondents use ash. Neither of the respondents said that they used DDT spray and tablets for forage seed treatment.

Table 4. 10 Forage seed storage practices of the households (N=120)

Storage structures	**Percent**
Gotera/gota	52
Sacks	87
Clay pot	16

4.4.11. Households' forage seed management

Table 4.12 shows the different forage seed management practices of the households. More than one-third of farmers clean the seed during sowing. This aims to ensure good crop stand and, eventually higher yield. A small number of respondents (18%) separate the seed during threshing. Interestingly, most farmers (58%) do have experience in manage seeds and storing the seed in a separate bag. As mentioned by the respondents, such a method of seed management helps farmers to differentiate seed from planting and grain for consumption. Yekoye Abebaw *et al*. (2022) also reported farmers' experience of seed treatment before planting and storing the seed in separate bags aiming to protect the seed from insects (e.g., weevils).

Table 4. 11 Forage seed management measurement practices of the households (N=120)

Forage seed management measure	**Frequency**	**Percent**
Seed cleaning during sowing	49	41
Separate seed during threshing	21	18
Seed treatment and storing seed in a separate bag	70	58
Threshing in a separate new floor	5	4

4.4.12. Forage seed cleaning practices

About 76% of the respondents clean the forage seed using different methods of seed cleaning. Table 4.13 displays the forage seed cleaning practices of the interviewed households in the study area. Wind winnowing is a common practice of the respondents during threshing to remove light particles like straw and dust. They practice hand sieving to select the seed by shape and size just before planting using homemade equipment known as *Sefed*. Women farmers separate large particles such as large soil clods or other inert matters to improve seed quality. They separate the seed from inert matter, small/broken damaged seeds, weeds, and other crops. Yenus Ali *et al.* (2021) also reported that farmers cleaned their seeds by hand-sieving at planting time using handmade tools to increase purity, reduce weed contamination, or even remove insect-damaged seed grains. None of the respondents used a machine for seed cleaning.

Table 4. 12 Farmers' forage seed cleaning practices (n=91)

	Yes		**No**	
Forage seed cleaning method	**Frequency**	**Percent**	**Frequency**	**Percent**
Hand sieving at planting	39	43	52	57
Wind winnowing at threshing	74	81	17	19

4.5. Cowpea seed quality

4.5.1. Seed purity

Results show signification ($p<0.05$) variations among the treatments for seed purity. The higher seed purity was observed for samples collected from formal sources and stored in traditional storage gotera (96.8%), whereas the lowest was from informal sources and stored in gotera (92.03%). The cowpea seed obtained from formal sources, regardless of the storage facilities, showed higher purity than the informal sources. The seed purity percentages of cowpea seed from formal sources are higher than the minimum seed purity percentages (95%) recommended for certified seed by the Ethiopian Standard Authority, ES 426/2017. In other words, seeds accessed from informal sources showed lower seed purity than the national standard. This suggests that the seed suppliers mostly determine the purity of cowpea seed in Ethiopia. The finding is in line with Mieso Keweti (2017). He reported that highly significant differences were observed for seeds collected from both formal and informal systems for physical purity maize in the humid tropics of southern Ethiopia. Similar findings were reported by Iyorkaa *et al.* (2021) from Nigeria, for which the seed from community-based seed producers performed below the licensed seed producers regarding inert matter, pure seeds, and moisture content.

4.5.2. Seed germination

The mean germination percentage among the treatments is 92.6% (Table4. 14). The highest value was recorded from cowpea seed collected from formal sources and stored in Gotera (95.8%), and the lowest was from informal sources and stored in sacks (88.31%). The higher germination rate was observed in the formal seed source. This is associated with the capacity of seed suppliers in terms of practicing proper storage, maintaining seed quality, and effective seed handling during processing. Previous studies for other crops show the effect of seed source on the germination capacity of the crops (Behailu Mekonnen, 2023; Yekoye Abebaw *et al.*, 2023). However, irrespective of their sources and storage conditions, the tested seeds fulfilled the minimum germination percentage for certified cowpea seed (75%) set by the Ethiopia Standard Agency, ES 426/2017. This shows the cowpea seed that farmers use in the area does not have germination problems.

4.5.3. Moisture content

The findings depict the absence of significant variations among treatments for moisture content (Table 14). All treatments showed below the recommended maximum moisture (13%) contents for cowpeas by the Ethiopian Standard Agency, ES 426/2017. The result is contradicted by the findings of Iyorkaa *et al.* (2021) who compared cowpea seed quality sourced from community-based seed producers and licensed seed producers. They reported significant variations between the two sources for moisture content, which is not observed in this study. This might be associated with the different varieties used, the growing conditions, and the management practices of producers. Nabila (2014), also reported that the different storage containers determine the moisture content of the seed.

4.5.4. Thousand Seeds

Table 4.14 also shows the significant differences among the treatments for TSW. The highest thousand seeds weight was found in formal seed sources stored by Gotera at 106 gm, and the lowest from informal sources stored in sacks was 96.7 gm. The TSW value of seeds collected from formal sources and stored in gotera was significantly higher than others. The higher TSW is normally used to assess seed quality and good crop yield.

Table 4. 13 Cowpea seed physical quality test

Treatment	Seed purity (%)	Germination (%)	Moisture content (%)	TSW (gm)
Sack, informal	92.37[a]	88.31[a]	9.3[a]	96.7[a]
Gotera, informal	92.03[a]	91.02[b]	9.4[a]	98.4[a]
Sack, formal	96.08[b]	95.04[c]	9.6[a]	99.9[a,b]
*Goter*a, formal	96.8[b]	95.8[c]	9.5[a]	106[b]
Mean	94.32	92.57	9.5	100.3
LSD (5%)	0.9	1.05	0.45	6.9
CV%	0.6	0.7	2.9	4.3
P-value	<0.05	<0.05	>0.05	<0.05

4.5.5. Seedling vigor test

To determine the vigor of cowpea seeds obtained from farmers who collected seed from formal and informal seed sources and kept under different storage conditions, various physiological tests were performed. This included vigor index I and II, seedling dry weight, shoot and root lengths, and germination speed. The findings showed that there were significant variations among the treatments for seedling shoot length, seedling dry weight, speed of germination, and vigor indexes. However, no significant variation was observed for seedling root length (Table 4.15). Regarding the speed of germination, the highest value was observed from formal seed sources and stored in Gotera (15.5%) and the lowest from informal sources but stored in sacks (11.7%). This shows that seeds from formal resources quickly germinate irrespective of the storage facilities farmers have. Seeds obtained from formal sources and stored in the gotera showed higher seedling dry weight (1.8 gm). Although they didn't mention where farmers stored the seeds, Nigussu Bekele *et al.* (2019) and Yekoye Abebaw *et al.* (2023), presented the better seedling dry weight for the seeds collected from the formal sources for chickpea and bread wheat, respectively.

Concerning vigor, the findings of this study agree with Ethiopia shows that the better seedling dry weight is from seeds collected from formal sources than the informal ones. The result was in agreement with the finding of Zewdie Bishaw *et al.* (2012), where they reported barley and wheat. Higher vigor and greater ability of the crop to withstand adverse field conditions. In contrast, seeds from the informal seed system exhibited lower vigor and slower germination, which can have negative implications for farmers. Melkam Anteneh (2015), reported that seeds with low germination rates can lead to financial losses for farmers, especially if it becomes evident too late in the planting season to replant.

Table 4. 14 Cowpea seed vigor test

Treatment	Seedling shoot length (cm)	Seedling root length (cm)	Seedling dry weight (gm)	Speed of germination (%)	VIG1 (%)	VIG2 (%)
Sack, informal	5.08[a]	4.6[a]	1.3[a]	11.7[a]	881.2[a]	118.9[a]
Gotera, informal	4.3[a]	4.6[a]	1.2[a]	10.4[a]	822.8[a]	117.6[a]
Sack, formal	7.5[b]	5.1[a]	1.7[b]	14.4[b]	1202.1[b]	162.7[b]
Gotera, formal	7.5[b]	5.1[a]	1.8[b]	15.5[b]	1222.9[b]	175.7[b]
Mean	6.14	4.6	1.54	13.07	143.7	1032.2
LSD (5%)	1.8	1.4	0.14	1.5	264.2	13.7
CV%	18.9	19.06	5.6	7.46	5.96	16
P-value	>0.05	<0.05	>0.05	>0.05	>0.05	>0.05

4.6. Mung bean seed quality

4.6.1. Seed purity

There is a highly significant ($p<0.01$) variation among the treatments regarding seed purity (Table 4.16). The seed purity of samples collected from formal seeds stored in both types of stores had better seed purity than the seeds collected from informal sources, regardless of the storage facilities. The higher seed purity was observed from samples collected from formal sources but stored in traditional storage (97.15%), whereas the lowest was from informal sources but stored in sacks (93.18%). This shows that both formal sources and sacks contribute to higher seed purity of mung bean seed in the study location. Seed accessed from informal sources does not meet the minimum certified seed quality standards set by the Ethiopian Seed Standard Agency, which is a minimum of 97% This implies that seed sources critically determine the seed purity of mung bean in Ethiopia.

4.6.2. Seed germination

Table 4.16, also shows the germination percentage of mung bean seeds tested. Highly significant ($p<0.01$) variations were observed between formal and informal seed sources no matter where the seed was stored. Higher germination percentage was recorded from samples collected from formal seed sources and stored in gotera (91.75%) and lower from seeds collected from informal sources and stored in sacks (81.50%). However, all the treatments showed a higher germination test than the minimum germination percentage determined for Quality Declared Seed (QDS) by the Ethiopian standards of 75% (SAE, 2017). The higher germination rate observed in the formal seed source is associated with the capacity of seed suppliers in terms of practicing proper storage, maintaining seed quality, and effective seed handling during processing. Previous studies for other crops show the effect of seed source on the germination capacity of the crops (Behailu Mekonnen, 2023; Yekoye Abebaw *et al.*, 2023).

4.6.3. Moisture content

Significant variations ($p<0.05$) in seed moisture content were observed among different seed sources and storage methods (Table 4.16). The highest moisture content was found in formal seed sources stored by *Gotera* at 9.25% and the lowest from informal sources stored in sacks (8.29%). According to the authors, (Nigussu Bekele *et al.*, 2019; Solomon Dafa, 2023; Yenus Ali *et al.*, 2021) reported Seed sources contribute to better seed moisture content. Moreover, different storage containers of wheat determine the moisture content of wheat seed (Nabila, 2014). In what way farmers accessed the seed and stored it, the moisture content of mung bean is close to the national standard (9%) set by (SAE, 2017). Similar results were reported for the percentage of moisture content of mung bean seed in Bangladesh (Ali *et al.*, 2010).

4.6.4. Thousand Seeds

This study also reported significant variations ($p<0.05$) among the treatments for thousand seed weight (TSW) as presented in Table 4.16. Both the higher and lower TSW were recorded for mung bean seeds stored in sacks but accessed from formal and informal sources with values of 64.08 gm and 53.15 gm, respectively. Interestingly, the results showed non-significant variations between storage facilities for TSW. The findings of the present study are in alignment with Yenus Ali *et al.* (2021) higher TSW was observed from seed accessed from formal sources. In general, higher TSW was observed from seed accessed from formal sources. Seed with a higher TSW is associated with better seed quality, better emergence, and higher yields (Yenus Ali *et al.*, 2021). Seed with a higher

TSW is associated with better seed quality, better emergence, and higher yields. The consistency of the reports from various scholars for different crops indicates that seeds accessed from formal sources perform better in TSW, which is a key factor for better seed quality, vigor, and higher yield.

Table 4. 15 Mung bean seed physical quality test

Treatment	Seed purity (%)	Germination (%)	Moisture content (%)	TSW (gm)
Sack, informal	93.18[a]	81.50[a]	8.29[a]	53.15[a]
Gotera, informal	94.32[b]	82.75[a]	8.60[a,b]	56.25[a]
Sack, formal	96.24[c]	89.25[b]	8.53[a,b]	64.08[b]
*Goter*a, formal	97.15[d]	91.75[b]	9.25[b]	59.95[a,b]
Mean	95.22	86.31	8.67	58.35
LSD (5%)	0.82	4.4	0.57	5.6
CV%	0.53	3.2	4.1	6.04
P-value	<0.01	<0.01	<0.05	<0.05

4.6.5. Seedling vigor test

Different physiological tests were conducted to assess the vigor of mung bean seeds obtained from farmers who collected seeds from formal and informal seed sources and storage methods (sack, gotera). This included seedling shoot length, seedling root length, seedling dry weight, speed of germination, and vigor index I and II (Table 4.17). The results showed that there were no significant differences between treatments for seedling shoot length. This implies the similar length of the young plant part of the mung bean that grows upwards from the seed regardless of the different seed sources and storage facilities. The results indicated a significant difference in seed storage methods regarding seedling root length. Seed from the formal sources was stored in sacks exhibiting the longest root length (5.29 cm), while formal seed sources stored by Gotera had the shortest root length (2.35 cm). These findings suggest that the storage method can impact root development in mung bean seedlings. Similar studies were reported for cereal seeds in Ethiopia for both seedling root length and seedling shoot length (Bishaw *et al.*, 2012).

The findings also revealed significant variations ($p<0.05$) among the treatments for both seedling dry weight and speed of germination. Seeds accessed from formal sources showed higher seedling weight and higher speed of germination than the seeds accessed from informal sources. Seeds obtained from formal sources and stored in gotera showed higher seedling dry weight (1.13 gm). Earlier findings for chickpeas (Nigussu Bekele *et al.*, 2019) and bread wheat (Yekoye Abebaw *et al.*, 2023) in Ethiopia show that the better seedling dry weight is from seeds collected from formal sources than the informal ones.

Similarly, the seeds from the formal sources showed a higher speed of germination than seeds from the informal sources. The higher and the lower speeds of germination were recorded from the seeds obtained from formal and informal sources, where the seeds were stored in a gotera. These seeds from formal sources might be shows quickly germinate. Moreover higher vigor and greater ability of the crop to withstand adverse field conditions (Pradhan, 2021). In contrast, seeds from the informal seed system exhibited lower vigor and slower germination, which can have negative implications for farmers. (Melkam Anteneh, 2015) Reported that seeds with low germination rates can lead to financial losses for farmers, especially if it becomes evident too late in the planting season to replant.

Concerning the vigor index, highly significant variations ($p<0.01$) were observed among treatments. The significant differences in vigor index I and vigor index II further emphasize the impact of vigor on seedling performance. Seeds obtained from formal sources and stored in gotera showed better VIG1 and VIG2. Higher vigor reflects the quality of the seed and better storage management. This is measured through better germination; seedling dry weight, seedling root length, and seedling shoot length.

Table 4. 16 Mung bean seed vigor test

Treatment	Seedling shoot length (cm)	Seedling root length (cm)	Seedling dry weight (gm)	Speed of germination (%)	VIG1 (%)	VIG2 (%)
Sack, informal	4.89^{a}	$3.12^{a,b}$	0.64^{a}	10.01^{a}	650.95^{a}	56.74^{a}
Gotera, informal	6.12^{a}	$4.02^{a,b}$	0.81^{a}	9.62^{a}	$837.89^{a,b}$	66.68^{a}
Sack, formal	5.59^{a}	5.29^{b}	0.82^{a}	11.83^{b}	969.37^{b}	72.92^{a}
Gotera, formal	5.01^{a}	2.35^{a}	1.13^{b}	11.46^{b}	675.29^{a}	102.97^{b}
Mean	5.40	3.69	0.84	10.72	783.37	74.82
LSD (5%)	1.9	1.75	0.2	1.7	140.81	21.2
CV%	32.62^{ns}	20.29	15.4	9.9	11.2	17.75
P-value	>0.05	<0.05	<0.05	<0.05	<0.01	<0.01

4.7. Comparisons of seed quality between forage crops

4.7.1. Comparison of seed quality based on seed sources

Table 4.18 below shows the results of quality parameters for cowpea and mung bean seeds farmers accessed from formal and informal sources. There are significant variations between formal and informal seed sources both for cowpea and mung bean for seed purity, seed germination, TSW, seedling dry weight, speed of germination, and VIG2. The variations between cowpea formal and informal sources were significant for seedling shoot length and VIG1, but not for mung bean. On the other hand, results showed significant variation between formal and informal sources for moisture content, unlike cowpeas. However, results clearly showed non-significant variations between the two sources for seedling root length, both for cowpea and mung bean.

The seed purity (94.5%), seed germination (95.5%), and moisture content (9.6%) of cowpea seed accessed from the formal sources are above the minimum certified seed quality standard set by the ESA. This indicates that seeds are at an acceptable level. This is associated with the proper pre- and post-harvest management of the formal seed suppliers. For cowpea seeds collected from informal sources, the germination percentage (89.6%) and moisture content (9.4%) values are at the acceptable level determined by the ESA. However, the average purity is 92.2%, which is lower than the national standard for certified seeds of cowpea (95%).

In Ethiopia, the seed quality standards set for mung bean by the (SAE, 2017) to the Quality Declared Seed (QDS). QDS is an alternative system for quality assurance that is less expensive and less demanding (Mastenbroek *et al.*, 2021). In Ethiopia, the QDS is practicing ensuring seed quality by setting standards and by giving major responsibilities to producers (Mohammed Hassena *et al.*, 2023). The findings of this study indicate that the average values of seed germination and moisture content for both formal and informal sources are within the acceptable levels of the ESA. However, the seed purity, for both sources, is below the national standards.

Thousand seed weight (gm) was found to be higher for formal sources than informal for both cowpea and mung bean with significant variations. TSW is associated with large seeds, which reflects better seedling vigor, quick germination, and eventually higher yield (Baysah *et al.*, 2018). Several studies show that TSW demonstrated a positive relationship with germination percentage, seed vigor, and grain yield, where higher thousand seed weights were associated with increased germination percentage and seed vigor, while lower weights corresponded to reduced values for these traits. This aligns with the findings of Alemayehu Adinew (2019). He reported that higher thousand seed weights lead to enhanced germination percentage, seedling emergence, plant density, spike formation, and ultimately, higher yield. Hence, formal seed sources contribute to better vigor and better yield than informal seed sources, both for cowpea and mung bean.

This study reports the higher values of speed of germination from seeds of formal sources, both for cowpea and mung bean. This indicates that seed sources matter in determining how quickly the seeds can germinate. Higher speed of germination is recorded for cowpea than mung bean, although from formal seed sources. This implies the difference among species for speed of germination. Studies show that there is a positive association between the speed of germination with germination percentage and TSW. Higher TSW and germination tend to result in faster seed germination. The finding is in alignment with the work of Girma Megersa *et al.* (2014) and Messeret Alemu (2024), who also reported similar relationships between seed weight, germination percentage, and germination speed.

The difference between the formal and informal sources for seedling root length, both for cowpea and mung bean is not significant. This finding shows seed sources may not meaningfully affect the seedling root length. The seedling root length mainly depends on the variety and growing conditions. It is commonly suggested that the selection of longer root lengths of cowpea and mung beans in drought-affected areas (Mohammed Ahmed *et al.*, 2017). Hence, this study suggests seedling root length as an important criterion in the study area where drought is a common phenomenon.

Table 4. 17 Comparison of seed quality between cowpea and mung bean regarding seed sources

Variable	Cowpea			Mung bean		
	Informal	Formal	*p-value*	Informal	Formal	*p-value*
Seed purity (%)	92.20^{a}	96.45^{b}	<0.01	93.76^{a}	96.69^{b}	<0.01
Germination (%)	89.67^{a}	95.47^{b}	<0.01	82.13^{a}	90.50^{b}	<0.01
Moisture content (%)	9.40^{a}	9.62^{a}	>0.05	8.45^{a}	8.90^{b}	<0.05
TSW (gm)	97.61^{a}	102.9^{b}	<0.05	54.7^{a}	62.01^{b}	<0.05
Seedling shoot length (cm)	4.72^{a}	7.57^{b}	<0.01	5.50^{a}	5.30^{a}	>0.05
Seedling root length (cm)	4.67^{a}	5.13^{a}	>0.05	3.57^{a}	3.81^{a}	>0.05
Seedling dry weight (gm)	1.32^{a}	1.77^{b}	<0.01	0.72^{b}	0.97^{a}	<0.05
Speed of germination (%)	11.13^{a}	15.01^{b}	<0.01	9.8^{a}	11.64^{b}	<0.05
VIG1 (%)	852.01^{a}	1212.5^{b}	<0.01	744.42^{a}	822.3^{a}	>0.05
VIG2 (%)	118.3^{a}	169.2^{b}	<0.01	61.7^{a}	87.94^{b}	<0.05

4.7.2. Comparison of seed quality based on storage facilities

Table 4.19 depicts the non-significant variations between storage conditions for all quality parameters except for germination. This clearly shows that, in the study areas, the quality of cowpea seed is not significantly influenced by storage facilities. Cowpea seeds, irrespective of the storage conditions, fulfill the minimum quality parameter for purity, germination, and moisture content as per the national quality standards (Table 4.19). Interestingly, this finding reports significant variation between storage conditions for cowpea seeds. This finding is in agreement with the work of Wawrzyniak *et al.* (2020). Farmers might not have used sacks properly for storing cowpea seeds. Negasa Fufa *et al.* (2020), reported that storage containers and storage period affect the germination of grain maize in Bako areas of Ethiopia.

Concerning mung bean seeds stored under different storage conditions, non-significant variations are reported for most of the quality parameters. These include germination, TSW, seedling shoot length, seedling root length, speed of germination, and VIG1. On the other hand, significant variations are observed for seed purity, moisture content, seedling dry weight, and VIG2. In general, in the study area, storage conditions are not the main responsible factor for quality variables. Studies by Alemayehu Adinew (2019) suggest the impact of storage types on seed moisture content. High moisture content and elevated temperatures can accelerate seed deterioration processes, emphasizing the importance of maintaining proper moisture levels during seed handling and storage.

Table 4. 18 Comparison of seed quality between cowpea and mung bean regarding storage conditions

Variable	Cowpea			Mung bean		
	Sack	*Gotera*	*p-value*	Sack	*Gotera*	*p-value*
Seed purity (%)	94.23[a]	94.43[a]	>0.05	94.71[a]	95.74[b]	<0.01
Germination (%)	91.68[a]	93.46[b]	<0.01	85.3[a]	87.25[a]	>0.05
Moisture content (%)	9.51[a]	9.51[a]	>0.05	8.4[a]	8.9[b]	<0.05
TSW (gm)	98.37[a]	102.23[a]	>0.05	58.6[a]	58.1[a]	>0.05
Seedling shoot length (cm)	6.32[a]	5.97[a]	>0.05	5.2[a]	5.5[a]	>0.05
Seedling root length (cm)	4.87[a]	4.93[a]	>0.05	4.2[a]	3.2[a]	>0.05
Seedling dry weight (gm)	1.53[a]	1.56[a]	>0.05	0.72[a]	0.96[b]	<0.05
Speed of germination (%)	13.11[a]	13.030[a]	>0.05	10.9[a]	10.5[a]	>0.05
VIG1 (%)	1041.67[a]	1022.9[a]	>0.05	810.2[a]	756.5[a]	>0.05
VIG2 (%)	140.87[1a]	146.67[a]	>0.05	64.83[b]	84.83[a]	<0.05

CHAPTER 5. CONCLUSION AND RECOMMENDATIONS

The study identified cowpeas, mung bean, pigeon peas, and Sesbania as the common forage crops in the study area. Farmers used seeds from diverse sources to produce these forages. In areas where drought is prevalent, the demonstration and production of these crops are highly recommended. The study shows the critical role of NGOs and local agricultural offices in seed dissemination, but sustainability remains a concern due to the dependency on external support. The lack of private sector involvement, seed producer cooperatives, and weak early-generation seed systems further constrain seed availability and quality. Additionally, seed storage practices and post-harvest management among farmers are inadequate, affecting seed viability.

Therefore, it is concluded that, under the study area conditions and the mentioned crops, seed sources found determinant factors for seed quality. The type of storage farmers use in the study area did not significantly affect the seed quality. I recommended actively seek and use high-quality seed sources, including certified formal seed sources from research centers and agricultural offices, and adopt modern storage techniques (e.g., hermetic storage) to enhance seed viability, and train farmers on best practices for seed storage to minimize deterioration. Furthermore, policymakers assist farmers in accessing improved seed varieties through partnerships with NGOs and private enterprises.

The study identified that smallholder farmers primarily rely on informal sources for forage seeds, such as saved seeds, relatives, and neighbors, rather than formal institutions. This dependency highlights the need for better access to certified seeds. Significant variations in seed quality were observed between formal and informal seed sources. Seeds from formal sources demonstrated higher purity, germination rates, and vigor compared to those from informal sources, emphasizing the importance of certified seeds for enhancing agricultural productivity. Although the study found that storage methods did not significantly influence seed quality in the study area, it is crucial to promote modern storage techniques to maintain seed viability and prevent deterioration.

Farmers face numerous barriers to accessing quality forage seeds, including high costs, seed shortages, and inadequate support from agricultural institutions. This situation is exacerbated by the lack of a well-structured seed supply system. The findings suggest that policymakers must facilitate partnerships between farmers, NGOs, and private enterprises to improve access to high-quality seeds and training on best practices for seed management. There is a critical need for enhanced education and training for farmers on effective seed storage and management practices to minimize seed quality deterioration and improve overall productivity.

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APPENDEXES

Figure 7. 1 During Survey data collection

Figure 7. 2. During lab data collection

Figure 7. 3. Forage growth during summer seasons

Annex 1. Questionnaire for household interview

Identification

I. Date of interview: _______________
II. Name of interviewer:_________________
III. Interviewee's (household head) code: _____________________
IV. Kebele:______________
V. Agroecological zone (Dega, Woyna Dega, Kolla): ______________
VI. Walking distance from the district capital city: _________________

PART ONE– Household information

1. Sex of the respondents 1) Male 2) Female
2. Age of the respondent: ____________ (years)
3. Religion of the respondent: 1) Orthodox 2) Muslim 3) Evangelical/protestant 4) Catholic 5) Others
4. Marital status of the respondent: 1) Single 2) Married 3) Divorced 4) Widowed 5) Others
5. The highest education of the respondents
   a. Can't read and write (Illiterate)
   b. Can read and write
   c. Primary education (1-8)
   d. Secondary education (9 -12)
   e. College and above
   f. Others (specify) ________________

6. Household's engagement in farming 1) Full time 2) Part-time
7. Household size

Age (years)	Male	Female	Total
< 5			
6-13			
13-63			
>60			

8. Do you rear livestock? 1) Yes 2) No
9. If yes, how many livestock do you have?

1. Ox 2. Cow 3. Heifer 4. Calf	5. Sheep 6. Goat 7. Poultry 8. Mule	9. Horse 6. Donkey 7. Camel 8. Pig

10. What are the main sources of the family's income?
    a. Crops/grain sale

b. Livestock/product sale
c. On-farm daily labor
d. Non-on-farm activities (petty trading, carpenter, etc)
e. Pension
f. Remittance
g. Monthly salary
h. Others (specify) ______________

11. Does the family engage in off-farm activities as a source of income? 1) Yes 2) No
12. Who contributes to household income?
    a. Husband
    b. Wife
    c. Children
    d. Other family members (e.g., relatives)
13. Do you have access to credit from any sources (formal, community-based organization)?
    1) Yes 2) No
14. In which wealth group, do you categorize yourself?
    a. Rich b. Average c. Poor

PART TWO– Farming information of the household

15. Do you have your agricultural land? 1) Yes 2) No
16. If yes, what size of the land is in total? _____timad
17. What is the size of the land for specific agricultural practices?

Activity	Area (timad)
Cultivated land	
Grazing land	
Woodlot	
Fodder crops	
Other (specify)	

18. Do you rent agricultural land? 1) Yes 2) No
19. Why do you rent agricultural land?
    a. For crop production
    b. For forage production
    c. For forest (woodlot)
    d. Others (specify) _______________

20. Do you think agricultural land is a shortage? 1) Yes 2) No
21. What are the major field crops you are growing? Please list them.

22. What are the major forages you are growing? Please list them.

23. What are the major vegetables you are growing? Please list them.
24. Which sources of labor do you have for agricultural activities?
    1) Family labor 2) Hired labor 3) Both family and hired labor

25. Is shortage of labor a problem in your farming activities? 1) Yes 2) No
26. How do you solve the labor shortage during critical farming activities?
    a. I hired labor
    b. Ask relatives (extended families) for support
    c. Organization of labor force among neighbors, relatives, and kinsmen (e.g., Debo,?
    d. Others (specify) _______________

27. Do you practice crop rotation? 1) Yes 2) No
28. What are the main factors that hinder your farming activities?
    a. Land shortage
    b. Shortage of improved seed
    c. Higher cost of fertilizer
    d. Higher cost of improved seed
    e. Pests
    f. Market problem
    g. Labor unavailability
    h. Lack of credit service
    i. Lack of mechanization service
    j. Others (specify) ______________________

PART THREE – Agricultural inputs used

29. Fertilizers, improved seeds, agrochemicals

Organic fertilizers		**Remarks**
Do you use chemical fertilizers for forage production?	1. Yes 2. No	
If yes, which chemical fertilizer types?	1. Urea 2. DAP 3. TSP 4. Others	
Do you use organic fertilizers for forage production?	1. Yes 2. No	
If yes, which organic fertilizer types?	1.Compost 2. Green manure 3. Others	
Do you use improved forage seed?	1. Yes 2. No	
Do you use agrochemicals for forage crop production?	1. Yes 2. No	
If yes, which agrochemicals?	1.Herbicides 2. Pesticides 3.Insecticides	

PART FOUR– Forages production

30. Which forage crops do you cultivate?

1. Cowpea 2. Alfalfa 3. Oats 4. Elephant grass	5. Pigeon pea 6. Sesbania 7. Tree lucerene 8. Vetch

31. How often do you cultivate forages?
    1) Once in a year 2) Once every two years 3) Once every three years 4) Once in four or more years

32. Have you practiced intercropping? 1) Yes 2) No
33. If yes, in which arrangements?
    1) Intercropping cereals with forage crops
    2) Intercropping pulse crops with forage crops
    3) Intercropping oil crops with forage crops
    4) Intercropping Two or more forage crops
    5) Others (specify) ______________________

PART FIVE– Forages seed sources

34. What was your initial source of forage seed? FH Project
35. Do you use seeds of local forage crop varieties? 1) Yes 2) No
36. What is the source of local forage varieties?

1. Own savings 2. Purchase from villagers 3. Local market 4. Farmers, neighbors, relatives	5. Nodal Farmers 6. Community-based seed producers (cooperatives, genetic conservation) 7. Others

37. Have you used improved forage seed? 1) Yes 2) No
38. What is the source of improved forage seed?

1. Woreda office of agriculture 2. Public research organizations 3. Public seed enterprises 4. Private seed producers 5. Cooperatives/unions	5. Own seed/saved 6. Farmers, neighbors, relatives 7. Others

39. Do you purchase forage seeds? 1) Yes 2) No
40. Did you buy more than one time? 1) Yes 2) No
41. If yes, how often do you purchase improved forage seeds?

1) Once in a year 2) Once every two years 3) Once every three years 4) Once in four or more years

42. What are the commonly available forage seeds in the district?

Source from?	Forage seed (mention the crop)
Neighbors, farmers, relatives	
Local markets	
Office of Agriculture	
Research centers	
NGOs	
Others (specify)	

43. If you access improved forage seed from formal sources (via research, office of agriculture, NGOs, private companies, cooperative unions, etc), what arrangements are in place?

1. Free of charge 2. Credit to be returned in cash 3. Credit to be returned in item 4. Direct purchase 5. Purchase with subsidies	5. Others (specify)

44. How do you access forage seeds in times of drought?
Use forage part by cut and carry system.

45. Which forage seed is more important in times of drought? Why? __Cowpea and Masho This type of variety drought resistant
46. Who is the main forage seed source during drought? __NGOs Like FH
47. Do you sell forage seeds? 1) Yes 2) No
48. If yes (sell), to whom you are selling?

1. Individual farmers in the district 2. Individual farmers outside the district 3. Traders 4. Institutional buyers (agri office, NGOs, private, cooperative, etc.) 5. Others (specify)

49. Do you access all the forage seeds you want? 1) Yes 2) No
50. If not, what are the main reasons?

1. Seed shortage 2. Higher seed price 3. Not timely delivery 4. Less attention by the government 5. Others (specify) Shortage of land and Market

51. Do you have the interest to purchase improve forage seeds? 1) Yes 2) No 3) No idea
52. If yes, what is the reason?

1. High yield
2. Adaptable to the environment
3. Better feed quality
4. Not timely delivery
5. Disease tolerance/resistance
6. Higher market price
6. Others (specify)

PART SEX – Forages seed production

53. Do you have experience in improving forage seed production? 1) Yes 2) No
54. If yes, when did you start forage seed production? _____ (years)
55. How do you produce forage seed?

1. With individual basis (individually))
2. With a group of farmers using cluster farmland
3. As a member of the producing organization such as cooperative
4. Others (specify)

56. How do you understand about forage seed quality?

1. Free from weeds or other crops
2. No mixture of the other varieties
3. No deformed (e.g. shriveled) seed
4. Uniformity in the field
5. No disease/insect damage
6. Other (specify)

PART SEVEN – Forages seed management

57. Which storage structures do you commonly use?

1. Gotera/gota
2. Sacks
3. Clay pot
4. Other (specify)

58. Do you use DDT spray on the seed during storage? 1. Yes 2. No

59. Do you use Ash on the seed during storage? 1. Yes 2.No
60. Do you use a Tablet on seed during storage? 1. Yes 2. No

61. What measure of seed management did you use?

1) Cleaning seed during sowing
2) Separate seed during threshing
3) Seed treatment and storing seed in a separate bag
4) Threshing in a separate new floor
5) Select a seed on the farm

61. What method of seed cleaning did you use?

a) Hand sieving at planting ( ),
b) Machine cleaning at planting ( )
c) Wind winnowing at threshing ()

PART X. Suggestions

The checklist is for **key informant interviews (KII)** with district experts (Woreda experts, DAs, NGOs, supporting Projects, Woreda administrative office) to collect information about the main Forage Seed sources (via available seed systems) and identify the key bottlenecks in accessing forage seed and possible options for improvement in East Belessa Woreda.

1. How do you see the trends of Forage seed production in Woreda in the past years (last two years)?

2. Is it a common practice in the Woreda to use improved forage seed varieties? Please list them.

3. Which varieties are now under production (2023/2024 GC) in the Woreda?

4. What are the challenges for farmers to secure forage seed from various sources? Including formal and non-formal approaches

5. What do you perceive about good quality seed? I.e. what parameters the farming Communities usually consider judging whether the seed is of good quality or not.

The checklist for **FGD** discussion could consist of 8-12 participants from the elders and progressive farmers including women inclusive to different ages (young to elder composition).

1. What do you suggest in improving the existing forage seed source in terms of availability(accessibility), and quality in the Woreda?

2. What do you suggest in improving the availability and quality of forage seed production in the Woreda?

3. In your experience what are the general problems in forage seed production in the woreda

4. Which seed source do you think the farmers prefer most? Why?

5. Do you think farmers have access to quality forage seeds? 1. Yes, 2. No

If not what are the reasons for lack of access to quality forage seed?

6. Do you provide improved seed management training to forage seed growers? 1. Yes 2.no

If yes, what are the contents of the training? ________________________________

If not, what are the reasons? ____